Construction Materials Science

Baghdad University/Civil Engineering Dept.
2012-2013/1st stage

Lecture No. 1

Construction material science is the engineering object that involved with the use of construction materials in constructing buildings in a way that achieve the strength, economy, safety and durability.

This science also search a new suitable materials to be used in building construction.

Types of building:

1- Lightweight building: such buildings transfer the load of the building by its bearing walls to the foundation, these buildings consist usually of one or two floors.

2- Heavy building: these buildings collect the load to the columns, by the roofs and beams, and transfer this load to the lower floor till the load reach the foundation and the soil within its bearing capacity , such buildings called "skeleton building" .

Main factors to be consider in construction:

1- Design a)architectural design
b) civil desing
c) other design such as sanitary, electric

2- Construction materials to conform the specification

3- Construction work

Mechanical properties of materials:-

Normal stress :

The application of an external force to a body cause internal resisting force within the body, whose resultant is equal in magnitude but opposite in direction to the applied force ,the applied force (N or lb) on a body divided by its area (mm^2 or ft^2).

$\sigma = P/A$

There are many types of stress occurred in the material such as:

1- Compressive strength
2- Shear stress
3- Tensile stress

- Strength: the ability of the material to stand under external load
- Ultimate strength: maximum ability to bear the load after which the material failed

Engineering strain:

When a member is subjected to a tensile or compressive stress, it undergoes a deformation (A). Tensile force causes an elongation of the body, while compressive caues a shortening of the dimension of the body in the direction of the force. The elongation (or shortening) per unit length is called strain (€).

- Volumetric Strain: the change in volume divided by the initial volume.

$\varepsilon = \Delta v/v$

- linear strain: change in length divided by the initial length.

$\varepsilon = \Delta L/L$

The major strains are –elastic strain
-plastic strain

<u>Stress-strain relationship:</u>

After testing the specimen, it is necessary to represent the data in the form of stress - strain diagram. The stress is defined as the load divided by the cross sectional area of the specimen at the start of the test. As the test proceeds, the actual cross sectional area decreases. The stress based upon the initial area is not the true stress, but it is generally used. The strain used is the elongation of a unit length of the test specimen taken over the gauge length. Typical stress - strain diagram are shown in Fig. below:

- Elasticity: the exposed load should be within specific limit named elastic limit at which material return to its normal state and above this limit called residue strength .
- Plasticity: opposite to elasticity, it represent the disability of material to return to its state after the release of the load.
- Modulus of elasticity: It is a measure of the stiffness of the ductile material. The slope of the initial straight portion of stress -strain diagram represents the modulus of elasticity or Young's modulus

$$E = \tan \theta = \text{Stress}/\text{strain}$$

Materials properties

They are the properties related with the material behavior under specific loading, such properties includes:

1- Reduction of area: As the load on the test material is increased, the original cross sectional area decrease until it is a minimum at the instant of fracture. It is usual to express this reduction in area as the ratio of the change in area to the original specimen cross sectional area expressed as a percentage.

$$\% \text{ reduction in area} = \{(A_o - A_f)/A_o\} * 100$$

Where - Af- Final cross sectional at the point of failure
Aq- Original cross sectional

2- elongation: Percentage of elongation is the measure of the ability of a material to undergo deformation without rupture. It is a measure of the ductility of material.

% Elongation = (Lf- Lq) / Lq * 100

Where:
Lf - Final length
Lo - Initial length

3- ductility: Is the property of a material of being deformed by stretching without recovery of shape upon removed of stretching force. Ductility of metals is ordinarily determined by measuring the elongation and reduction of cross sectional area of a tensile strength test specimen. It is deformation of material before failure, and after removing the load the material return to its previous state partly or completely. Ductility means change in length to the initial length, concrete considered as brittle material with strain of 0.003 which represent the maximum ability of concrete and when strain exceeds 0.005 the material considered as ductile material and less than it considered as brittle material.

- 4- toughness: The resistance to impact. Toughness is also considered to mean resistance to fracture when the material is deformed above the elastic limit. It is a measure of the work required to cause fracture to occur. Toughness related to ability of material to absorb energy until failure

- 5-brittleness: Brittleness: opposite to toughness ductility and give indication for impact resistance or dynamic strain, the deformation and failure occurs in brittle materials without graduated deformation and called sudden failure or sudden breakage, example for brittle materials such as: concrete, glass, brick, wood and gypsum.

It refers to small resistance to sudden blow. A brittle metal breaks suddenly without appreciable permanent deformation or warning of approaching failure.

6- Resilience: Is that property of an elastic body by which energy can be stored up in the body by loads applied to it and given up in recovering it\s original shape when the loads are removed.

- 7-creep, creep curve: the increase in strain under the effect of steady stress, the amount of creep depend on time , temperature , material state , the amount of load and loading period

We have discussed the mechanical properties of materials on room temperature.

Many structures, particularly these associated with energy conversion, like turbines, reactors, steam and chemical plant operate at much higher temperature. As the temperature is raised, materials under loads continuous deformation with time, i.e. start to creep, the strain instead of depending only on the stress, now depends on temperature and time also.

Creep occurs in three stages:
Stage 1 - Primary creep stage
Consist of a short part during which strain increases rapidly
Stage 2 - Secondary creep stage
Consist of a long period where the rate is much slower and constant
Stage 3 - Tertiary creep stage
At this stage the creep rate increases and the material fractures

8-Fracture : this property occurs under failure of material and give indication to the beginning of failure at which the material is not structurally effective.

9-Fatigue: weakening in material to resist periodic loading or long time loading. Fatigue we have considered so far only the strength of material under static loading. In many structures, repeated loading is applied, and when a material fails under a number of repeated loads, each smaller than the ultimate strength, failure in fatigue is said to take place.
The results of fatigue test are represented by a relationship between stress and number of cycles to failure

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- Stiffness: the ability of material to resist the deformation , this property related to the stress- strain relationship.
- Hardness: the resistance of material to plastic deformation and to abrasion , scratch and rust.

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Lecture No. 2

Bonding Materials

Material with adhesive and cohesive properties which make it capable to bond mineral fragments into a compact whole. This definition embraces a large variety of cementing materials, among them:

1. Gypsum plaster
2. Lime
3. Cement

1. Gypsum plaster :

Gypsum plaster comprise all that class of plastering and cementing materials which are obtained by partial or complete dehydration of natural gypsum and to which contain materials that serve as retarders or hardeners, or that impart greater plasticity to the product, may not have been added during or after calcinations.

1.1 Raw materials - Gypsum rocks:

Pure gypsum is a hydrous lime sulfate ($CaSO_4 . 2H_2O$), the composition of which by weight is:

Lime sulfate	Lime CaO	- 32.6%
	Sulfur trioxide SO_3	- 46.5%
Water H_2O		- 20.9
Total=		- 100 %

Natural deposit of gypsum are very seldom pure, the lime sulphated being adulterated with silica, alumina, iron oxide, calcium carbonate and magnesium carbonate. The total of all impurities varies from a very small amount up to a maximum of about 6%.

1.2 Manufacture of gypsum plaster:

1.2.1 Process of manufacture:

There operations are involved in the process of manufacturing plaster. Crushing, grinding and calcinations. Rock gypsum is crushed to fragments about 25mm in diameter, which are passed through a finishing mill. The grain gypsum is then calcined in rotary kilns.

1.2.2 Theory of calcinations:

If pure gypsum is subjected to any temperature above 100 °C, but not exceeding 190 °C, three-fourth of the water of combination originally present is driven off:

$$CaSO_4.2H_20 \xrightarrow{100\text{-}190\ °C} CaS04\ .½H_2O + 1\ ½\ H_2O$$

The resultant product is called plaster of Paris (CaSO4. ½ H_2O). Plaster of Paris readily recombines with water to form gypsum, hardening in a very few minutes:

$$CaSO_4.\ ½\ H_2O + 1\ ½\ H_2O \longrightarrow CaSO_4.2H_2O$$

If the gypsum is calcined at temperature much above 190 °C it losses all its water of combination, becoming an anhydrous sulfate of lime:

$$CaSO_4.2H_20 \xrightarrow{T > 190\ °C} CaSO_4 + 2\ H_2O$$

1.3 Gypsum products:

1.3.1 Plaster of Paris:

Produced by calcinations of pure gypsum, no foreign materials being added either during or after calcinations.

1.3.1.1 Uses:

a. It is used as a wall plaster in finish coat.
b. It is used as a mortar for masonry construction.
c. It is used for casting ornamental work.

1.3.1.2 Chemical requirements in accordance with Iraqi standard No. 28/1988:

a. The sum of soluble salts expressed as (Na_2O+MgO) not more than 0.25% by weight of plaster.
b. The percentage of chemically combined water should be between 4-9%.
c. The percentage of impurities not more than 5%.
d. The percentage of SO_3 not less than *45%*
e. The percentage of CaO not less than 30%.

1.3.1.3 Physical requirements in accordance with Iraqi standard No. 28/1988:

a. Fineness: The percentage retained on 1.18mm sieve not more than 0%.

b. Setting time should be between 8-25 minute.

c. Mechanical resistance: The diameter impression resulted by a dropping ball not more than 5mm.

d. Compressive strength: Not less than 5MPa for standard cube 50*50*50mm.

e. Modulus of rupture: Not less than 1.5MPa

1.3.2 Ordinary plaster:

It is a hemi hydrate product ($CaSO_4$. ½ H_2O), produced by the calcinations of a gypsum containing certain natural impurities or by the addition to a calcined pure gypsum of certain materials which serve to retard the set or render the product more plastic.

1.3.2.1 Uses:

a. It is used as a wall plaster in first coat.

b. It is used as a mortar for masonry construction.

1.3.2.2 Chemical requirements in accordance with Iraqi standard No. 28/1988:

a. The percentage of SO_3 not less than 35%.

b. The percentage of CaO not less than 25%.

c. The sum of soluble salts expressed as (Na_20+MgO) not more than 0.25% by weight of plaster.

d. The percentage of chemically combined water not more than 9%.

e. The percentage of loss of ignition not more than 9%

1.3.2.3 Physical requirements in accordance with Iraqi standard No. 28/1988:

a. Fineness: The percentage retained on 1.18mm sieve not more than 8%.

b. Setting time should be between 8-25 minute.

c. Compressive strength: Not less than 3MPa for standard cube 50*50*50mm.

1.3.3 Technical plaster:

It is produced by mixing two types of plaster: Hemi hydrate product ($CaSO_4$. ½ H_2O) and anhydrous product ($CaSO_4$) with 50% for each.

1.3.3.1 Uses:

a. It is used as a wall plaster in first coat.

b. It is used as a mortar for masonry construction.

1.3.3.2 Chemical requirements in accordance with Iraqi standard No. 28/1988:

a. The percentage of SO_3 not less than 50%.

b. The percentage of CaO not less than 27%.

c. The sum of soluble salts expressed as (Na20+MgO) not more than 0.25% by weight of plaster.

d. The percentage of chemically combined water not more than 9%.

e. The percentage of loss of ignition not more than 9%

1.3.3.3 Physical requirements in accordance with Iraqi standard No. 28/1988:

a. Fineness: The percentage retained on 1.18mm sieve not more than 5%.

b. Setting time should be between 12-20 minute.

c. Compressive strength: Not less than 6MPa for standard cube 50*50*50mm.

d. Modulus of rupture: Not less than 2MPa

e. Mechanical resistance: The diameter impression resulted by a dropping ball not more than 5mm.

1.3.4 Anhydrous plaster:

It is produced by the complete dehydration of gypsum, the calcinations being carried on at temperature exceeding 180 °C. It has low solubility in water compared with ordinary plaster, thus certain material can be added during the grinding process to increase its ability to react with water.

1.3.4.1 Uses:

a. As wall plaster in all coats.

b. It is used as a mortar for masonry construction.

1.3.5 Keen cement:

It is anhydrous plaster produced the calcinations, at a red heat or over, of gypsum to which certain substances, usually ($Al_2(SO_4).2\text{-}18H_2O$) had been added.

1.3.5.1 Properties:

a. Its set is extremely slow, usually between 1-7 hours.

b. It gains in strength very gradually, but ultimately attains a great degree of hardness and a strength exceeding that of any ordinary gypsum plaster.

c. Its plasticity is high.

d. Its resistance to water is higher than ordinary plaster.

1.3.5.2 Uses:

a. It is used as a wall plaster in finishing coat and comers.

b. It is used as a wall plaster in areas exposed to moisture instead of cement and lime.

1.4 Properties of gypsum plasters:

1.4.1 Setting and hardening:

The term "setting" is meant the initial loss of plasticity, whereas "hardening" means the subsequent gain in strength and in ability to resist indentation or abrasion. The setting of plaster of Paris and other gypsum plasters is a process recombination of the partly or totally dehydrated lime sulfate or gypsum.

1.4.2 Percentage of water in plaster:

The water-plaster ratio is greatly affecting the strength of plaster. The higher the water plaster ratio, the greater are the plasticity and flow ability of plaster, but when it exceed the optimum value, part of water remain between paste particles and tends to pull the particles apart, reducing the cohesion between them and between the plaster and building units and leading to a reduced strength and durability.

1.4.3 Condition of setting:

The strength of plaster drops to a large degree when the plaster remains wet for a long period exceeding 3-days after setting. The reason is due to decomposition of some of plaster crystals in water, leading to reduced chemical adhesion.

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Lecture No. 3

2. Lime :

2.1 Definition and classification:

2.1.1 Quick lime:

Is the name applied to the commercial form of calcium oxide CaO, obtained by the calcinations of a stone in which the predominating constituent is calcium carbonate CaCOs, often replaced, to a greater or less degree by magnesium carbonate MgCOs, this product being one that will slake on the addition of water.

2.1.2 Hydrated lime:

Is quick lime has been chemically satisfied with water during manufacture.

2.2 Raw materials - Lime stone rocks:

Pure lime stone rocks consist entirely of CaCOs. Pure calcium carbonate consists of 56 parts by weight of CaO to 44 parts of CO_2.

Lime stones encountered in practice depart more or less from this theoretical composition. Part of the lime is almost always replaced by a certain percentage of magnesia MgO. In addition to magnesia, silica, iron, oxide and alumina are usually present and too slight extent, sulflir, and alkalies.

The physical character of the lime stone has an effect upon the burning temperature. A naturally, coarse, porous stone is acted upon by heat much more rapidly than a dense, finely crystalline stone, and may be burned more rapidly and at a lower temperature.

2.3 Manufacture of lime - Theory of calcinations:

The burning or calcinations of lime accomplishes three objects:

a. The water in the stone is evaporated.

b. The lime stone is heated to the request temperature for chemical dissociation.

c. The CO_2 is driven off as a gas, leaving the oxides of calcium and magnesium.

2.4 Uses of quick lime:

Lime may be used as:

a. Building materials.

b. Finishing materials.

2.5 Properties of quick lime:

2.5.1 Plasticity:

The term "plasticity" is commonly used to describe the spreading quality of the material of the material in plastering. If it spreads easily and smoothly, it is plastic, if it sticks under the trowel, or cracks, and drops behind the trowel, it is non plastic.

2.5.2 Sand- carrying capacity:

Practically all lime used structurally is made up in the form of mortar by the addition of sand to lime paste for the following reasons:

a. Sand is cheaper than lime.

b. To diminish the great shrinkage which accompanies the setting and hardening of lime and also to prevent the consequent cracking.

c. To counteract the extreme stickiness' of some high- calcium limes.

It is important that the "sand- carrying capacity" of the lime be properly established. If too little sand is used, excessive shrinkage will cause a weakening of bond between the plaster or mortar and the masonry materials or plastered surface. On the other hand, too much sand produces a non plastic and weak mortar.

2.5.3 Setting time:

The setting of lime and lime mortar is a chemical process involving the evaporation of the large excess of water used in forming the lime paste, followed by the gradual replacement of the water of hydroxide by CO_2 in the atmosphere, causing the lime hydrate to revert to the original calcium carbonate.

$CaO + H_2O \longrightarrow Ca(OH)_2$

$Ca(OH)_2 + CO_2 \longrightarrow CaCOs + H_2O$

2.5.4 Tensile and compressive strength of lime mortars:

The physical properties of lime mortar vary with the:

a. Chemical composition of the lime: Magnesia lime makes it stronger than calcium limes.

b. Character of the sand: Fine sand makes stronger mortar than coarse sand.

c. The amount of water: Suitable amount of water produces stronger lime mortar.

d. The conditions under which the mortar sets: The humidity and amount of CO2 in the atmosphere influence the rate of setting of lime drying the air and charging it with carbon dioxide, greatly accelerating the setting process.

2.6 H hydrated lime:

2.6.1 Process of manufacture:

Hydrated lime is a dry powder resulting from the hydration, at the place of manufacture, of ordinary quick lime. Three stages of manufacture characterize the preparation of hydrated lime:

a. The quick lime is crushed or pulverized to a fairly small size.

b. The crushed materials are thoroughly mixed with a sufficient quantity of water.

c.The slaked lime is, by air separation, screening, or otherwise separated from lumps of anhydrate lime and impurities, or the entire mass must be finely pulverized.

2.6.2 Uses:

Hydrated lime may be used as:

a.Building materials.

b.Finishing materials.

2.6.3 Properties:

a. Mortar prepared from hydrated lime is generally inferior to those prepared from quick lime from the stand point of plasticity and sand - carrying capacity.

b. The strength of hydrated lime mortars, both in tension and in compression, is somewhat higher than that of the corresponding quick lime mortars.

c. Hydrated lime mortars are more quickly setting than from ordinary quick lime mortars.

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Lecture No. 4

Classification of bricks according to constituent raw material:

1. Clay bricks
2. Lime - sand bricks
3. Concrete bricks

1. Clay bricks:

1.1 Raw materials:

a. Alumina

Alumina is main constituent of every clay. Loam soil (adhesive soil) forms good clay. In absencemof sand, pure clay will develop cracks due to shrinkage on drying and burning. A good clay bricks should contain about 20% of alumina.

b. Silica Free silica (sand), if added to clay in suitable proportion makes hard and prevents it from warping and shrinkage on drying. Silica, if present in greater proportion, makes a brick brittle. Silica present in the combined form (aluminum silicate) does not form good bricks, as it will shrink and develop cracks.

Both silica and alumina should be in free form.

c. Lime: This also should be present in small quantities in the brick earth. It should be in a finely produced condition and it should not be in the form lamps or clods.

Lime prevents shrinkage of raw bricks. It helps fusion of sand at the kiln temperature. This fused sand will bind the bricks particles fast.

d. Iron oxide: A small quantity of oxide of iron (5-6%) is desirable. It helps the fiision of sand like lime. It gives red colure to burn bricks. Excess of iron oxide imparts dark blue or blackish colure to brick, while, alower percentage of iron oxide makes the brick yellow in colure. Iron oxide makes the bricks hard and strong.

e. Magnesia: A small amount of magnesia helps to decrease the shrinkage of bricks. This gives a yellow tint to the bricks. But excess of magnesia is not desirable as it tends to produce the decay of bricks.

1.2 Composition of good clay brick:

A good clay brick should contain the following:

1. Clay or alumina - AI2O3 - 20%
2. Sand or silica - Si02 - 60%
3. Remaining ingredients, such as:

- Lime
  Iron
  oxide   -20%
  Magnea
Manganese

1-3 Harmful ingredients in clay bricks:

a. Excess of lime:

Excess of lime makes the colure of the brick yellow instead of red. Lumps of limestone remaining in the finished brick are undesirable because, when such a brick comes in contact with water, lime will begin to slake. During slaking, lime expands and also generates heat. Due to this, stresses will be produced, which will result in producing cracks in bricks.

b. Iron pyrites:

These will decompose and oxide the clay during the burning of bricks. After oxidation a black discoloration will be produced on the bricks, making it look ugly.

c. Pebbles: The presence of pebbles, girt, gravel etc. will be undesirable because they prevent the clay from being mixed well. They prevent the manufacture of smooth and regular, standard bricks. They also spoil the appearance of the bricks. Pebbles, gravel, grit, etc., should be removed before mixing and pugging of clay are done.

e. Organic matter:

This includes leaves, twigs. Etc. of plants, roots, grass, bones of animals etc. These if prevent and burnt along with bricks, produced empty pockets or pores and will produce porous bricks.

f Alkalis (MgO , K_2O):

I. It lowers the fiision temperature and molts bricks.
II. Changes the shape of bricks or get twisted.
III. These salts have hygroscopic action; they absorb moisture, present in the atmosphere and keep brick damp which is harmful for health and decays the structure.

$MgO + H_2O \rightarrow Mg(OH)_2$

$K_2O + H_2O \rightarrow 2\,KOH$

g.Salts:

Salts such as sodium sulphate cause efflorescence.

1.4 Manufacture of bricks:

Manufacture of clay bricks involves the following operation:

1.4.1 Preparation of clay:

a. Removal of loose soil:

The top layer of loose disintegrated soil up to about 20 cm depth has to be removed as this contains a lot of impurities.

b. Digging, spreading and cleaning:

Next, the earth has to be dug up. For small quantity, digging may be done manually. For large scale work, it may be done by machine.

c. Weathering:

The earth is left to weather for a few weeks, this is necessary to increase the plasticity of soil and improves its quantity.

d. Blending:

This refers to mixing the clay, after making it loose and adding any required ingredients to the top of the heap.

e. Tempering:

This is necessary to make the clay fiilly consistent, and fit for molding into raw bricks, by adding the required amount of water to make it plastic.

1.4.2 Molding:

Molds required for making a brick are made of rectangular blocks slightly large in size (10% larger than the burnt bricks). It is done to allow for the shrinkage of the molded brick on drying and burning.

The molding is improved by the following process:

a. Dry press process:

In this method, clay is not made sufficiently plastic, but only small amount of water is mixed with clay as to form a damp powder. With plunger machines, this powder is compressed in the mold, in the form of bricks. Such bricks are directly burned, no drying is needed, but care is to be taken during burning where the temperature should be raised gradually.

b. Stiff mud process:

In this process the clay is only sufficiently moist to process the required coherence under moderate pressure, which results in economy of time in drying and fuel in burning. Such clay is forced to come out of any opening having dimensions equal to length of bricks, by means of a wire. Hence these arealso known as wire cut bricks.

c. Soft mud process:

This process is used where the clay is too wet, there for, it must be dried before molding. Bricks are molded under pressure in a soft mud brick machine, which tempers the clay in its pigging chamber,sands or wets the molds, presses the clay into 4 to 9 molds at a time, strikes off the excess clay, bumps the molds uniformly and dumps the bricks into a pallet. The pallets of bricks are carried away to the dryer as fast as made.

1.4.3 Drying:

As wet clay bricks come from different brick machine, they contain from 7-50% moisture depend on whether dry press stiff mud or soft mud process has been used moisture in clay may be classified as:

Equilibrium moisture: is that moisture in the material which exerts a vapor pressure equal to that exerted by the surrounding air of a given temperature and humidity.

Free moisture: is held strongly in the pore spaces.

ost of the free water is removed in the drying process and the remaining moisture during the burning process. Mechanical dryer, who permit of automatic control of temperature, humidity and air velocity, have come into general use. As the free water of the clay body is removed, the clay particles tend to coalesce causing shrinkage. The general effect of such shrinkage is to increase the resistance to moisture flow in the dried layers. If the drying is carried on too rapidly as by means of hot dry air, the moisture is removed from the surface of the solid more rapidly than the interior of the solid so that the surface harden and cracking occur. It is desirable to dry clay with moist air, reducing the drying rate to the point where diffusion of water to the surface can keep up with the vaporization at the surface. The average time necessary for drying clay brick is about 3 days, and the temperature required is from 38 °C to 149 °C.

1.4.4 Burning:

The burning of clay in a kiln requires an average time of 3 to 4 days. The process of burning may be divided into the following stages:

a. Water smoking:

During this period which removes most of the water in the clay under temperature ranging from 125°C to 175 °C.

b. Dehydration: Dehydration consists of expelling chemically combined water by breaking down the clay molecules.

It begins at about 425 °C and complete at about 750 °C.

c. Oxidation:

Oxidation begins during the dehydration stage. All combustible matter is consumed, carbon is eliminated, the fluxing materials are changed to oxides, and sulfur is removed.

1.5 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.

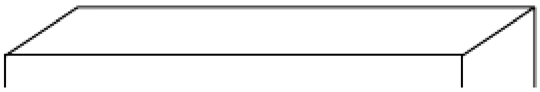
Grade B; Intended for use in building construction subjected to loads and not exposed to sever abrasion by weathering action, such as exterior walls not exposed to penetration of water.

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:

24cm±3%



Lecture No. 5

1.6 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.

1.6.1 Compressive strength:

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

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

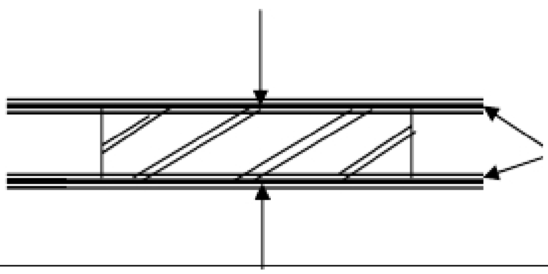
1.6.2 Water absorption:

The absorption of water by brick is often considered to be indicative of its probable durability. The test also provides a means of checking on the consistency of the bricks produced by one factory. In this test the specimen shall be dried to constant weight in a ventilated oven at 110 °C to 115 °C for about 48 hours. Next the specimen shall be completely immersed in clean water for 24 hours. Each specimen shall then be removed, the surface water wiped off with a damp cloth and the specimen weight.

Water absorption = {(W2-W1)/W1 } *100%

Where W2 - weight of brick after 24 hours in water

Wl- weight of dry brick



1.6.3 Effloresce:

Soluble salts, if present in bricks, will cause effloresce on the surface of bricks. Effloresce test is carried out in accordance with Iraqi standard No. 24.The test is very useful for comparing samples of bricks from different sources, such as when we want to test bricks from several different factories at one time. In this test take a representative sample of 10 bricks and place them on end in the pan containing distilled water to a depth of 2.5 cm for 7 days. Allow the bricks to dry for 3 more days in similar pan not containing water.

The effloresce shall report as:

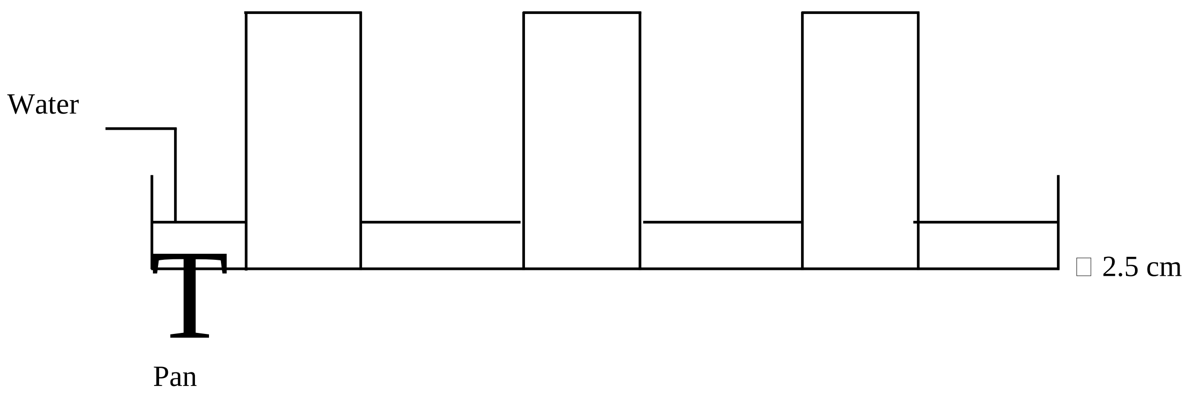
Nil - No effloresce visible.

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.



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

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

Lecture No. 6

2. Sand - Lime bricks:

2.1 Raw materials:

The raw materials required for manufacture of sand - lime bricks are as follow:

2.1.1 Sand

The sand used in sand - lime brick should meet the physical and chemical requirements of Iraqi standard No. 572:

a. Contain not less than 70% silica.

b. Well graded between 0.005 - 0.5 mm.

c. Free from impurities such as organic matter, rock, minerals and soluble salts.

d. The percentage of clay not more than 10%

e. Iron compounds not more than 1.5%.

f Gypsum content not more than 1%.

g. ($CaO + MgO$) not more than 5%.

2.1.2 Lime: The lime used in sand lime brick should meet the requirements of Iraqi standard No. 572:

a. Activity of lime shall not be less than 83%.

b. The percentage of lime retaining on 75 |im sieves should not be greater than 2%.

2.1.3 Water: Water used in sand lime brick should be fit for drinking.

2.1.4 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.

2.2 Mix proportion: The percentage of lime should be between *9-15%* of the weight of sand.

2.3 Manufacture: a. Sand, lime and pigment are taken in suitable proportions and they are thoroughly mixed with are quired quantity of water.

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

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

$CaO + H_2O + SiO_2$ □ $Ca0.SiO_2. H_2O$ " Tobermorite " " Hydrous calcium silicate "

$Ca(OH)_2 + CO_2$ □ $CaCOs + H_2 O$

2.4 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.

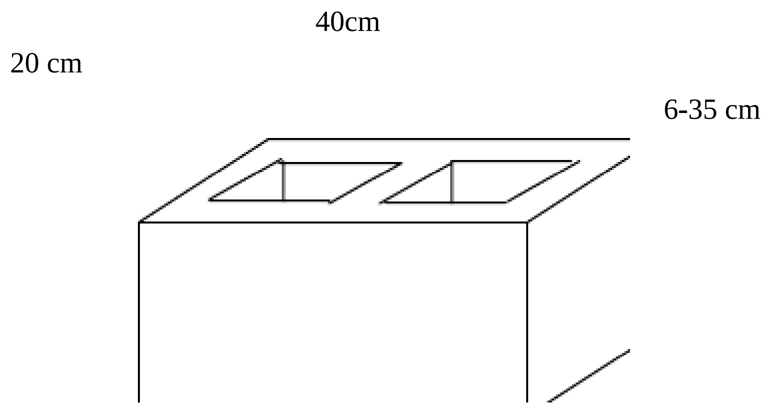
c. These bricks are hard and strong.

d. These bricks are uniform in colure and texture.

e. Sand lime bricks are used for ornamental work.

3. <u>Concrete bricks:</u>

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 flirnace slag. Mix proportion varies from 1:2:4 to 1:8:16 according to the required bearing capacity. These bricks are often mad hollow for economical purposes and to reduce the weight of the brick. The dimensions of the brick are as follow:



3.1 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.

3.2 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.

<u>Lecture No. 7</u>

Blocks

<u>Introduction :</u>

Blocks are structural units used in roofing, blocks will be loaded in the structures therefore it should not used before 14 days of production. The block should be clear from cracks or defects that reduce the bearing capacity and durability of the block. The faces of the block should be rough to ensure cohesion between the block and finishing layers.

<u>Manufacture of blocks:</u>

Blocks are made from cement and water and the sand will be added gradually, then mix it in the mixer for about 5 minutes to have homogeneous mix, then pour the mix in the moulds. Open the moulds and leave the block for 14 day before use. To check the strength of the block its important to test one sample before use. Blocks used in many applications such as bearing walls or filling concrete skeletons. All the problems that faces the block works related to cracking and settlement when the foundation is weak. The main purpose for block failure in structure appears when it is exposed to water; therefore it should be ensured that construction joints between blocks should be strong.

<u>Types of blocks:</u>

- <u>Concrete blocks</u>

Its dimension (200x300) mm and its height should not less than 100mm (the height less than the length or the height less than 6 times the
There are 3 types of concrete blocks

1. Solid block: this block does not have pores except two circular holes Ø 10 cm each. This type of block used in bearing walls the modulus of rupture not less than (70 kg /cm^3)

But nowadays this type rarely used due to:

1- Heavy weight
2- High cost
3- Moisture insulation (it keeps the inner moisture for long time)
4- Difficulty in extended the sanitary and electric services.

❖ Hollow blocks

This block has artificial holes and can be classified in to:

a) **lightweight hollow block**: the weight of this block is light due to the use of aggregate have high ratio of pores this type is used for special purposes, due to its high cost, such as (adding loads

b) **Regular hollow blocks**: can be classified due to its dimensions, and it will be named according to its thickness to:
-block 20 (20x20x40)cm=used in external walls or architectures.
-block 15(15x20x40)cm= used in external and internal walls
-block 12(12x20x40)cm=used in partitions
-block 10(10x20x40)cm= used in partitions
-block 4 (4x20x40)cm= used in sliding windows

c) Grill blocks: hollow block with different engineering shapes, used for decoration

❖ Itonic block:

lightweight block have good isolation to sound and heat with efficiency 6 times more than the concrete stone, this type used in walls and roofs to reduce weight on columns and foundations its weighted (400-500) kg/m^3, also it resist temperature up to 1200C^o for 3 hours, but its cost is too expensive.

❖ Silica blocks:
It is Italian blocks produced by white silica sand, its dimension (40x20x70) cm, it is used in arches and decorations and in building furnaces because it can resist high temperature.

❖ <u>Glass block:</u>

This block is made of glass with different shapes and with sizes of (19x19x8)cm and (20x20x7)cm and quartz white cement paste used in building such blocks reinforced with steel bars 6mm diameter anti-rust, the major properties of this blocks are:

- have fabulous appearance
- give beautiful lightening

The defects of this block are:

-heavy weight

-difficult in building

❖ <u>lime block:</u>

Materials used in it are:

-lime

-sand: made of good standard silica sand empty from impurities and salt

-water

-Sand-lime block :made by mix lime and sand (about 5-9% lime) then add colours and put the mix in the mould, after steam curing under pressure ($10 kN/mm^2$) for about 6-8 hours the resulted block will have three types:

-1st type: compressive strength not less than 250 kg/cm^2

- 2nd type: compressive strength not less than 150 kg/cm^2

-3rd type: compressive strength not less than 75 kg/cm^2

❖ <u>burned clay block:</u>

Made by forming mix of clay and water then burned it in special furnace and form the specimens by dry-process or by compressed process and the compressive strength of the block should not be less than120 kg/cm^2.

❖ <u>Hourdy blocks</u>

The shape of this block is not regular like the other types of blocks, it changed due to its use, also the weight of this block changed due to its use, for example in roofs lighter hourdy blocks use rather than in walls. Density of hourdy blocks between (999-1039) kg/m^3 and the crushing strength is between (7.1-9.9) N/mm^2 and the compressive strength not less than (30)kg/cm^2.

Advantages and disadvantages of hourdy blocks:

-hide the structural defects and cover the beams and outstandings

-get rid of paints and paste and help to make the re-painting process much better

-moisture resistant it is the perfect solution for humidity properties because of UPVC properties, therefore it is perfect in humid places.

- good thermal and sound insulation
- lightweight but strong enough and resist cracking because it is made of high quality PVC
- multi-purpose uses roofs, walls, in rooms or in bathrooms and kitchens, roofs for Balcones and garages
- available in many colours which is steady with adequate gloss to give it natural appearance
- easy to clean

properties of hourdy block:

1- durability: have good durability to wind end environments

2- multipurpose uses such as (foundations, retaining walls)

3- maintenance: this block does not need maintenance except when exposed to water

4- fire resistance: stand about 6 hours against fire

5- compressive strength for this block is:

-hollow block (7.5-12.5)N/mm^2

-solid block (7.5-21)N/mm^2

-hourdy block (3-7)N/mm^2

Lecture No. 8:

Tiles :

Tiles are thin slabs of brick earth,burnt in kiln. Tiles are thinner than bricks and have greater tendency to crack and warp in drying and burning than ordinary bricks and are more liable to breakage. Therefore, great care is needed in their manufacture. They should be dried in the shade, burnt and cooled gradually in specially made kilns.

Types,classifications and uses of tiles:

Tiles divided according to their uses in to:

1- Roofing tiles 2- flooring tiles

3-wall tiles 4-drain tiles

5-glazed tiles

1-roofing tiles:

These tiles should be strong, durable and perfectly leakproof, although they are expensive but they need less maintenance cost, the main types of roofing tiles are described below:

- Flat tiles:are rectangular in shape and of variouse dimensions. They are laid in cement or lime mortar. Many types of flat tiles are discussed below:
  (a)slate tiles: the available size (60cmx30cmx15mm)and(50cmx25cmx10mm) , these tiles should be reasonably straight, uniform in colour, good texture and free from veins, cracks, fissures and white patches.the water

absorption after 24 hours immersion in cold water should be maximum 21% by weight.

(b)burnt clay flat terracing tiles:

These tiles should be uniform in shape, size and should be free from irregularities like bends, twists, cracks. The water absorption should not exceed 20% by weight. The compressive strength should not be less than $7.5 N/mm^2$

- Pot or country tiles: these tiles are sometimes called pan tiles. They are hand moulded ,first into flat tile then to the required shape on wooden pattern and burnt in a kiln after drying.these tiles are semi-circular in section, such tiles used either alone or with flat tiles. These tiles are less liable to be displaced by birds and may used as sole covering to the roof. These tiles are laid on sloped roofs along with the conecave side up and longer end towards the ridge. Then another row of same tiles with convex side up and small end towards the ridge is laid covering the adjoing edges of every pair of tiles below, such tiles commonly used in rural areas.
- Allahabad tiles: these tiles are of different shapes. They are generaly laid side by side and joints are covered with half round tile. and they are used for making good and pleasing roofs ,they should not absorb water more than 20% by weight.
- Corrugated tiles:these tiles have corrugation and when they are placed in position a side lap of one or two corrugation is formed.placing such tiles on a roof give very good appearance of corrugated galvanized sheets, but they can be easily blown by violent winds.
- Manglore tiles: they are red colour and of double channeled basel mission manglor pattern, due to its projections they interlock with each other when placed in position, the life of these tiles is about 25 years with 5% replacement per year.
- Encaustic tiles: these tiles are employed for decorative purposes and are consist of three layers:

  1- The face is a thin coat of pure clay of the required colour

  2- The body is of coarse clay

3- The back is formed with thin layer of clay different from the body to prevent warping

2-flooring tiles

These tiles are flat and usually square or rectangular in shape. These can be made in any colour and of any geometrical shape.they should give ringing sound when struck with each other, and should not absorb water more than 24% by weight . the fracture surface of the tile should be clean, dense and sharp edges, and show maximum resistance to impact. Common size of flooring tiles are (15cmx15cmx18mm),(20cmx20cmx20mm)and (22.5cmx22.5cmx22mm).

3-wall tiles

These are similar to the floor tiles except for their design and degree of burning. They are burnt at low temperature, glazed and burnt again at a low temperature, they can be made in different designs and colours and be built to any size.these tiles are used on face work , arches and architectural ceiling.

4-Drain tiles

Usually are long curved sectiones of various shapes and sizes such as semi-circular or circular . they are used for draining waste water and for carrying sewage glazed tiles should be used.

5-glazed earthenware tiles

Such tiles are of earthenware having top surface glazed and underside unglazed so the tile may be adhere properly to the base, these tiles are made in two sizes (14.9cmx14.9cm)and (99mmx99mm), having thickness 5mm,6mm and 7mm,the joint thickness is 1mm. they should not absorb more than 18% of water , such tiles are used for finishing the surfaces of walls and floors of water closets, bathrooms, kitchens and hospitals (where cleanliness is important)

Lect. No.9

Properties of building tiles

-quality : building tiles should be made from good clay of even texture, they should be well burnt and uniform in size and shape and should be free from irregularities such as bends, twists and cracks.

-warpage test:in case of flooring tiles warpage should not exceed 2% along the edge and (1.5)% along the diagonal. In case of terracing tiles should not exceed in any direction 1%.

-characteristics of good tiles: a good tiles should posses the following characteristics:

1-should posses uniform colour

2-should be properly burnt

3-should be free from cracks ,flaws or bends

4-should be hard and durable

5-should have proper shape and size

6-when placed in position, it should fit well

7-its broken surface should exhibit even and compact structure

8-it should give a clear ringing sound when struk with light hammer or with another tile.

Manufacture of tiles

The manufacture of common tiles includes:

1-preparation of clay

2-moulding of tiles

3-drying of tiles

4-burning of tiles

1-preparation of clay

-The selected clay (best blue clay for tiles is generally found a few feet below brick earth) is made free from any impurities such as girt and pebbles.

-The clay grind into powder in crushing roller or mills and then thoroughly pugged , for making superior tiles the powdered clay is mixed with large quantity of water then stirred up well and the mixture is allowed to settle. The heavier and coarse particles sink in to the bottom and the finer particles run off into the lower layer where the matter is allowed to dry leaving the fine clay ready for mixing this method is known as plunging process

-to make the tiles hard and impervious a mixture of ground glass and pottery ware may be added in required quantity to the clay of tiles

2-moulding of tiles

Three methods are used for molding the tiles:

-wooden patterns: the tiles which are not uniform in section throughout their entire length are molded in patterns (made of well seasoned wood).flat cracks of clay are made and when partly dry they are molded, pressed and turned round a wooden pattern to give them the required shape

-potter's wheel: this method is similar to that adopted by potter in the manufacture of earthenware vessels. This method adopted when tile is of perfectly circular shape, it may have diameter vary along its length.

-mechanical method:this method of molding is adopted for tiles having a uniform section througout their length. The pugged clay is prepared by mechanical means through opening of required shape and size. The moulded clay coming out of the opening is received on a platform (wooden or iron) and the tiles are cut off to the required length by means of wire frames.

<u>3-drying of tiles</u>

Two_days after molding tiles are slightly beaten with a flat wooden mallet to correct the irregularity in shape due to warping. On the next day they are lifted up when hand hard and the edges , the under surfaces are scraped. They are then placed on edge and left to dry for about 2-days under shade to prevent warping and cracking when they are ready for loading in kiln.

<u>4-burning of tiles</u>

The tiles are burnt in a typical kiln known as sialkote kiln, which can accommodate 3000 to 4000 tiles. Such kilns are partly underground and generally provided with a roof.a layer of bricks is laid flat on rows of long narrow flues. The burning is affected by firing wood placed in these flues. The bricks are arranged in such a fashion that open spaces are left in between them. Above the layer of bricks the dried tiles are placed on edge layer by layer, until the kiln is completely loaded with raw tiles.

The doorways are then closed with bricks in mud plaster and top is covered with old tiles and ash.the firing of the kiln is started and the fire is kept low till the gases are driven out. The temperature raised gradually till the inner portions of the flues become red hot (at about $800C^{O}$), then it slaked for about 6 hours, the temperature raised again till the flues are white hot (about $1300C^{o}$) and kept as such for about 3 hours. The tiles is again slaked 6 hours then icreased once more to white hot and kept steady for about 3 to 4 hours.finally the flues are filled with fuel and doorways are closed by brickworks in mud. The kiln is then gradually allowed to cool down. The process of burning the tiles is completed in about 72 hours.

"Single firing technology " is a new automatic process achieved the following advantages:

-drastic reduction of the firing circle from 72 hours to an average of just one hour .

-reduced fuel consumption

-reduced total cost of production

-improved quality design of the burnt tiles.

Timber

Lec. No.10

Timber has been one of the primary materials of engineering construction; it is widely used for structural purpose.

The engineering should have some knowledge of the classification of trees and of their growth and structure in orders to understand the flindamentals of the physical and mechanical properties of timbers.

Classification of trees:

For the engineering purposes, trees are classified according to their mode of growth:

Trees : a. Endogenous

b. Exogenous:

b.l Softwoods

b.2 Hard woods

a. Endogenous trees:

This group is confined largely to tropical semitropical regions. Timber from these trees has very limited engineering applications. Example of endogenous tress is:

Palms: because of their long, straight stems are some times locally used as piles.

Bamboo: Is used structurally to a considerable extent.

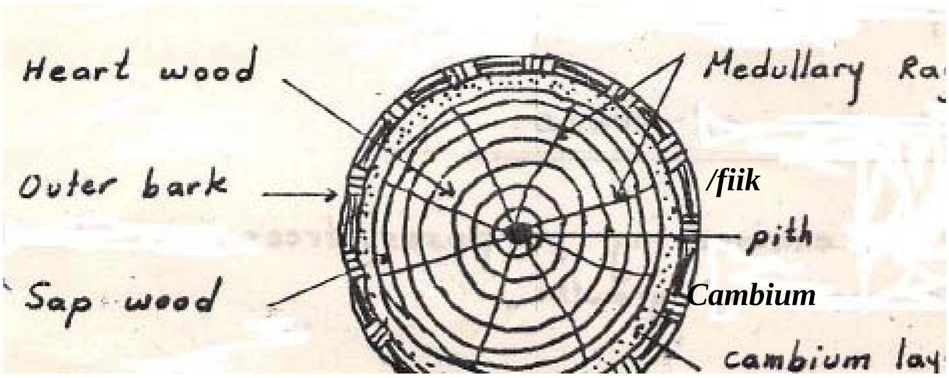
b. Exogenous trees:

These trees increase in bulk growing outer bark and annual rings are formed in the horizontal section of such a tree. Timber which is mostly used for engineering purpose belongs to this category. This timber can be divided into two groups:

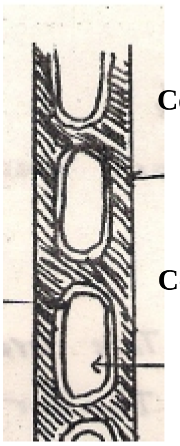
a. Soft woods: Such as deodar

b. Hard woods: such as oak and teak.

Structure of wood:



Cross section of an exogenous tree

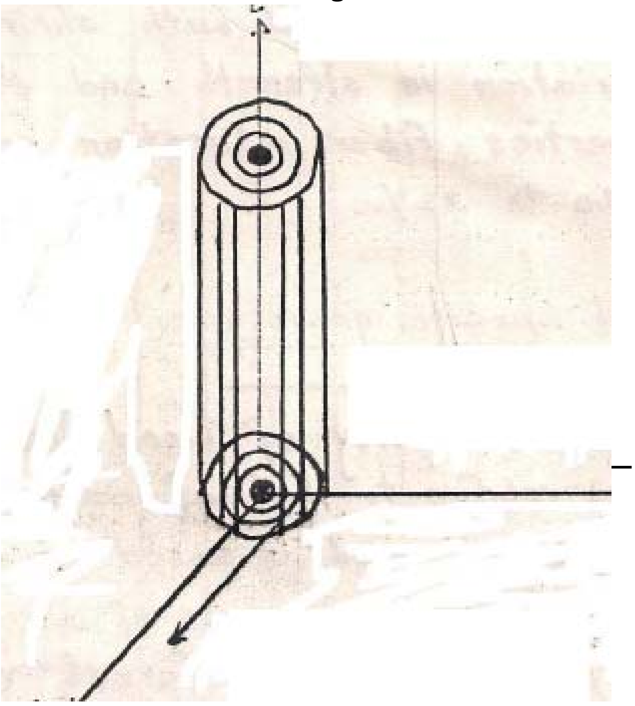


Longitudinal section of an exogenous tree

Structural axes of wood:

1. Longitudinal axis: Parallel to the length of the fiber
2. Tangential axis: Perpendicular to the fibers and tangential growth rings.
3. Radial axis: Perpendicular to the fibers and to the growth rings, i.e. parallel to the wood rays that radiate from the center of a tree as seen in cross section.

� **Longitudinal axis**



Moisture of timber:

Freshly cut wood from live trees is said to be in green condition. Green wood contains moisture in two general forms:

a. Free moisture: contained in the cell cavities of the walls.

b. Hygroscopic moisture: held in submicroscopic capillaries of the cell walls.

In the green condition, the cell walls of wood are almost saturated but the amount of free water varies widely between the species and even between sapwood and heartwood of the same species. Moisture content is expressed as a percentage of the oven dry weight of wood.

Fiber Saturation point:

The moisture content at which all free water is removed (i.e. cell cavities empty) while the cell walls are fiilly saturated. Changes in moisture content below the fiber saturation point are associated with shrinkage and swelling, as well as variation in strength and elastic properties and other properties. Fiber saturation point in range general between 20 to 32%.

Density and specific gravity:

The specific gravity of wood is its density (weight per unit volume) relative to that of water. By convention, the specific gravity of wood is based on weight of oven dry only per unit volume. Because of shrinkage the oven dry in a given piece occupies different volumes, depending on moisture content of the piece. Average specific gravities of woods based on oven dry weight and volume range between 0.13 to 1.20 while the specific gravity of wood substance itself, is about 1.5, regardless of species. Consequently the specific gravity of any particular species of wood is a measure of the relative amount of solid substance per unit volume, e.g. wood with a specific gravity of a contains V3 solid wood substance, the remainder of its volume being occupied by cell cavities, intercellular species and cell wall capillaries.

Seasoning of wood:

As a result of daily and seasonal fiuctuations in relative humidity and temperature, most wood in service continually gaining or losing moisture. The most practical means of minimizing trouble some variations in moisture content is by seasoning timber prior to its fabrication finished products or used structurally so the object of seasoning is to lower the moisture content of the wood a point at which the swelling and shrinkage is reduced a minimum for given conditions.

Seasoning process:

There are two principle methods of seasoning timber:

a. Natural seasoning: This consists of stacking the timber the air, and allowing it to dry naturally, the water being expelled gradually and shrinkage occurring informally. This process takes from two to four years to complete.

It is necessary to stack the timber with intervals between each so that the air can circulate all around.

b. Artificial seasoning: Avery large proportion of commercial timber is now dried by the kiln methods more particularly in the case of hardwoods. The advantages of kiln drying lie in the rapidity of the process and in the possibility of controlling the various factors influencing the correct seasoning results.

The three principle factors concerned in these methods are:

a. The temperature of the process.
b. The moisture.
c. The circulation.

Proper kiln can control the rate and degree of drying, that the tendency during drying to warp and split is reduced minimum. Uneven shrinkage may occur when the loss of moisture from the surface is greater than that from the interior. This shrinkage can be controlled by supplying moisture inside the kiln which assists in keeping the surface soft until the heat has penetrated to the interior, so that warping and cracking are prevented.

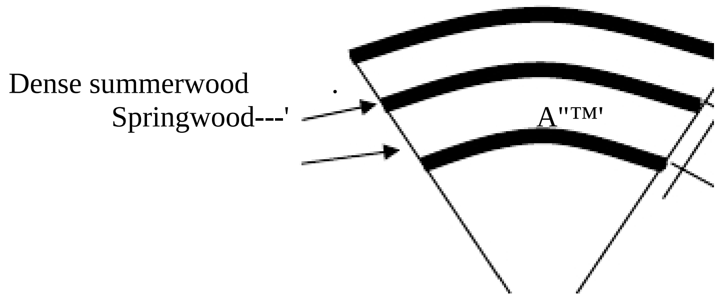
In artificial drying, temperatures of 70 to 82°C are useful employed for a period depending on the type of wood.

Shrinkage, warping and checking in drying:

The **shrinkage** of woods in drying is due to the loss of moisture from the walls of the cells. Shrinkage from green to oven dry condition in different species ranges as following:

Volumetric	7 to 21 %
Longitudinal	0.1 to 0.3 %
Radial	2 to 8%
Tangential	4 to 14%

The amount of shrinkage varies in different direction being small longitudinal in the direction of the fibers, contractively large radial, and greatest tangentially. The different between tangential and radial shrinkage is explained by the fact that bands of dense summerwood are continuous in tangential direction and shrink a great deal forcing the loc of springwood along with them. However, in a radial direction summerwood bands alternate with bands of less dense springwood, and the total shrinkage is the summation of shrinks of summerwood and springwood which is smaller than for all summerwood.



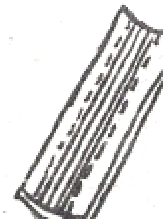
The **warping** of lumber is due either to unequal drying different portions or to unequal shrinkage of both radial and tangential direction. The warping can be classified into:

a. Bow:

This defect is indicating by the curvature formed in the direction of length of timber as shown in Fig.:

b. Cup:

This defect is indicating by the curvature formed in the transverse direction of timber as shown in Fig.:



c. Cup:

When a piece of timber has spirally distorted along its length, it is known as twist:

Checking of timber in drying is a result of the inability of the timber to accommodate strains consequent upon unequal shrinkage.

Types of checking:

Temporary checking:

A great many small checks occur particularly in the ends of timbers, owing to the more rapid drying from the cross section and the consequent extent of shrinkage of the end portion. These checking are considered temporary, because they close up and becomes impressible as the inner portion of the timber dries and shrink.

Permanent checking:

Large checking, caused by the shrinkage of timber in a longitudinal direction along the rings which is greater than that along the radius.

Case hardened checking:

Some woods, mostly hardwoods, become case hardened when rapidly dried in the kiln, that is the outer port dries and shrinks, and commonly checks, while the interior is still in its original conditions. The drying of the interior is thus retarded, but when it does occur great internal strains are set up, resulting in the formation of large or numerous radial checks follow the rays. When these checks are comparatively small, but numerous, the wood is said to be honeycombed. Case hardening of timber may be avoided by air seasoning before placing in the kiln or by admitted steam to the kiln.

Natural defects in timber:

1. Knots: one of the most common defects, they originate in the timber cut from the stem or branches of a tree because of the encasement by the successive annual layers of wood.

Knots can be classified as:

Pin knots - does not exceed 6.5mm.

Small knots - between 6.5-20mm.

Medium knots - between 20-40mm.

Large knots - greater than 40mm.

Large knot

Small or medium knot

Effect of knots:

In structural beams the effect of knots on the bending strength largely depends upon their location. Knots in the tension side of a beam near point of maximum stress will have a significant effect on the maximum load a beam will sustain, whereas knots on the compression side are somewhat less serious. Knots in any position have little effect on shear. Stiffness of beams is not greatly affected by knots.

In long columns, in which stiffness is the controlling factor, knots are not of importance. In short or intermediate columns, the reduction in strength caused by knots is approximately proportional to the size of the knot, although large knots have a somewhat greater affect than small ones.

Knots increases hardness and strength in compression perpendicular to grain. Knots are harder to work and machine than the surrounding wood, may project from the surface when shrinkage occurs, and are a cause of twisting.

2. Shakes:

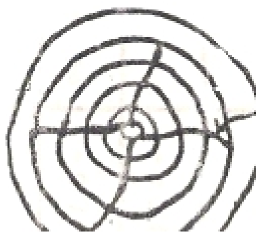
These are cracks which partly or completely separate the fibers of wood. Shakes can be classified into:

Cup shakes - These are caused by the rupture of tissue in a perpendicular direction as shown in Fig. 1:

Cup shakes

Fig. 1

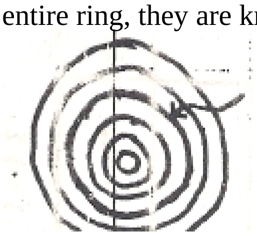
Heart shakes - These cracks occur in the center of cross- sectional of tree and they extend from pith to sap wood in the direction of modularly rays as shown in Fig. 2. These cracks occur due to shrinkage of interior part of tree. Heart shakes divide the tree cross sectional into two to four parts.



Heart shakes

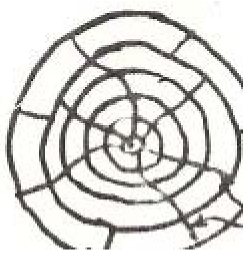
Fig. 2

- Ring shakes - When cup shakes cover the entire ring, they are known as radial shakes. Fig. 3.



Star shakes - These are cracks which extend from bark towards the sap wood. They are usually confined up to the place of sap wood. They are usually formed due to extreme heat or frost. Fig. 4.

Radial shakes - These are similar to star shakes, but they are fine, irregular and numerous. They usually occur when tree exposed to sun for seasoning after being felled down. They run for a short distance from bark towards the center. Fig. 5.



Radial shakes

Fig. 5

Wind shakes - If wood is exposed to atmospheric agencies, its exterior surface shrinks. Such a shrinkage results into cracks as shown in Fig. 6.

Wind shakes

Fig. 6

Mechanical properties of woods:

The intelligent use of wood for any structural purpose requires a general knowledge of the mechanical properties of different woods, in order that one selected may conform in its structure qualities to the requirements imposed, and in order that a given purpose may be served at a minimum expense.

1. Tensile strength: Timber in construction is practically never subjected to pure tensile stresses for the simple reason that the end connections cannot be so devised that they do not involve either shear along the grain or compression across the grain.

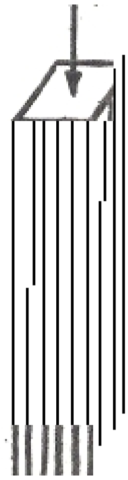
Failure in tension across the grain involves principally the resistance offered by the thinner - walled wood elements to being tern apart longitudinal.

2. Compressive strength: The compressive strength of wood in a direction normal to the grain is simply a matter of the resistance offered by the wood elements to being crushed or flattened. The cells with thinnest walls collapse first, end the action proceeds gradually.

Compression -l to grain

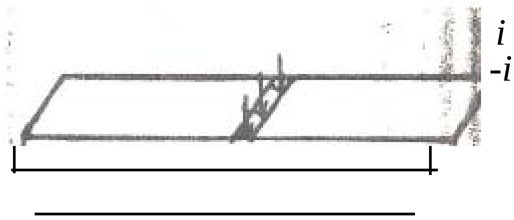
The compressive strength of wood in a direction 11 to the grain depends upon the internal structure and the moisture content of the wood and the manner of failure is fixed by these same factors. The individual fibers of wood act as so many hallow columns bound firmly together, and failure involves either buckling or bending of the individual fibers or bundles of elements.

Compression 11 to grain



3. Flexural strength: The flexural strength of timber is determined by the following formula:

Sb= 3/2(PL/bh²)



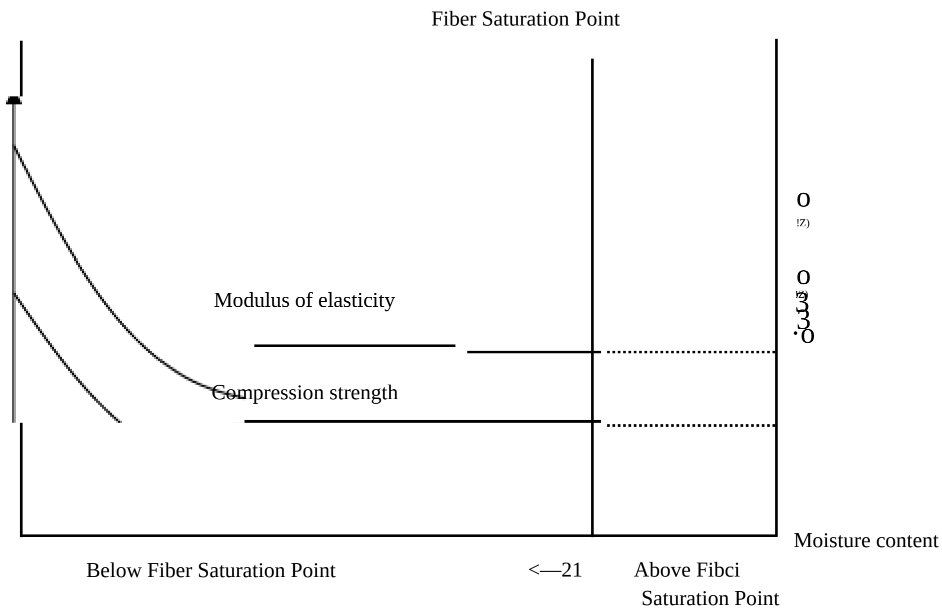
The tensile strength of all timber is greatly an excess of its compressive strength (about 3 times as much the average), and the latter will usually be the determining factor in limiting the cross- breaking strength. (Compressive strength will always be the determining factor, assuming there exist no defects such as knots or uneven grain on the tension side of the beam).

4. Stiffness: Stiffness of timber largely upon the same factors as strength. Dense woods are always stiffer than open, porous woods, and heavy woods are stiffer than light woods.

Moisture and strength:

All woods gain in strength and in stiffness when thoroughly air seasoning or kiln dried. The extent of this effect depend upon the size and type of the timbers dried only by air seasoning, even through the process is prolonged for several months or even years, seldom lose sufficient moisture to benefit their strength to more than a slight degree. Such timbers, therefore, cannot be safely depended upon to show any greater strength than if they where in the original green condition. The explanation of this fact is that a great part of the moisture which is first evaporated from wood is water which exists only as " free water " in the cell cavities, whereas only variation in the moisture content of the walls of the wood element affects strength in any way.

The relationship between strength and moisture content can be seen in Fig. below:



Lect. No.11

Metal: