Atomic structure and chemical bonding

Atomic structure : (the nucleus consisting of protons and neutrons and the electrons surrounding the nucleus) in order to lay a foundation for understanding how atomic structure affects the properties, behaviour, and resulting applications of engineering materials

Some of the important properties of solid materials depend on geometric atomic arrangements and also the interactions that exist among constituent atoms or molecules.

- Materials \rightarrow Molecules \rightarrow Atoms
- Atoms = protons (p) + neutrons (n) + electrons (e)



The atomic number (Z) : number of protons in nucleus

The mass number (A): number of protons plus neutrons

All atoms of same element have the same Z value

Isotopes: atoms of the same element with different numbers of neutrons and thus different A

${}^{A}_{Z}C {}^{12}_{6}C {}^{13}_{6}C$

The **atomic mass unit (amu)** (is a unit measurement for atoms and molecules like the mass of human expressed by kg or Ib) may be used to calculate atomic weight.

The electrical charges on the proton (e) and electron (e) are equal and opposite. All atoms, in their normal state, contain equal numbers of protons and electrons and are electrically neutral. The mass of the proton is about 2000 times that of the electron.

Atom: A neutral particle consisting of a nucleus containing most of its mass, and electrons occupying most of its volume.

- Electron: A subatomic particle with a charge of -1.
- Nucleus: Consists of two types of subatomic particles; protons, each with an electric charge of +1, and neutrons which have no charge.



(Nucleon is a term for either a proton or neutron. Thus A is the number of nucleons in an atom and the number of neutrons is A-Z.

Bonding Forces & Energies

- 1- The nature of various states of matter can be explained by using atomic forces (bonding forces) and potential energy of interatomic distance.
- 2 -There are 2 forces (attractive and repulsive) that act on a collection of atoms, depending on the relative distances between various atoms.
- 3- Attractive forces acting on atoms pull them together (would they collide?).

4- Repulsive forces (short range force) acting between nuclei and electrons of individual atoms.

Interatomic Bonds

- A . Primary bonding
- 1 Ionic bonding
- 2 Covalent bonding
- 3 –Metallic bonding
- B. Secondary Bonding
- Van der Waals bonding

Ionic Bonding

1.Formed between highly electropositive (metallic) elements and highly

electronegative (non-metallic) elements large difference electronegativity.

2. Ionic bonding results from the *transfer* of electrons from a metal to a non-metal.

- 3. Occurs between + and ions.
- 4. Requires electron transfer.
- 5. Large difference in electronegativity required.
- Example: NaCl





2. Covalent Bonding

- 1.- In covalent bonding stable electron configurations are assumed by sharing of electrons between adjacent atoms.
- 2.- Two atoms that are covalently bonded will each contribute at least one
- electron to the bond, and the shared electrons may be considered to belong to both atoms.
- 3.- Number of covalent bonds in an atom is determined by number of valence electron.

Strengths of Covalent Bonds

1• We know that multiple bonds are shorter than single bonds.

- 2• We know that multiple bonds are stronger than single bonds.
- 3• As the number of bonds between atoms increases, the atoms are held closer

and more tightly together.



3. Metallic Bonding

- 1- Valence electrons are detached from atoms, and spread in an 'electron sea' that "glues" the positive ions together.
- 2- A metallic bond is non-directional (bonds form in any direction) \rightarrow atoms pack closely.
- 3- The "bonds" do not "break" when atoms are rearranged ——— metals can experience a significant degree of plastic deformation.
- 4- Binding energy & melting temp (wide range).
- 5- All elemental metals, highly conductive, Ductile.
- 6- Examples of typical metallic bonding: Cu, Al, Au, Ag, etc. Transition metals (Fe, Ni, etc.) form mixed bonds that are comprising of metallic bonds and covalent bonds involving their 3d-electrons. As a result the transition metals are more brittle (less ductile) that Au or Cu.

Schematic illustration of metallic bonding



Secondary Bonds

Van der Waals Bonds·

Van der Waals bond or physical bond

- 1. Exist between virtually all atoms or molecules.
- 2. The presence of any of the 3 primary bonding types may obscure it.
- **3.** This force arises from atomic or molecular dipoles electric dipoles.
- 4. Electric dipoles
- 5. Separation of positive and negative portions of an atom or molecule
- 6. Columbic attraction between +ve end of one dipole and -ve end dipole.

Schematic illustration of van der Waals bonding between two dipoles



Summary: Bonding

Туре	Bond Energy	Comments
lonic	Large!	Nondirectional (ceramics)
Covalent	Variable large-Diamond small-Bismuth	Directional (semiconductors, ceramics polymer chains)
Metallic	Variable large-Tungsten small-Mercury	Nondirectional (metals)
Secondary	smallest	Directional inter-chain (polymer) inter-molecular

خواص المواد الهندسية Engineering materials properties

أن خواص المواد الهندسية هي تلك الميزات التي تتميز بها المواد المختلفة بعضها من بعض وتظهر على شكل صفات خاصة للمادة سواء كان ذلك بالإحساس البسيط لتلك الصفة أو باستعمال الأجهزة والآلات الدقيقة لقياسها.

ويمكن تقسيم خواص المواد الهندسية الى -:

 دفراص فيزياوية: Physical properties مثل الابعاد والشكل والوزن النوعي والمساحة ومحتوى الرطوبة والتركيب المجهري.

خواص ميكانيكية :Mechanical properties مثل مقاومة الشد والضغط والقص و السحبية والصيلادة والانحناء والمرونة والمطاوعة.

خواص كيميائية : Chemical properties مثل التركيب الكيمائي ، الحامضية أو القلوية المقاومة للصدأ.

4. خواص حرارية : Thermal properties كالتوصيل الحراري والتمدد.

5. خواص كهربائية ومغناطسية :Electrical and Magnetic properties كالتوصيل الكهربائي والنفاذ المغناطسي.

6. خواص صوتية : Acoustical properties كالتوصيل الصوتي والانعكاس الصوتي وامتصاص الصوتي وامتصاص الصوتي وامتصاص

7. خواص بصرية : Optical properties مثل اللون وانكسار الضوء وامتصاص وانعكاس الضوء

ولما كانت الخواص الميكانيكية هي التي تحدد سلوك المواد تحت تأثير الاحمال المختلفة لها . اصبح الالمام بهذه الخواص أساسيا عَند تصميم اي عمل هندسي يتعرض لتأثير الاحمال.

أهم الخواص الميكانيكية-:

 1. المرونة -Elasticity : هي قدرة المادة على استعادة شكلها وابعادها الاصلية بعد زوال الحمل المؤثر.

 2. اللدونة -Plasticity: هي قدرة المادة على الاحتفاظ بشكل كامل أو دائم بعد حصول تشوه نتيجة للحمل المؤثر.

3. السحبية -Ductility: هي قابلية المادة لحدوث تغير لدن كبير بها دون حدوث تشقق تحت تأثير اجهاد الشد (أي قابلية المادة للسحب.)

 الزحف -Creep: هي الخاصية التي تعبر عن انفعال المادة مع الحرارة والزمن تحت تأثير الإجهاد الثابت.

5. الانطراقية -Malleability: هي تقبل المادة حدوث تغير لدن كبير بها دون تشقق تحت تأثير اجهادات الضغط

 6. التقصف - Brittleness: هي الخاصية التي تجعل المادة تتشقق قبل حدوث تغير ملحوظ و هي عكس السحبية.

7. المقاومة -Strength: عي أقص ى إجهاد يمكن أن تتحمله المادة دون انهيا ر أو تشقق أو حدوث تغيير كبير وتقاس بالجهد المسلط على وحدة المساحة. والمقاومة القصوى هي أكبر إجهاد تتحمله المادة خلال تأثير حمل يتزايد ببطىء حتى الكسر.

8. الصلابة -Toughness: هي قدرة المادة على مقاومة التغير.

9. الصلادة -Hardness: هي الخاصية التي تجعل سطح المادة يقاوم التآكل والخدش وتكون المواد الصلدة صعبة التشغيل (القطع والقص والثقب.) 10. التحمل - Endurance: هي قدرة المادة على مقاومة الاحمال المؤثرة مرات عديدة ويعرف حد التحمل بأنه اكبر إجهاد متكرر يمكن تعريض المادة له عدد لا نهائي من المرات دون ان يحدث انهيار للمادة.

11. المتانة Durability -: هي قدرة المادة على مقاومة الاحمال الديناميكية دون كسر ، اي قدرتها على المتصاص الطاقة دون كسر وتقاس بالمساحة المؤثرة تحت منحنى الاجهاد والانفعال.

12. (الرجوعية) الاستيعاب Resilience:

هي قدرة المادة على امتصاص الطاقة دون ان بحدث لها اي تغير دائم ، اي ان الطاقة تسترجع كليا بمجرد زوال الحمل المؤثر وتقاس بالمساحة.

13. نسبة بواسون Poisson's ratio: هي نسبة الانفعال الجانبي الى الانفعال الطولي في عينة معرضة لحمل محوري.

Binding Materials

المادة الرابطة- : هي عبارة عن مادة لينة تتصلب بمرور الوقت تعمل على ربط اجزاء الطابوق او الحجارة مع بعضها في البناء الواحد وتعرف محليا بالمونة.

استخدامات المواد الرابطة Uses of Binding materials

- ربط وتثبيت الوحدات البنائية من الطابوق او الحجارة.
 - ربط وتثبيت وحدات التبليط مع بعضها.
- توزيع الثقل بصورة منتظمة في جميع أجزاء الكتل البنائية.
 - 4. تستعمل المادة الرابطة لإنهاء الجدران والسقوف.
- 5. تساعد في مقاومة نفاذ الرطوبة من وجه الجدار الخارجي الى الداخل من خلال مفاصل البناء .

خواص المواد الرابطة الجيدة Properties of good binding materials

- اينة ويسهل مزجها والعمل بها ونشر ها على السطوح.
- تتماسك مع السطوح اللاصقة لها بدرجة كافية بعد التصلب.
 - 3. تكون ذات تحمل جيد بعد تصلبها.
 - ٤. تتصلب بسرعة مقبولة.
- .5 ذات قوام جيد وذات قابلية جيدة لمقاومة التغير ات الجوية.
- 6. ذات خواص هندسية تقارب خواص الوحدات البنائية او وحدات التبليط والاكساء.

أنواع المواد الرابطة التي قسمين رئيسين هما تقسم المواد الرابطة التي قسمين رئيسين هما 1. المواد الرابطة التي تقاوم الرطوبة وهي: - مونة السمنت – نورة 2. المواد الرابطة التي لا تقاوم الرطوبة وهي: -مونة الجص والبورك -مونة الطين

Gypsum Mortar مونة الجص:

تستعمل هذه المونة للبناء بالحجر والطابوق للإعمال فوق مستوى مانع الرطوبة (البادلو) و على النطاق المحلي فقط حيث ان استعمالها الشائع عالميا لأغراض البياض الداخلي وتصنيع الصفائح العازلة للصوت والحرارة. والجص هو مادة كبريتات الكالسيوم الحاوية على نصف جزيئة ماء تقريبا (CaSO_{4.}1/2H₂O).

يصنع الجص من الترسبات الجبسية في انحاء مختلفة من العالم والتي تكون بشكل متبلور ونادرا ما تكون بشكل نقي تماما ، حيث تحتوي على مواد سليكونية من رمل وحصى أو طينية أو كلسية أو مركبات معدنية أو خليط منها. وان نسب هذه الشوائب يجب ان لا تزيد عن 30 % وزنا من مادة كبريتات الكالسيوم المائية والا أصبحت مادة الخام غير صالحة لصناعة الجص. والجبس هو المركب المتبلور لكبريتات الكالسيوم المائية (CASO_{4.}2H₂O) حيث تحرق بدرجة حرارة (170) درجة مئوية وان مقدار ما يفقده الجبس من ماء بهذه الدرجة هو جزيئة ونصف من مجموع جزيئاتها في حالة وجوده بصورة متعادلة، ويفقد الجبس جميع ماءه في درجة حرارة (400) درجة مئوية ويتحول الى الجبس اللامائي (CASO₄). يعتبر الجص من المواد البنائية المهمة فهو يستعمل لغرضين : 1. البياض 2. يستعمل كمادة رابطة اساسية في البناء،

Raw materials - Gypsum rocks: المزاد الخام

Pure gypsum is a hydrous lime sulphate (CaSO₄. $2H_2O$), the composition of which by weight is:

Lime CaO -	32.6%
Lime sulphate	
Sulphur trioxide SO ₃ -	46.5%
Water H ₂ O -	20.9
Total=	
	- 100 %

Manufacture of gypsum plaster:

rotary kilns.

There operations are involved in the process of manufacturing plaster: 1. Excavating 2. Crushing (~25mm diameter).3. Grinding 4. Heating (calcining) 5. Cooling 6. Pulverizing 7. Marketing in Bags. Rock gypsum is crushed to fragments about 25mm in diameter, which are passed through a finishing mill. The grain gypsum is then calcined in

عملية التصنيع : : Manufacturing process

Two types of gypsum are available in nature: gypsum rock and gypsum earth. The gypsum earth requires much less machinery, since it does not have to be crushed, and can usually be obtained with less labor.

The plant which use gypsum earth have the disadvantage of the deposits being local in character, and consequently being exhausted in the course of a few years.

خطوات التصنيع : Manufacturing steps:

1. Winning of the crude material, the gypsum earth or gypsite is sometimes loose enough to be shoveled directly into wagons or tram cars. 2. Rock gypsum is usually delivered at the mill in pieces of convenient size for handling.

3. It is then passed through crushers, which are essestially heavy jaws of chilled iron having a bavkward and forward motion. The rock is reduced to sizes which can be fed into a gyratory crusher. There are various styles

of this machine but they are all essentially of a pattern similar to a coffee mill and they reduce the material to small fragments.

4. The gypsum is next ground to a coarse powder by a means of buhrs.

5. A 75 per cent dehydrated gypsum is referred to as Plaster of Paris. The pulverized Plaster of Paris is the basic material used to make many of the gypsum building materials. For refined grade of Plaster of Paris the **two types of oven are used for calcination of gypsum**, kettle and rotary processes are used.

a. Kettle method: طريقة القدور

The excavated raw materials are crushed, and if the kettle process is used, ground until about 60 per cent pass No. 100 sieve. In the rotary process the final pulverization is omitted until calcination is completed. The kettles employed for calcinations are 2.5 or 3 m in diameter and about 2 m high. The pulverized material is chuted into the kettle and temperature raised gradually so as to drive off the mechanically held water. At about 100°C the whole mass bubbles up violently and then sinks. At 150°C the combined water begins to boil out and between 170° and 200°C the process is stopped. The kettle process requires about 2 to 3 hours to calcine a charge yielding 5 to 6 tones. The calcined product is then cooled .

b. Rotary process (cylinder method): طريقة الأسطوانات الدوارة

In the rotary process the raw material is crushed to pass through 25 mm mesh and is then fed into a rotating cylinder inclined to the horizontal. Calcination is accomplished with the introduction of hot furnace gases.

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:

100-190 °C CaSO4.2H20 ----- ► CaSO4 .½H2O + 1 ½ H2O

The resultant product is called plaster of Paris (CaSO4. $\frac{1}{2}$ H₂O). Plaster of Paris readily recombines with water to form gypsum, hardening in a very few minutes:

CaSO₄. $\frac{1}{2}$ H₂O + 1 $\frac{1}{2}$ H₂O ----- CaSO₄. 2H₂O

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

Gypsum products:

1. Plaster of Paris: مسحوق باریس

Plaster is made by heating gypsum (CaSO₄.2H₂O) powder, thus converting it to calcium sulphate hemihydrate (CaSO₄.1/2H₂O). The hemihydrate is also known as stucco or Plaster of Paris . Probably so named because of the very large deposit of pure gypsum found beneath Paris. When water is added to the stucco, the material rehydrates to give a solid mass of gypsum. This rehydration is accompanied by an increase in temperature and a slight expansion of the plaster, causing the gypsum to perfectly fill a mould.

Uses of plaster

1• plaster boards - a layer of plaster sandwiched between two sheets of cardboard.

2• fibrous plaster - plaster with fibres (often made of glass) mixed into it to increase its strength. Fibrous plaster is usually cast into a mould then used in slabs.)

3• plaster cornices - the decorative plaster projections used under the eaves and above doorways and windows in buildings

4• plaster mouldings

5• chalk plaster

Physical requirement in accordance with Iraqi standard :

1. Fineness : the percentage retained on 1.18 mm sieve not more than 1%

2. Setting time : should not be less than 20 minutes

3. Compressive strength : not less than 5 N/ mm^2

2. Ordinary plaster : الجص العادي العادي

It is a hemihydrate product $CaSO_4$. 1/2H₂O, produced by calcination of a gypsum containing certain natural impurities, or by the addition of a certain materials which serve to retard the set of pure gypsum action of a set like a number of the set of pure gypsum and the set of pure gyps

استخداماته :Uses

- 1. It is used as a wall plaster in first and second coat
- 2. It is used as a mortar masonry construction

Physical requirements in accordance with Iraqi standard :

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.

3. Technical plaster : الجص الفني

Technical plaster. Is calcined gypsum produced by heating gypsum in either vertical or horizontal furnaces at temperature between (120 to 170 °C) and for a period of half to three hours.

Uses

1. It is used as a wall plaster in first and second coat

2. It is used as a mortar masonry construction

Physical requirements in accordance with Iraqi standard :

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

4. Anhydrous plaster: الجبس المكلس اللامائي

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.

Uses:

a. As wall plaster in all coats.

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

5. Keene's cement : سمنت کین

is made by burning a very pure rock gypsum at a red heat (700°C), cooling, and then adding 1.0 per cent of potassium and aluminium sulphates to accelerate the set. Subsequently the material is ground so that 90 per cent or more passes No. 100 sieve.

Properties :

1. It is pure $CaSO_4$ of pure white colour.

2. Keene's cement is not injured by storage and mortars of it may be re tempered.

3. Set occurs between 20 minutes to 6 hours.

4. At 7 days the tensile strength is 3.16 N/mm^2 .

5. It gains in strength very gradually, but ultimately attains a great degree

of hardness and a strength exceeding that of any ordinary gypsum plaster.

- 6. Its plasticity is high.
- 7. Its resistance to water is higher than ordinary plaster.

Uses :

It is used as a finish plaster only where a greater resistance to moisture and surface abrasion is required.

Properties of Gypsum :

Gypsum items have a number of valuable properties like :

- 1. small bulk density,
- 2. incombustibility,
- 3. good sound absorbing capacity,
- 4. good fire resistance, rapid drying and
- 5. hardening with negligible shrinkage
- 6. superior surface finish,
- 7. resistance to insects and rodents
- 8. low energy input during burning to produce gypsum plaster.

The major shortcomings are :

- 1. its poor strength in wet state
- 2. high creep under load.

الجص الفني	البورق	الجص الاعتيادي	الخاصية
5	مفر	8	النعومة (%) المتبقي على المنخل المرقم (16) الذي مقاس فتحاته (1.18مم) لا يزيد على
12 20	8 25	8 *25	وقت التماسك (دقيقة) لا يقل عن لا يزيد على
6	5	3	قوة تحمل الضغط (نيوتن/مم ²) لا تقل عن
2	1.5	8_3	معاير الكسر (نيوتن/مم ²) لا يقل عن
5	5	-	قوة الصلادة (مم) لا يزيد قطر الثلمة للكرة الساقطة على

Table 1: Requirements of gypsum according to Iraqi specification

Characteristics of Building Gypsum

Compared with other binding materials, building gypsum has the following characteristics:

1. Fast Setting and Hardening

The setting time of building gypsum changes with the calcination temperature, grinding rate and impurity content. Generally, mixed with water, its initial setting needs just **a** few minutes at room temperature, and its final setting is also within 30min. Under the natural dry indoor conditions, total hardening needs about one week. The setting time can be adjusted according to requirements. If the time needs to be postponed, delayed coagulant can be added to reduce the solubility and the solution rate of building gypsum, such as sulphite alcohol wastewater, bone glue activated by borax or lime, hide glue, and protein glue; if it needs to be accelerated, accelerator can be added, such as sodium chloride, silicon sodium fluoride, sodium sulphate, and magnesium sulphate.

2. Micro-expansion

In the hardening process, the volume of building gypsum just expands a little, and there won't be any cracks. Thus, it can be used alone without any extenders, and can also be casted into construction members and decorative patterns with accurate size and smooth and compact surface.

3. Big Porosity

After hardening, the porosity of building gypsum can reach 50%-60%, so its products are light, insulating, and sound-absorbing. But these products have low strength and large water absorption due to big porosity.

4. Poor Water Resistance

Building gypsum has low softening coefficient (about 0.2-0.3) and poor water resistance. Absorbing water, it.will break up with the freeze of water. Thus, its water resistance and frost resistance are poor, not used outdoors.

5. Good Fire Resistance

The main component of building gypsum after hardening is $CaSO_{4.}2H_{2}O$. When it contacts with fire, the evaporation of crystal water will absorb heat and generate anhydrous gypsum which has good thermal insulation. The thicker its products are, the better their fire resistance will be.

6. Large Plastic Deformation

Gypsum and its products have an obvious performance of plastic deformation. Creep becomes more serious especially under bending load. Thus, it is not used for load-bearing structures normally. If it is used, some necessary measures need to be taken.

الألواح الجبسية : Gypsum plaster board :

It is a gypsum product made of thin layers of card board or wood cemented together with wall plaster, used for lining walls and ceiling of buildings. The boards may be strengthened by incorporating fibers as fibrous gypsum plaster boards. They are very light weight and have high fire resisting properties. Gypsum plaster boards can be sawn to desired size and shape. They are available in widths 400, 600, 800, 900, 1200 mm; in length 1200, 1500, 1800, to 3600 mm in steps of 100 mm and; in thickness 9.5 to 15 mm. They are classified as :

1- Gypsum wall board :

it has a face to which decoration may be applied.

2- Gypsum wall board with reduced water absorption rate :

These boards have additives in the core and/or /the paper liners to reduce water absorption .

الألواح الجبسية هي عبارة عن ألواح تنتج من الجص بحيث يكون لباب اللوح من الجص المطابق للمواصفة القياسية العراقية المرقمة (28 لسنة 2010)[4]. تغلف الألواح وتلصق بقوة باستعمال ورق قوي ومتين ذي مواصفات خاصة تتناسب مع الغرض وموقع الاستعمال للحصول على ألواح مستوية ومستطيلة الشكل تغلف بها الجدران والوحدات البنائية والسقوف وقواطع الحديد والخشب أو قضبان وأعمدة الفولاذ، أو قد تستعمل ألواح القواطع الجاهزة أساساً لعمليات البياض بالجص. تمتلك الألواح الجبسية خصائص تجعلها ملائمة للاستعمال في المواقع التي تتطلب الحماية من الحريق أو العزل الصوتي أو الحراري، تثبت بواسطة المسامير أو المسامير المواقع التي تتطلب الحماية من الحريق أو العزل الصوتي أو الحراري، تثبت بواسطة المسامير أو المسامير

Gypsum block

وحدات بنائية مصمتة أو مجوفة مستطيلة الشكل تستعمل في بناء الجدران الداخلية المحملة (bearing walls) وغير المحملة كقواطع (partitions) بعيدة عن مصادر الرطوبة، وتستعمل كذلك في الطبقة الداخلية للجدران الخارجية غير المحملة في الظروف الجافة الاعتيادية. تصنع الكتل الجبسية من الجص المطابق للمواصفة القياسية العراقية المرقمة (28 لسنة 2010)[4] والركام المطابق للمواصفة العراقية المرقمة (2235 لسنة 2005)[10] مع مضافات.

Bricks

وحدة بناء معمولة من عناصر لمركبات معدنية غير عضوية قوية ومتينة وبأشكال هندسية منتظمة. يعرف الطابوق بسميات عديدة وذلك حسب نوع المواد الخام ومصدرها وطرق تحظيرها بأشكالها المختلفة وكذلك متانتها ومقاومتها للظروف القياسية مثل العزل الحراري ومنع الرطوبة والتأكل بفعل الحوامض والقواعد.

Classification of bricks according to constituent raw material

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

Clay bricks:

Types of Clay

Clays occur in three principal forms, all of which have similar chemical compositions but different physical characteristics.

1. Surface Clays:

Surface clays may be the up thrusts of older deposits or of more recent sedimentary formations. As the name implies, they are found near the surface of the earth.

- **2. Shale's**: Shale's are clays that have been subjected to high pressures until they have nearly hardened into slate.
- **3. Fire Clays**: Fire clays are usually mined at deeper levels than other clays and have refractory qualities.

Surface and fire clays have a different physical structure from shale's but are similar in chemical composition **1.** All three types of clay are composed of silica and alumina with varying amounts of metallic oxides.

1. Raw materials: المواد الخام

a. Alumina

Alumina is main constituent of every clay. In absence of sand, pure clay will develop cracks due to shrinkage on drying and burning.

b. Silica

Free silica (sand), if added to clay in suitable proportion makes hard and prevents it from Warping and shrinkage on drying.

c. Lime

Lime should be present in small quantities in the brick earth. Lime prevents shrinkage of raw bricks. It helps fusion of sand at the kiln temperature.

d. Iron oxide

A small quantity of oxide of iron (5-6%) is desirable. It helps the fusion imparts dark blue or blackish colure to brick, while, a lower 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. But excess of magnesia is not desirable as it tends to produce the decay of bricks.

Composition of good clay brick:

A good clay brick should contain the following:

1.Clay or alumina - Al₂O₃- 20%

2.Sand or silica - SiO_2 - 60%

3. Remaining ingredients, such as:

-Lime, Iron oxide, Magnesia, Manganese (20 %).

- Harmful ingredients in clay bricks:

a. Excess of lime:

Excess of lime makes the colure of the brick yellow instead of red and when the brick contact with water, lime will begin to slake generates heat and expands. 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.

d. Organic matter:

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

e. Alkalis (MgO, K₂O):

• It lowers the fusion temperature and melts bricks.

• Changes the shape of bricks or get twisted.

• 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.

f. Salts:

Salts such as sodium sulphate cause efflorescence.

2. Manufacture of bricks:

Manufacture of clay bricks involves the following operation:



Diagrammatic Representation of Manufacturing Process

2.1 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:

Now 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.

b. blending:

This is 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 fully consistent, and fit for moulding into raw bricks by adding the required amount of Water to make it plastic.

2.2 Moulding

Moulds 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 moulded brick on drying and burning. The moulding is improved by the following process:

a. Dry press process:

In this method, a small amount of water is mixed with clay as to form a damp powder, with plunger machines, this powder is compressed in the mould, in the form of bricks. Such bricks are directly buried, 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 are also 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 moulding, Bricks are moulded under pressure in a soft mud brick machine, which tempers the clay in its pigging chamber, sands or Wets the moulds, presses the clay into 4 to 9 moulds at a time, strikes of the excess clay, bumps the moulds uniformly and dumps the bricks into a pallet. The pallets of bricks are carried away to the dryer as fast as made.

2.3 Drying:

As wet clay bricks come from different brick machine they contain 7-50% moisture depend on moulding process. Most of the free water is removed in the drying process and the remaining moisture during the burning process. 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.

2.4 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 remove 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 $^{\circ}$ C and complete at about 750 $^{\circ}$ C.

e. Oxidation:

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

Kiln Burning: The kiln used for burning bricks may be underground, e.g. Bull's trench kiln or over ground, e.g. Hoffman's kiln. These may be rectangular, circular or oval in shape. When the process of burning bricks is continuous, the kiln is known as continuous kiln, e.g. Bull's trench

and Hoffman's kilns. On the other hand if the process of burning bricks is discontinuous, the kiln is known as intermittent kiln.

Brick Classes:

a. **First Class bricks:** These bricks are table moulded and of standard shape. The surface and edges of the bricks are sharp, square, smooth and straight. The comply all the qualities of good bricks and used for superior work of permanent nature.

b. **Second class bricks:** These bricks are ground moulded and they are burnt in kilns. The surface of bricks is somewhat rough and shape is also slightly irregular. These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

c. **Third class bricks:** These bricks are ground moulded and they burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges.

d. **Fourth class bricks:** These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundation, floors, roads, etc because of the fact that the over burnt bricks have compacted structure and hence, they are sometimes found stronger than even first class bricks.

Tests for bricks :

A brick is generally subjected to following tests to find out its suitability of the construction work.

ii. Absorption

iii. Crushing strength or compression strength

iv. Hardness

v. Presence soluble salts

vi. Shape and size

vii. Soundness

viii. Structure

PROPERTIES

All properties of brick are affected by raw material composition and the manufacturing process. Most manufacturers blend different clays to achieve the desired properties of the raw materials and of the fired brick. This improves the overall quality of the finished product. The quality control during the manufacturing process permits the manufacturer to limit variations due to processing and to produce a more uniform product.

The most important properties of brick are 1) durability, 2) colour, 3) texture, 4) size variation, 5) compressive strength and 6) absorption.

Durability

The durability of brick depends upon achieving incipient fusion and partial vitrification during firing. Because compressive strength and absorption values are also related to the firing temperatures, these properties, together with saturation coefficient, are currently taken as predictors of durability in brick specifications.

Colour

The colour of fired clay depends upon its chemical composition, the firing temperatures and the method of firing control. Of all the oxides commonly found in clays, iron probably has the greatest effect on colour. Regardless of its natural colour, clay containing iron in practically any form will exhibit a shade of red when exposed to an oxidizing fire because of the formation of ferrous oxide. When fired in a reducing atmosphere, the same clay will assume a dark (or black) hue. Creating a reducing atmosphere in the kiln is known as flashing or reduction firing.



Clamp or Pazawah

Compressive Strength and Absorption

Both compressive strength and absorption are affected by properties of the clay, method of manufacture and degree of firing. For a given clay and method of manufacture, higher compressive strength values and lower absorption values are associated with higher firing temperatures. Although absorption and compressive strength can be controlled by manufacturing and firing methods, these properties depend largely upon the properties of the raw materials.

Qualities of Good Brick:

(i) Bricks should be table moulded, well burnt in kilns, copper coloured, free from cracks and with sharp and square edges.

(ii) Bricks should be uniform shape and should be of standard size.

(iii) Bricks should give clear ringing sound when struck each other.

(iv) Bricks when broken should show a bright homogeneous and compact structure free from voids.

(v) Bricks should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks, when soaked in cold water for a period of 24 hours

(vi) Bricks should be sufficiently hard no impression, should be left on brick surface, when it is scratched with finger nail.

(vii) Bricks should be low thermal conductivity and they should be sound proof

(viii) Bricks should not break when dropped flat on hard ground from a height of about one meter.

(ix) Bricks, when soaked in water for 24hours, should not show deposits of white salts when allowed to dry in shade.

(x) No brick should have crushing strength below 55kg/cm²



Intermittent Kiln



Bulls Trench Kiln



Hoffman continuous kiln

Defects of bricks

Over burning of bricks: Bricks should be burned at temperatures at which incipient, complete and viscous vitrification occur. However, if the bricks are over burnt, a soft molten mass is produced and the bricks loose their shape. Such bricks are not used for construction works.

Under burning of bricks: When bricks are not burnt to cause complete vitrification, the clay is not softened because of insufficient heat and the pores are not closed. This results in higher degree of water absorption and less compressive strength. Such bricks are not recommended for construction works.

Bloating: This defect observed as spongy swollen mass over the surface of burned bricks is caused due to the presence of excess carbonaceous matter and sulphur in brick-clay.

Black core: When brick-clay contains bituminous matter or carbon and they are not completely removed by oxidation, the brick results in black core mainly because of improper burning.

Efflorescence: This defect is caused because of alkalis present in bricks. When bricks come in contact with moisture, water is absorbed and the alkalis crystalise. On drying grey or white powder patches appear on the brick surface. This can be minimised by selecting proper clay materials for brick manufacturing, preventing moisture to come in contact with the masonry,

by providing waterproof coping and by using water repellent materials in mortar and by providing damp proof course.

Chuffs: The deformation of the shape of bricks caused by the rain water falling on hot bricks is known as chuffs.

Checks of cracks: This defect may be because of lumps of lime or excess of water. In case of the former, when bricks come in contact with water, the absorbed water reacts with lime nodules causing expansion and a consequent disintegration of bricks, whereas shrinkage and burning cracks result when excess of water is added during brick manufacturing.

Spots: Iron sulphide, if present in the brick clay, results in dark surface spots on the brick surfaces. Such bricks though not harmful are unsuitable for exposed masonry work.

Blisters: Broken blisters are generally caused on the surface of sewer pipes and drain tiles due to air imprisoned during their moulding.

Sand Lime Brick



It is a brick manufactured from 90% silica sand and 10% hydrated lime and water. It possess uniform shape and dimension, more than clay brick

Raw materials:

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

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.

d. The percentage of clay not more than 10% . Iron compounds not more than 1.5%.

f. Gypsum content not more than 1%.

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

2. Lime:

Hydrated lime Ca(OH)₂ used and it is essential that:

a. the lime is free from any impurities and it must be completely hydrated before the brick goes through the hardening process.

b. the lime have activity not less than 82% in accordance with IS, and not less than 92% in accordance to international specification.

3. Sometimes fly ash or rice husk used instead of lime.

4. Water:

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

5. Pigment:

To make coloured sand lime bricks, suitable colouring pigment should be added in the mixture of sand and lime The Quantity of pigment varies from 0.2 to 3% of the total weight of the brick.

Mix proportion:

The percentage of lime should be between 9-15% of the weight of sand.

Manufacture:

1. Preparing raw materials.

2. Raw materials mixed with a properly adjusted moisture content, the sand and lime mix is conveyed to feed the brick process.

3. The presses are of the rotary table type with an output of up 3000 bricks per hours.

4. As each brick is produced it is normally automatically stacked to await transfer to the hardening chamber known as autoclaves.

5. Autoclaves are long steel cylinders six or seven feet in diameters and each holding up to 20000 bricks. Essentially the autoclave is a large pressure cooker into which the uncured bricks are conveyed on trucks running on rails. Once the bricks are in place within the autoclave, the chambers is sealed. Steam is introduced and the pressure steadily raised for about an hour and then maintained at pressures of 8 to 16 bars and the temperature is raised up to approximately 200 C°. After some hours the steam is then shut off and that in the autoclave released through a valve, this allows the bricks to cool steadily. At this point the bricks are cured and have developed their final properties, especially the strength, and are ready for removal from the autoclave for packaging

Properties of sand lime brick:

Shape and size:

Accurate shape and size and standard brick dimensions are 240*115*75 mm and 240*240*160 mm (according to Iraqi specification).

Absorption:

The water absorption of calcium silicate brick is 12%.

Density:

Density varies between about 1700 Kg/m³ and 2100 Kg/m³ depending on the composition of the brick and manufacturer.

Strength:

Compressive strength of sand lime brick in general is between 14 to 27.5 N/mm^2 depending on the quality of brick being produced, also strengths greater than 48.5 N/mm² can be achieved. Compressive strength according to I.S is between 14 and 17 N/mm².

Drying shrinkage:

Sand lime brick shrinks on drying out in a similar manner to concrete products, amount of shrinkage is about 0.01 to 0.04%.

Frost damage:

The effect of repeated freezing and thawing on sand lime brick under normal conditions is slight, but under sever conditions the brick will be affected.

Efflorescence

It is a white deposit on the surface of bricks and blocks and is a result of the crystallization of a soluble salts in the product. This type of brick is free of soluble salts and is not subjected to efflorescence.

Advantages of calcium silicate bricks:

- 1) Low Thermal Conductivity
- 2) Rigid & Light Weight (Density 250 kg/M³)
- 3) Good Mechanical Strength (Above 10kg/cm²)
- 4) Fire resistant
- 5) Low shrinkage
- 6) Low specific Heat
- 7) Non Combustible & Non Corrosive
- 8) Low maintenance Cost
- 9) Long life
- 10) Easily Workable (cuts easily)

Difference between clay and sand lime brick:

- 1. Shape of sand lime bricks are more uniform than that of clay brick.
- 2. Sand lime bricks are free from soluble salt and free from efflorescence.
- 3. It is no need to soak the brick in water before building it.
- 4. Sand lime brick can be product with several colors.
- 5. Sand lime brick has less thermal expansion.

Concrete brick

This type of brick is manufactured from Portland cement, coarse aggregate, fine aggregate and water. Dimensions of concrete brick similar to that of clay brick or any other dimensions, but its volume not more than 3000 cm³ according to Iraqi specifications No (1068)/1990. The most dimension used is 20*10*5 cm.

Types of concrete brick:

1. Solid concrete brick

2. Perforated concrete brick, percentage of pores not more than 25% of its volume.

3. Hollow concrete brick , percentage of pores are more than 25% of its volume.

Engineering properties of concrete brick:

1. Straight edge, uniform shape and all the brick have the same dimensions.

2. Its strength depend on percentage of mix. Compressive strength according to I.S are not less than 20 N/mm2.

3. can be product with several colors.

4. It possess large drying shrinkage like concrete, so cannot be used before 28-30 days.

5. Density of concrete brick is about 2300 Kg/m3.

6. It is not good thermal insulation material.

7. It is affected by a sulfide saults.

8. Absorption percentage not more than 6.5%.

Uses: Concrete brick in external walls , load bearing wall , foundation and in ornamental works.

Classification of engineering materials

The factors which form the basis of various systems of classifications of materials in material science and engineering are:

(1) the chemical composition of the material,

(2) the mode of the occurrence of the material in the nature,

(3) the refining and the manufacturing process to which the material is subjected prior it acquires the required properties,

(4) the atomic and crystalline structure of material and

(5 the industrial and technical use of the material.

Common engineering materials that falls within the scope of material science and engineering may be classified into one of the following six groups:

1. Metals (ferrous and non-ferrous) and alloys

2.	Ceramics	3. Polymers	4. composite
		2	

5. Advanced materials

1. Metals:

Elements with a valence of 1, 2 or 3. They are crystalline solids composed of atoms held together by a matrix of electrons.

Atoms in metals and their alloys are arranged in a very orderly manner and in comparison to the ceramics and polymers, are relatively dense.

General properties:

1. High electrical conductivity, 2. high thermal conductivity, 3. ductile and relatively high stiffness, 4. toughness and strength. 5. They are ready to machining, casting, forming, stamping and welding.

Engineering metals are generally

ii. Stainless steel \longrightarrow Fe + C + Cr + Mn ... etc.

iii. $C \longrightarrow$ improves Strength

iv. Cr \rightarrow improves the corrosion resistance ... etc

Classification: of metals and alloys:

i. Ferrous: Plain carbon steel, Alloy steel, Cast iron,

ii. Nonferrous: Light Alloys (Al, Mg, Ti, Zn), Heavy Alloys (Cu, Pb, Ni),

Refractory Metals (Mo, Ta, W), Precious metals (Au, Ag, Pt)

Applications:

1. Uses of metals in construction:

a. Metals used as structural materials, frame structure, trusses, beams and others.

b. Metals used as non-structural materials when they used as plate, doors, windows, stairs.

c. Metals used as reserved materials to cover roofs, or as damp proofing materials.

- d. Metals used in making pipes, tanks and so on.
- 2. Automobiles: body, springs, engine block, etc.
- 3. Airplanes: engine components, fuselage, landing gear assembly, etc.
- 4. Trains: rails, engine components, body, wheels
- 5. Machine tools: drill bits, hammers, screwdrivers, saw blades, etc.
- 6. Electrical wiring.
- 7. Magnets

Examples:

- 1 Pure metal elements (Cu, Fe, Zn, Ag, etc.)
- 2. Alloys (Cu-Sn=bronze, Cu-Zn=brass, Fe-C=steel, Pb-Sn=solder)
- 3 Intermetallic compounds (e.g. Ni₃Al)

2. Ceramics:

The word ceramic is derived from the Greek word keramik. The term covers inorganic non -metallic materials whose formation is due to the action of heat Clays, bricks, cements, glass are the most important ones. These are crystalline compounds between metallic and non-metallic elements. They are most frequently oxides, nitrides and carbides. For example, some of the common ceramic materials include aluminium oxide (or alumina, Al_2O_3), silicon dioxide (or silica, SiO₂), silicon carbide (SiC).

General properties: Light weight, Hard, High strength, stronger in compression than tension, tend to be brittle, low electrical conductivity, High temperature resistance and corrosion resistance.

Classification: of ceramics:

1. Traditional Ceramics: Includes pottery, china, porcelain products...etc, these products utilizes natural ceramic ores.

2. Advanced Ceramics: Alumina, magnesia, Carbides, Nitrides, Borides, Silicide's ...etc, they are synthetic materials, usually of better mechanical properties. Electronic ceramics falls in the same category.

3. Glass, Glass Ceramic and Vitro Ceramic: Glasses are essentially vitreous (amorphous, non-crystalline), Glass ceramics are mostly recrystallized from glassy medium and, Vitro Ceramics have crystalline microstructure which are partially vitreous at the grain boundaries.

Applications:

- 1. Electrical insulators
- 2. Abrasives
- 3 Thermal insulation and coatings
- 4 Windows, television screens, optical fibers (glass)
- 5 Corrosion resistant applications
- 6 Electrical devices: capacitors, varistors, transducers, etc.
- 6. Highways and roads (concrete)
- 7. Biocompatible coatings (fusion to bone)
- 8. Self-lubricating bearings
- 9 Magnetic materials (audio/video tapes, hard disks, etc.)
- 10. Optical wave guides
- 11 Night-vision

3. Polymers: High molecular weight organic substance made up of a large number of repeat (monomer) units. Their properties are linked directly to their structure, which is dictated mostly by intermolecular bonds.

General properties:

compared with metals, polymers have lower density, lower stiffness and tend to creep. They have higher thermal expansion and corrosion resistance. Furthermore, polymers have low electrical conductivity and low thermal conductivity. The prime weakness is that polymers do not withstand high temperatures.

Classification: according to their properties:

i. Plastics: (Hard), they can be semi-crystalline or amorphous (glassy).

1. **Thermoplastics**: Such as Polyethylene (PE) and Polymethylmethacrylate (Acrylic and PMMA) are composed of "linear" polymer chains. They flow under shear when heated. They can be compression- or injection- molded.

2. Thermosets: Such as Polystyrene (PS) and Polyvinylchloride (PVC) are composed of "branched" polymer chains. They not flow when heated. The monomers are 'cured' in a mold ('RIM').

ii. Elastomers: (Soft) Rubbery cross-linked solids that will deform elastically under stress, e.g. natural rubber

Thermoplastic elastomers are a special type of elastomer in which the cross-linking becomes reversible upon heating.

iii. Solutions: Viscosity modifiers, polymeric surfactants, lubricants.

Applications and Examples

- 1 Adhesives and glues
- 2. Containers
- 3 Moldable products (computer casings, telephone handsets
- 4 Clothing and upholstery material (vinyl's, polyesters, nylon)
- 5 Water-resistant coatings (latex)
- 6 Biodegradable products (corn-starch packing "peanuts")
- 7 Biomaterials (organic/inorganic interfaces)
- 8 Liquid crystals
- 9 Low-friction materials (Teflon)
- 10 Synthetic oils and greases
- 11 Gaskets and O-rings (rubber)
- 12 Soaps and surfactants

4. Composite:

A combination of two or more materials to achieve better properties than that of the original materials. These materials are usually composed of a "Matrix" and one or more of "Filler" material. Wood is a natural composite of cellulose fibers in a matrix of polymer called lignin. The primary objective of engineering composites is to increase **strength to weight ratio**. Composite material properties are not necessarily *isotropic*, i.e., directional properties can be synthesized according to the type of filler materials and the method of fabrication.

1. General properties: Low weight, high stiffness, brittle, low thermal conductivity and high fatigue resistance. Their properties can be **tailored** according to the component materials.

Classification:

1. Particulate composites (small particles embedded in a different material): e.g. Cermets (Ceramic particle embedded in metal matrix) and Filled polymers.

2. Laminate composites (golf club shafts, tennis rackets, Shield Glass)

3. Fiber reinforced composites: e.g. Fiber glass (GFRP) and Carbon-fiber reinforced polymers (CFRP)

Applications:

1 • Sports equipment (golf club shafts, tennis rackets, bicycle frames)

- 2 Aerospace materials
- 3 Thermal insulation
- 4 Concrete
- 5 "Smart" materials (sensing and responding)
- 6 Brake materials
5. Examples:

- 1 Fiberglass (glass fibers in a polymer)
- 2 Space shuttle heat shields (interwoven ceramic fibers)
- 3 Paints (ceramic particles in latex)
- 4 Tank armor (ceramic particles in metal)

Other Types of Engineering Materials

1. *Classes:* Some literatures allocate a unique category for it.

2. *Biomaterials:* (really using previous 5): Including Bone substitution, Wide variety of Dental materials and else.

3. *Liquids and Gases:* play a major role in thermal, hydraulic and pneumatic systems. Used in heat transfer, materials flow, power/pressure transmission and lubrication. Have low electrical and thermal conductivity.

4. *Natural materials:* e.g. Wood, Leather, Cotton/wool/silk, Bone.

Advanced Materials

- 1. Semiconductors
- 2. Biomaterials
- 3. Materials of the Future
- 4. (A) Smart Materials
- 5 .(B) Nano engineered Materials

Flexural Test:

Tensile strength of concrete is measured indirectly by the flexural test. The flexural test shows the ability of unreinforced concrete beam or slab to withstand failure in bending. Flexural strength signifies the highest stress experienced within the material at its moment of rupture. Flexural strength is also known as bend strength, fracture strength and modulus of rupture.

Standard Test of Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

• Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm)

Third-point loading



Flexural Strength Test Arrangement

Procedure

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.

- 2. Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
- 3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
- 4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
- 5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

Calculation

The Flexural Strength or modulus of rupture (f_b) is given by

 $f_b = pl/bd^2$ (when a > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

 $\label{eq:fb} f_b=3pa/bd^2 \ \ (when \ a<20.0 cm \ but>17.0 \ for \ 15.0 cm \ specimen \ or <13.3 \ cm \ but>11.0 cm \ for \ 10.0 cm \ specimen.)$

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (kg)

TORTION TEST

Torsion loading is the application of a torque force such that a member is twisted about its axis. Many products and components are subjected to torsional forces during their operation. It is common in rotating shafts. By testing these products in torsion, manufacturers are able to simulate real life service conditions, check product quality, verify designs, and ensure proper manufacturing techniques. This test is generally carried out on cylindrical or tubular specimen with a reduced mid-section, Figure 1. A typical torsion test specimen is mounted between the two heads of a machine, shown in Figure 4, and is twisted. Figure 3: Torsion test specimens Figure 2:

1• Torsion tests are made on materials to determine such properties as the modulus of elasticity in shear, the torsional yield strength, and the modulus of rupture.

2• Torsion-testing equipment consists of a twisting head, with a chuck for gripping the specimen and for applying the twisting moment to the specimen, and a weighing head, which grips the other end of the specimen and measures the twisting moment, or torque.

3• The deformation of the specimen is measured by a twist-measuring device called a troptometer.

4• Determination is made of the angular displacement of a point near one end of the test section of the specimen with respect to a point on the same longitudinal element at the opposite end.



Fig: 1 Test Speciment



Fig: 2 Torsion test machine

Shear Testing

Shearing is defined as the application of load in opposite directions along two parallel surfaces. As displacement occurs, the parallel surfaces remain parallel to one another, but are shifted. Note that an extra pair of vertical shear forces in Figure 1 must be presented to avoid free-body rotation.

Hook's law is still obeyed under shear by linear elastic materials, but for an isotropic material the shear stress τ and the shear strain γ are related by the shear modulus G such as:

$$\tau = G \gamma \tag{1}$$

The shear stress is given by

$$\tau = \frac{F}{A} \tag{2}$$

The shear strain is defined by the *shear angle* θ , such as:

 $\gamma = \tan \theta \tag{3}$



Figure 1: Pure shear loading

4. Impact testing (toughness testing)

Impact tests consist of striking a suitable specimen with a controlled blow and measuring the energy absorbed in bending or breaking the specimen. The energy value indicates the toughness of the material under test.

There are several types of the impact tests and the most famous type is the Izod test.

In the Izod test, a 10mm square, notched specimen is used, it is preferred to use a specimen that have a more than one or two and even three notched in the same specimen. The striker of the pendulum hits the specimen with a kinetic energy of 162.72 J at a velocity of 3.8m/s.

Since test use a notched specimen, useful information can be obtained regarding the resistance of the material to the spread of a crack which may originate from a point of stress concentration such as sharp comers, undercuts, sudden changes in section, and machining marks in stressed components. Such points of stress concentration should be eliminated during design and manufacture.

A second type of impact test is the Charpy test. While in the Izod test the specimen is supported as a cantilever, but in the Charpy test it is supported as a beam. It is struck with a kinetic energy of 298.3 J at a velocity of 5m/s. The Charpy impact test is usually use for testing the toughness of polymers.



HARDNESS TESTING:

Hardness usually implies resistance to deformation, resistance to permanent or plastic deformation or resistance to indentation.

There are three general types of hardness measurements depending upon the manner in which the test is conducted. These are

- 1. Scratch hardness
- 2. Indentation hardness
- 3. Rebound, or dynamic, hardness.

SCRATCH HARDNESS

• With this measure of hardness, various minerals and other materials are rated on their ability to scratch one another.

• Hardness is measured according to the Mohs scale.

• This consists of 10 standard minerals arranged in the order of their ability to be scratched.

The softest mineral in this scale is talc (scratch hardness 1), while diamond has a hardness of 10. A fingernail has a value of about 2, annealed copper has a value of 3, and martensite a hardness of 7.

• Most hard metals fall in the Mohs hardness range of 4 to 8.

• A different type of scratch-hardness test measures the depth or width of a scratch made by drawing a diamond stylus across the surface under a definite load.

Hardness has already been defined as the resistance of a material to

indentation or abrasion by another hard body (good hardness generally means that the material is resistant to scratching and wear). It is by indentation that most hardness tests are performed. A hard indenter is pressed into the specimen by a standard load, and the magnitude of the

indentation (either area or depth) is taken as a measure of hardness.

Hardness tests are commonly used for assessing material properties because they are quick and convenient. However, a variety of testing methods is appropriate due to differences in hardness among different

materials.

1. The Brinell hardness test

In this test, hardness is measured by pressing a hard steel ball into the

surface of the test piece, using a known load. It is important to choose the combination of load and ball size carefully so that the indentation is free from distortion and suitable for measurement. The relationship of the Brinell hardness [HB] which is between load P (kg), the diameter D (mm) of the hardened ball indenter and the diameter d (mm) of the indentation on the surface is given by the expression:

$HB = \frac{load (Kg)}{Area of curved surface indentation}$

Figure shows how the Brinell hardness value is determined. The diameter of the indentation is measured in two directions at right angles

and the average taken. The diameter is measured either by using a microscope scale, or by a projection screen with micrometer adjustment.

2. The Vickers hardness test

This test is preferable to the Brinell test where hard materials are concerned, as it uses a diamond indenter. (Diamond is the hardest material known - approximately 6000 HB.) The diamond indenter is in the form of a square-based pyramid with an angle of 1 36° between opposite faces .Since only one type of indenter is used the load has to be varied for different hardness ranges. Standard loads are 5, 10, 20. 30, 50 and 1 00 kg. It is necessary to state the load when specifying a Vickers hardness number. For example, if the hardness number is found to be 200 when using a 50 kg load, then the hardness number is written as HV (50) = 200.



Principle of the Brinell hardness test.



3. The Rockwell hardness test

Although not as reliable as the Brinell and Vickers hardness tests for laboratory purposes, the Rockwell test is widely used in industry as it is quick, simple and direct reading. Universal electronic hardness testing machines are now widely used which, at the turn of a switch, can provide either Brinell, Vickers or Rockwell tests and show the hardness number as a digital readout automatically.

In principle the Rockwell hardness test compares the difference in depth of penetration of the indenter when using forces of two different values. That is, a minor force is first applied (to take up the backlash and pierce the skin of the component) and the scale are set to read zero. Then a major force is applied over and above the minor force and the increased depth of penetration is shown on the scales of the machine as a direct reading of hardness without the need for calculation or conversion tables. Figure shows a typical Rockwell hardness testing machine. The standard Rockwell test can not be used for very thin sheet and foils and for these the Rockwell superficial hardness test is used.



Lecture 4

Stress—Strain Behaviour

The proportional limit

Up to the proportional limit for the material, the graph is a straight line and so the stress is proportional to elastic strain and Hooke's Law applies.



1- Load is proportional to deformation .

2 - Stress is proportional to strain, material behaves *elastically*, There is no permanent change to the material; when the load is removed, the material resumes its original shape .

3 - After the proportional limit, the graph changes from a straight Line

Hooke's Law

Within the elastic region of the stress-strain diagram, stress is linearly proportional to strain (up to proportional limit).

-That relationship was formalized by Robert Hooke in 1678

-In mathematical terms Hooke's Law

P/A

E = Stress / Strain = -----

 $\Delta L/L$

where stress = P/A in N/m^2

strain = $\frac{\Delta L}{L}$ unitless

 $E = Modulus of elasticity in N/m^2$

For shear stress in the same region Hooke's Law $\eta = G\gamma \eta$ (tau) is the shear stress G is the shear modulus or the modulus of rigidity γ (gamma) is the shear strain.

Modulus of Elasticity or Young's Modulus(E)

An elastic modulus (also known as modulus of elasticity) is a quantity that measures an object or substance's resistance to being deformed elastically (i.e., non-permanently) when a stress is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region: A stiffer material will have a higher elastic modulus.

If stress (σ) is measured in Mega Pascal (Mpa), then since strain(ε) is a dimensionless quantity, the units of modulus of elasticity (E) will be in Mega Pascal's

It is the slope of the initial linear portion of the stress-strain diagram. In other words it is the ratio of stress to elastic strain. $E = \sigma / E$

The modulus of elasticity may also be characterized as the "**stiffness**" or ability of a material to resist deformation within the linear range.

E (Steel) $\approx 200 \times 10^3 \text{ MPa}$

E (Aluminium) \approx 70 x 10³ MPa

E (Concrete) $\approx 30 \times 10^3$ MPa

Poisson Ratio

The Poisson Effect :

A positive (tensile) strain in one direction will also contribute a negative (compressive) strain in the other direction, just as stretching a rubber band to make it longer in one direction makes it thinner in the other directions (see Fig. 2). This lateral contraction accompanying a longitudinal extension is called the **Poisson effect**.



Figure: The Poisson Effect

So there is a tensile strain in the axial direction and a compressive strain in the other two (lateral) directions.

The ratio of lateral strain of material to axial strain within elastic limit define as

Poisson's ratio.

 $v = (\text{lateral strain} / \text{axial strain}) = (\epsilon \text{ lateral} / \epsilon \text{ longitudinal})$ Greek letter v (nu)

The Poisson's ratio is a dimensionless parameter that provides a good deal of insight into the nature of the material. The major classes of engineered structural materials fall neatly into order when ranked by Poisson's ratio.

Hooke's Law in Shear

For many materials, the initial part of the shear stress-strain diagram is a straight line through the origin, just as it is in tension. For this linearly elastic region, the shear stress and shear strain are proportional, and therefore we have the following equation for Hooke's law in shear:

 $\tau = G\gamma$

In which, G is the shear modulus (also called the modulus of rigidity).

The elastic modulus, shear modulus and Poisson's ratio are related by

E = 2G(1+V)

Material	Poisson's
Class	Ratio ν
Ceramics	0.2
Metals	0.3
Plastics	0.4
Rubber	0.5

Example: Two points fixed on steel bar of 10 mm diameter, the distance between points was 50 mm. tensile force applied on its ends (8 kN). The distance increased by 0.025 mm and the diameter decreased by 0.0015 mm. Determine:

1 -Normal stress

2 -Longitudinal and lateral strains 3- Poisson's ratio

Brittle and Ductile behaviour of stress – strain curve:

Metallic engineering materials are commonly classified as either ductile or brittle materials. A ductile material lies one having a relatively large tensile strain up to the point of rupture (for example, structural **steel** or **aluminium**) whereas a brittle material has a relatively small strain up to this same point. An arbitrary strain of 0.05 mm/mm is taken as the dividing line between these two classes of materials. **Cast iron** and **concrete** are examples of brittle materials.



Typical stress-strain curve of a ductile metal



Ductile and brittle material behavior

1. Ductile Materials

The capacity of a material to allow large extensions, referred to the ability to be drawn out plastically, is termed its ductility. Materials with high ductility are termed ductile materials, members with low ductility are termed brittle materials. A quantitative value of the ductility is obtained by measurements of the percentage elongation or percentage reduction in area, both being defined below.

Percentage elongation =
$$\frac{\text{increase in gauge length to fracture}}{\text{original gauge length}} \times 100$$

Percentage reduction in area = $\frac{\text{reduction in cross-sectional area of necked portion}}{\text{original area}} \times 100$



Figure : Stress-strain diagrams for various materials

A property closely related to ductility is malleability, which defines a material's ability to be hammered out into thin sheets. A typical example of a malleable material is lead. This is used extensively in the plumbing

trade where it is hammered or beaten into corners or joints to provide a weatherproof seal.

2.Brittle materials

A brittle material is one which exhibits relatively small extensions to fracture so that the partially plastic region of the tensile test graph is much reduced. There is little or no necking at fracture for brittle materials.

Brittle materials often have relatively large Young's moduli and ultimate stresses in comparison to ductile materials.

1. Yield strength

- 1. The yield point, is defined in engineering and materials science as the stress at which a material begins to plastically deform.
- 2. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed.
- 3. Knowledge of the yield point is vital when designing a component since it generally represents an upper limit to the load that can be applied. It is also important for the control of many materials production techniques such as forging, rolling, or pressing.
- 4. In structural engineering, yield is the permanent plastic deformation of a structural member under stress.

Determination of Yield Strength in Ductile Materials

In many materials, the yield stress is not very well defined and for this reason a standard has been developed to determine its value. The standard procedure is to project a line parallel to the initial elastic region starting at 0.002 strain. The 0.002 strain point is often referred to as the 0.2% offset strain point. The intersection of this new line with the stress-strain curve then defines the yield strength as shown in Figure :



2. Toughness:

- 1. It is the ability of a material to withstand bending without fracture due to high impact loads.
- 2. Toughness of material decreases when it is heated .
- 3. It is also measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to failure point and is the area under stress strain curve.
- 4. For example, if a load is suddenly applied to a piece of mild steel and then to a piece of glass, the mild steel will absorb much more energy before failure occurs. Thus mild steel is said to be much tougher than a glass.
- 5. This property is desirable in parts subjected to shock and impact loads. Notch toughness is the measure of the metal's resistance to brittle fracture in presence of flaw or notch and fast loading conditions. To the opposite of brittleness, the ability of a material is to resist fracture under shock loading.

Basically, two main impact tests for measuring the toughness of material in Joule are available namely Izod and Charpy test. Figure below shows the three types of Notches used for fracture study. U type notch specimens can also be used for testing. In case of ductile materials, when the material is stressed, it plastically deforms by absorbing high energy and then the material fractures. But in the case of brittle materials, the cohesive strength of the material exceeds before getting plastically deformed and hence absorbs less energy before getting fractured. Unit of toughness is joule per cubic meter (J/m^3) .



Different types of Notches (a, b, c)

Thermal Stresses

1. An increase in temperature results in expansion, whereas a temperature decrease produces contraction. This deformation is isotropic (the same in every direction) and proportional to the temperature change.

2. It follows that the associated strain, called *thermal strain*, is

$$\varepsilon T = \alpha(\Delta T)$$

Where the constant α is a material property known as the *coefficient of thermal expansion*,

and ΔT is the temperature change = $t_2 - t_1$ The coefficient of thermal expansion represents the normal strain caused by a **one-degree** change in temperature. 3. ΔT is taken to be positive when the temperature increases, and negative when the temperature decreases. Thus, in equation above positive ΔT produces positive strain (elongation) and negative ΔT produces negative strain (contraction).

4. The units of α are 1/°C(per degree Celsius) in the SI system, and 1/°F (per degree Fahrenheit) in the U.S. Customary system. Typical values of α are 23×106 /°C (13×106 /°F) for aluminium and 12×106 /°C(6.5×106 /°F) for steel.

5. If the temperature change is uniform throughout the body, the thermal strain εT is also uniform. Consequently, the change δT in any dimension *L* of the body is given by

 $\delta T = \varepsilon T L = \alpha(\Delta T) L$

6. If thermal deformation is permitted to occur freely (by using expansion joints or roller supports), **no internal forces** will be induced in the body – there will be strain, but no stress.

7. In cases where the deformation of a body is **restricted**, either totally or partially, **internal forces** will develop that oppose the thermal expansion or contraction. The stresses caused by these internal forces are known as *thermal stresses*.

8. $\sigma = E \cdot \alpha \cdot (\Delta T)$

-:مثال

إذا كان فرق درجات الحرارة المتوقع بين الجو الخارجي والخرسانة المغطاة بطبقة حماية هو عشرون درجة مئوية .

فأحسب إجهادات القص المتولدة بين الخرسانة وطبقة الحماية إذا كان معامل المرونة للخرسانة

2000 N / mm², $\alpha = 1 \times 10^{-5}$ $\sigma = E \cdot \alpha \cdot (\Delta T)$ $= 2000 \times 1 \times 10^{-5} \times 20 = 0.4 \text{ N/mm}^2$

Lime

Lime is classified based on the calcination of limestone, and they are:

1. Fat Lime

Fat lime is white in color, which has high calcium oxide content. This lime can set and become hard only in the presence of carbon dioxide.

It is also called high-calcium lime, pure lime, rich lime or white lime. But, it is mostly known as fat lime as it slakes quickly. It contains specific properties such as very slowly hardening, a high degree of plasticity and soluble in water.

Uses of fat lime:

- It is used in plastered surfaces for whitewashing.
- It is used as lime mortar (a combination of lime and sand) for plastering and pointing works.
- It is used as a Lime Surkhi mortar for foundations, thick masonry walls, etc., where surkhi is the powder obtained by pounding burnt bricks.

2.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 $CaCO_3$, often replaced, to a greater or less degree by magnesium carbonate MgCO₃, this product being one that will slake on the addition of water.

Uses of quick lime:

Lime may be used as:

- a. Building material.
- b. Finishing materials.

3. Hydrated lime:

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

Hydraulic lime is the lime that contains small quantities of silica, alumina and iron oxide, which are collectively in the chemical composition with calcium oxide.

It is also known as water lime because it can set under water and become hard even in the absence of carbon dioxid

Uses of hydraulic lime:

- It resembles cement as it contains 30% of clay and can be used in major civil engineering works.
- It can set in thick walls where there is no free-flowing of air.
- It forms a thin paste with water.

Manufacture of lime :

Raw materials - The production of lime begins with the quarrying and crushing of limestone. Limestone is a general term that covers numerous varieties of sedimentary rock. Limestone can be composed of the following four minerals, plus impurities: calcite (CaCO₃), aragonite (also CaCO₃ but with a different crystal structure from calcite), dolomite (CaMg (CO₃)₂), and magnesite (MgCO₃)

Pure lime stone rocks consist entirely of $CaCO_3$. Pure calcium carbonate consists of 56 parts by weight of CaO to 44 parts of CO₂.

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, sulphur, and alkalis.

1. Crushing

The first step in the manufacturing of lime is to crush the pieces of limestone to make them smaller. There are two basic types of primary crushers: compression and impact.

Compression crushers use slow, steady amounts of pressure to reduce the size of the rock, whereas impact crushers rely on intense, repeated blows. Compression crushers are used mainly for larger stones, impact crushers for smaller sizes. In some plants, stones undergo secondary crushing as well. The crushed stone is screened to provide the desired stone size and then conveyed to storage in conical stockpiles.

2. Calcination

Limestone is converted into lime through heating in a kiln, a process known as calcination. When limestone is subjected to high temperatures, it undergoes a chemical decomposition resulting in the formation of lime (CaO) and the emission of carbon dioxide gas (CO_2).

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 CO₂ is driven off as a gas, leaving the oxides of calcium and magnesium.

High-Calcium Lime $CaCO_3 + heat \longrightarrow CO_2 + CaO$ Dolomitic Lime $CaCO_3 - MgCO_3 + heat \longrightarrow 2CO_2 + CaO - MgO$

Lime Kilns

Lime kilns can be categorized into three groups: rotary kilns, vertical kilns, and miscellaneous.



Figure 2-3. Preheater rotary kiln system for lime production.

Properties of Lime

Lime is one of the oldest binding materials used in several ancient architectural works. A good quality lime should own the following properties:

- It should possess good plasticity.
- It should be flexible and easily workable.
- When used in mortar, it should provide greater strength to the masonry.
- It should solidify in less time and become hard.
- It should comprise of excellent binding properties which adhere to brick or stone masonry units perfectly.
- It possesses high durable properties as it is less shrinkable when used in mortar.
- It should be highly resistant to moisture and can be used for pointing works.



Vertical kiln

Properties of quick lime: Plasticity:

The term "plasticity" is commonly used to describe the spreading quality 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.

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 CO₂ in the atmosphere, causing the lime hydrate to revert to the original calcium carbonate. $CaO + H_2O ----- \blacktriangleright Ca(OH)_2$ $Ca(OH)_2 + CO_2 - ---- \blacktriangleright CaCO_3 + H_2O$

Hydrated lime: 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 anhydrite lime and impurities, or the entire mass must be finely pulverized.

Uses:

Hydrated lime may be used as:

A .Building materials.

B .Finishing materials.

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.

Types of lime mortar:

- 1. Sand lime mortar
- 2. Cement lime mortar

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 CO_2 in the atmosphere influence the rate of setting of

lime drying the air and charging it with carbon dioxide, greatly accelerating the setting process

1. 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.

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

إطفاء النورة (الجير المطفأ) Hydration of Lime

هي المادة الناتجة من معالجة الجير الحي(النورة)بإطفائه (إضافة الماء)قبل الاستعمال بمدة كافية لتبريده ليصبح على هيئة مسحوق ابيض اللون جاف خال من الكتل المتماسكة بعد ان تكمل عملية الإطفاء تتحول الكتل الى مسحوق ناعم ينقل الى احواض فيها كمية من الماء ليحل بشكل كثيف يمرر من خلال مناخل ناعمة لتفصل المواد الغريبة وعند مزج النورة مع الرمل تتصلب كربونات الكالسيوم مع ذرات الرمل وتربطها مع بعضها لتشكل كتلة واحدة.

مونة السمنت – نورة (جير) Cement – Lime mortar

تكون نسب المزج المستعملة هي-:

1نورة 1 :سمنت 6 :رمل

1سمنت 2 :نورة 9 :رمل

1سمنت 3 :نورة 12 :رمل

ولكل نوع من الأنواع الثلاث ميزات متباينة في المونة الناتجة بالنسبة لسرعة تصلبها وليونتها وزيادة التحمل مع الوقت ومقاومتها للماء والاملاح وتماسكها مع المواد البنائية وسهولة نشر ها والعمل بها.

خواص مونة سمنت – نورة Properties of Cement – Lime mortar

زيادة قوة الربط بين الطابوق والمونة لسهولة تداخل المونة بين أجزاء الطابوق الدقيقة.

2 . سهولة استعمال هذا المزيج الذي يجمع بين خواص السمنت والنورة من ناحية ليونة النورة وصعوبة العمل بالسمنت وسهولة نشر المزيج المتكون.

3. زيادة تحمل المونة الناتجة من هذا المزيج بعد التصلب.

4. الحصول على وقت تماسك أطول بالنسبة للنورة وتماسك بدائي سريع بالنسبة للسمنت

5. الحصول على كتلة مقاومة للماء والرطوبة بالنسبة لتداخل حبيبات السمنت وحبيبات النورة وليس هناك علاقة في تفاعل أي من المادتين على الأخرى.

6. ان سعر النورة عادة اقل من سعر السمنت فكلما زادت نسبة النورة في المزيج كلما كان سعر المونة اقل.

7. الاحتفاظ بماء المزيج لمدة أطول لوجود السمنت.

Lecture 3

Mechanical Properties of Building Materials

Mechanical properties of the materials are find out by applying external forces on them. These are very important properties which are responsible for behaviour of a material in its job. The mechanical properties are:

Strength, 2. Hardness, 3. Elasticity
Plasticity, 5. Brittleness, 6. Fatigue
Impact strength, 8. Abrasion resistance, 9. Creep

Concept of Stress : Let us introduce the concept of stress, as we know that the main problem of engineering mechanics of material is the investigation of the internal resistance of the body, i.e. the nature of forces set up within a body to balance the effect of the externally applied forces.

The externally applied forces are termed as loads. These externally applied forces may be due to any one or more of the followings:

(i) due to service conditions

- (ii) due to environment in which the component works
- (iii) through contact with other members

(iv) due to fluid pressures

(v) due to gravity or inertia forces (Self-weight of the structure).

1. Strength (stress):

Strength of the materials refers to the ability of a material to resist the externally applied forces without breaking or yielding.

Three types of static stresses to which materials can be subjected:

1. Tensile stress - tend to stretch the material

2. Compressive strength - tend to squeeze it

3. Shear stress - tend to cause adjacent portions of material to slide against each other.

Ultimate strength: maximum ability to bear the load after which the material failed.

Simple Stress

Simple stress is expressed as the ratio of the applied force divided by the resisting area or :

 $\sigma = Force / Area.$

It is the expression of force per unit area to structural members that are subjected to external forces and/or induced forces. Here we are using an assumption that the total force or total load carried by the bar is uniformly distributed over its cross-section.

The tensile strength, compressive strength and shear strength can be defined by:

$\sigma = P / A$

In this formula: σ is the strength of a material (MPa);

P is the largest load of a specimen when it is destructed or failed, (N);

A is the force bearing area of a specimen (mm^2) .

Units :

The basic units of stress in S.I units i.e. (International System) are $N \mspace{N} / m2$ (or Pa , Pascal)

$MPa = 10^{6} Pa$, $GPa = 10^{9} Pa$, $KPa = 10^{3} Pa$

Sometimes N/mm^2 units are also used, because this is an equivalent to MPa, while US customary unit is *pound per square* inch, **psi**. (lb/in²).

Simple stress can be classified as normal stress, shear stress, and bearing stress.

TYPES OF STRESSES :

Only two basic stresses exists : (1) normal stress and (2) shear stress. Other stresses either are similar to these basic stresses or are a combination of this e.g. bending stress is a combination tensile, compressive and shear stresses. Let us define the normal stresses and shear stresses in the following sections. **Normal stresses :** We have defined stress as force per unit area. If the stresses are normal to the areas concerned, then these are termed as normal stresses. The normal stresses are generally denoted by a Greek letter (σ).



This is also known as uniaxial state of stress, because the stresses acts only in one direction however, such a state rarely exists, therefore we have biaxial and triaxial state of stresses where either the two mutually perpendicular normal stresses acts or three mutually perpendicular normal stresses acts as shown in the figures below :



Tensile or compressive Stresses:

The normal stresses can be either tensile or compressive whether the stresses acts out of the area or into the area



Shear Stresses:

Let us consider now the situation, where the cross – sectional area of a block of material is subject to a distribution of forces which are parallel, rather than normal, to the area concerned. Such forces are associated with a shearing of the material, and are referred to as shear forces. The resulting stress is known as shear stress.



where V is the resultant shearing force which passes through the centroid of the area A being sheared.

$$au = \frac{V}{A}$$

Deformation: - Change in shape of a material due to application of load. It is of 2 types a. Elastic Deformation b. Plastic Deformation

a. *Elastic Deformation:* - The sample is deformed on application of load but it comes back to its original shape once the load is removed. Hence, it's a temporary deformation.



b. *Plastic Deformation:* - The material doesn't come back to its original shape after removal of load. Hence, it's a permanent deformation.



Strain of Building Materials :

Engineering strain:

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

 $\varepsilon = (L_2 - L_1)/L_1$ $\varepsilon = \Delta L / L_1$

Where (ε) is the engineering normal strain, (L_1) is the original length of the fibre and (L_2) is the final length of the fibre. Measures of strain are often expressed in parts per million or micro strains.

Stress-Strain Diagram

Suppose that a metal specimen be placed in tension-compression testing machine. As the axial load is gradually increased in increments, the total elongation over the gage length is measured at each increment of the load and this is continued until failure of the specimen takes place. Knowing the original cross-sectional area and length of the specimen, the normal stress σ and the strain ε can be obtained. The graph of these quantities with the stress σ along the y-axis and the strain ε along the x-axis is called the stress-strain diagram. The stress-strain diagram differs in form for various materials. The diagram shown below is that for a structural steel











Typical tensile testing specimen

Concepts of Stress and Strain

- 1. Stress can be defined by ratio of the perpendicular force applied to a specimen divided by its original cross sectional area, formally called engineering stress.
- 2. To compare specimens of different sizes, the load is calculated per unit area, also called normalization to the area. Force divided by area is called stress. In tension and compression tests, the relevant area is that perpendicular to the force.
- 3. In shear or torsion tests, the area is perpendicular to the axis of rotation. The stress is obtained by dividing the load (P) by the original area of the cross section of the specimen .
- 4. The unit is the Mega Pascal (Mpa) = Newton's/ mm^2 .
- 5. Strain is the ratio of change in length due to deformation to the original length of the specimen, formally called engineering strain. strain is unitless, but often units of m/m (or mm/mm) are used.
- 6. The parameters used to describe stress-strain curve are tensile strength, yield strength or yield point, percent elongation, and reduction of area. The first two are strength parameters; the last two indicate ductility.
Different limits and regions under Area of Stress Strain Curve:

1. Elastic Limit

Elastic limit is the point which shows the maximum stress that can be applied to the body without resulting in permanent deformation when stress is removed. At elastic limit when the load is removed from the body, it returns to original size and shape.

At elastic limit stress is no longer linearly proportional to strain.

Elastic region: Elastic region is the area under the curve from initial point to elastic limit.

2. Plastic limit:

Plastic region is the area under curve which starts from elastic limit to fracture point. Under the area body shows plastic behaviour i.e. when the load is removed from body, it does not come back to its original size and shape.

3. Yield point

Yield point is the point which shows the stress at which a little or no increase in stress results to large increase in strain that is material continues to deform without increase in load. At this point the material will have permanent deformation. For steel, yield point is also just above proportional limit. Yield point is of two types: Upper yield point, and

Lower yield point.

Among the common materials, only steel exhibits yield point. For

annealed mild steel, upper yield point occurs at 260 MPa and lower

yield point occurs at 230 MPa.

4. Ultimate Tensile Strength:

As the stress on material is increased further, the stress and the strain increases from yield point to a point called ultimate tensile strength (UTS) where stress applied is maximum. Thus ultimate tensile strength can be defined as the highest stress on the specimen which it can withstand. For annealed mild steel, ultimate tensile strength occurs at 400 MPa.

5. Fracture Stress

After ultimate tensile strength, the applied stress decreases until the stress is obtained where material fractures called fracture stress. Fracture stress is also called breaking strength.

6. Necking:

Necking covers the area from ultimate tensile stress to fracture point. It is the region where cross sectional area of material will decrease in a localized spot and capacity of material to carry load will decrease. In necking region, stress strain curve has neck like curve.

Metals

Metals form about a quarter of the earth crust by weight One of the earliest material used dated back to pre-historic time.

Metals can initially be divided into two general classifications, and Steelworkers work with both: ferrous and nonferrous metals.

All metals except gold are generally found chemically combined with other elements in the form of oxides and sulphates. Commonly known as **ores.**

Metals make up the largest class of chemical elements in the Periodic Table.

• Approximately three quarters of elements are metals. Most metals are silvery in colour, have a characteristic lustre, and are solid (rather than liquid or gaseous).

• Most metals are also malleable (can be shaped with a hammer), ductile (can be

drawn into a wire), and good conductors of both heat and electricity.

Pure Metals and Alloys

Metal that are not mixed with any other materials are known as pure metals.

```
E.g. Iron (Fe), Copper (Cu) and Zinc (Zn)
```

Alloys are **mixtures** of two or more metals formed together with other elements/materials to create new metals with improved Mechanical Properties and other properties of the base metal.

E.g. Brass (Copper and Zinc),

Stainless steel (steel and chromium)

Alloy = metal A + metal B + \dots + other elements

Alloys may consist of two more components:

a. **Ferrous metals** are those which have the iron as their main constituent, such as crude (pig) iron, cast iron, wrought iron and steels.

Ferrous metals: all have certain properties:

1. they contain **iron**

2.they will corrode unless protected

3. they are attracted by magnets.

b. **Non-ferrous metals:** are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver .

Non-ferrous metals: also have

1.certain unique properties:

- 2. they do not contain iron
- 3. they are not magnetic
- 4. they are mostly **pure metals**.

```
استعمالات المعادن Uses of metals
- 1- تستعمل كمواد انشائية كما في الأبنية الهيكلية.
- 2- تستعمل كمواد غير انشائية كما في الالواح والحديد المزخرف والمنقوش في السلالم والشبابيك
والابواب.
- 3- تستعمل كمواد حافظة كما في القواطع الخارجية او في تغطية السقوف.
- 4- تستعمل كمواد مصنوعة كما في الخزانات لتجهيز وتصريف المياه.
```

The ferrous metals commonly used in engineering practice are *cast iron, wrought iron, steel and alloy steels*. The basic principal raw material for all ferrous metals is crude (pig iron) which is obtained by smelting *iron ore*, coke and limestone, in the *blast furnace*.

S.No.	Iron ore	Color	Iron %
1.	Haematite (Fe_3O_4)	Red	70%
2.	Magnetite (Fe_2O_3)	Black	72%
3.	Limonite	Brown	62.5%
4.	Siderite	Brown	48%

Extraction of Iron :

- 1- Iron is found in iron oxide in the earth.
- 2-Three primary iron ores: magnetite, hematite, Limonite.
- 3- Iron is extracted using blast furnace.
- 4- Steps in extraction of iron :
- a .Ores is washed, crushed and mixed with limestone and coke
- b. The mixture is fed into the furnace and is then melted
- c .Coke(a product of coal, mainly carbon) is used to convert the iron oxides to iron.
- d. Limestone helps to separate the impurities from the metal
- e. The liquid waste is known as slag that floats on the molten iron
- f. They are then tapped off (separated)

g. The iron produced is only about 90% to 95% pure.

h. The iron is then further refined using the basic oxygen furnace and the electric arc furnace to produce steel which is widely used now.

Main Types of Iron:

1. Pig iron

The calcined ore is smelted in blast furnace. Composition:

Pig iron contains 2-6% carbon, 0.5-3.5% silicon, 0.5-2% manganese, 0.02-0.1% sulphur and 0.03-1% Phosphorus.

حديد الاهين Pig Iron يحصل مباشرة من الفرن النفاخ وعلى شكل حديد الزهر وخواصه مرتبطة بطريقة الصهر يحصل مباشرة من الفرن النفاخ وعلى شكل حديد الزهر وخواصه مرتبطة بطريقة الصهر وانتخاب مواد الخام .ان مقدار الكاربون فيه متغير بين % (6 - 2) وهو على أنواع منها الأبيض والرصاص ي والنوع القابل للطرق، ان رصاص ي غير لماع وبوجه لون حديد الاهين هو غالبا خشن نسبيا في حالة عدم الانهاء . عندماً يكسر يظهر في سطوح الكسر التركيب البلوري لحبيبات الحديد واضحا ويعتبر حديد الاهين اكثر انواع مقاومة للتآكل ومع هذا يجب المحافظة عليه عند استعماله. ان حديد الاهين ذو دقة عالية في تحمل قوى الضغط ولكنه ضعيف في حالة الشد والقص يستعمل لعمل وبمقاطع مختلفة

Properties:

Pig iron is

- 1. hard and brittle with fusion temperature of 1200°C and melts easily.
- 2. It can be hardened but cannot be tempered and magnetized
- 3. Its compressive strength is high but is weak in tension and shear.
- 4.Pig iron does not rust and cannot be riveted or welded.

Uses:

Pig iron is most suitable for making columns, base plates, door brackets, etc.

2. Cast iron: Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements. a. White cast iron

- b. Grey cast iron
- c. Malleable cast iron
- d. Ductile cast iron .
- e. mottled, chilled and toughened.

Cast Iron Production (Blast furnace)

Blast furnace was invented in 14th century. A typical blast furnace along with its various parts is shown in Fig .below. Modern blast furnaces range in size from 20 to 35 m diameter. It is set on the top of brick foundation. There are four major parts of blast furnace from bottom to top:

- 1. hearth,
- 2. bosh,
- 3. stack and
- 4. top.

Uses: On account of cheapness, strength, ease with which it may be melted and cast into more or less intricate shapes, ease of machining, high damping capacity, and ease with which its hardness may be varied, cast iron is the most used of the cast metals employed in engineering constructions and machines. Some of the more common uses of cast iron are making ornamental castings such as wall brackets, lamp posts; bathroom fittings such as cisterns, water pipes, sewers, manhole covers, sanitary fittings and; rail chairs, carriage wheels and machine parts subjected.

Properties: Cast iron is

- 1. hard and brittle. It can neither be riveted nor welded.
- 2. It is strong in compression (600 N/mm²) but weak in tension (150 N/mm²) and shear.
- **3.** Its specific gravity is 7.50.
- 4. It has low melting point (1200°C) and is affected by sea water.
- 5. It cannot be magnetized and is not suitable for forging.
- 6. Iron containing large amounts of manganese and chromium are likely to be permanently white, while those having a high silicon content are grey. With proper adjustment in composition, cast iron may be rendered white by cooling rapidly or grey by cooling slowly from the molten state.



Typical blast furnace

3.Wrought iron:

Wrought iron considered to be pure iron, is produced by removing the impurities of cast iron. The total impurities are limited to 0.5 per cent with a maximum percentage of carbon as 0. 15, silicon 0.15-0.2%, Phosphorus 0.12-0.16%, sulphur 0.02-0.03% and manganese 0.03-0.1%. It is manufactured in reverberator or puddling furnace .

حديد مطاوع يصنع الحديد المطاوع من تنقية حديد الزهر، ان مقدار الكاربون فيه لا يتجاوز % 0,2 وهو مستعمل أكثر من أنواع الحديد الأخرى حيث تصنع منه قضبان حديد التسليح وحديد الشيلمان والمشبكات الحديدية والمقاطع الاخرى المستخدمة لأغراض بنائية كما تصنع منه أيضا صفائح الحديد المضلعة والمستوية باختلاف أنواعها. يكون لون الحديد المطاوع اغمق من حديد الاهين وذو تركيب ناعم في المقطع وهو اكثر تحمل لقوى الشد من حديد الاهين ومقاومة الضربات .

Properties:

Wrought iron is

- 1. ductile, malleable, tough and moderately elastic.
- 2. Its ultimate crushing strength is 200 N/mm2 and ultimate tensile strength is 40 N/mm².
- 3. Transverse to the direction of the rolling the tensile strength ranges from 60 to 85 per cent of its strength parallel to this direction.
- 4. The modulus of elasticity of wrought iron is $1.86 \times 105 \text{ N/mm}^2$ —
- 5. The melting point of wrought iron is 1500°C and sp. gr. about 7.80. It can be forged and welded.
- 6. Wrought iron effectively resists corrosion. It is tough and withstands shocks and can neither be hardened nor tempered.

At about 900°C wrought iron becomes so soft that its two pieces can be joined by hammering. Alloying elements used in wrought iron include nickel, copper and molybdenum. Addition of nickel from 1.5 to 3.5 per cent produce substantial increases in the elastic limit and tensile strength. Nickel is also beneficial in preventing reductions of impact strength at subzero temperatures. Copper may be added to increase corrosion resistance properties.

Uses:

Roof coverings, rivets, chains, ornamental iron works such as gates, etc. are made of wrought iron.

4.Steel:

Steel is the most suitable building material among metallic materials. This is due to a wide range and combination of physical and mechanical properties that steels can have. By suitably controlling the carbon content, alloying elements and heat treatment, a desired combination of hardness, ductility and strength can be obtained in steel. On the basis of carbon content steel may be classified as under:

- 1. Mild steel 0.5-0.3% (carbon percentage)
- 2. Medium carbon steel 0.3-0.8%
- 3. High carbon steel 0.8- 1.5 %
- 4. Hard steel > 1.0 %

Steel Production Furnaces

The iron picks up carbon from the coke and impurities from the ore. The amount of carbon picked up by the iron is more than is needed in the production of steel. The carbon becomes part of the pig iron used in the making of steel. *The control of this carbon during the subsequent processes determines the properties of the steel.*

The crude (pig) iron is then processed for purification work for production of various kinds of iron and steel in form of ingots (large sections) using different furnaces. The steel ingots can be further processed in rolling mill or blooming mill to produce different structural shapes and sections of steel.

Steel-making processes are:

- 1. Bessemer process
- 2. Cementation process
- 3. Crucible process
- 4. Open Hearth process
- 5. Electric Smelting process
- 6. Duplex process
- 7. basic oxygen process, L-D process

Steel is the material produced under strict technical conditions, and it has the following advantages:

1. even materials,2. stable properties,3. high strength, 4.certain plasticity and toughness, 5. the properties to bear impacts and vibration loads, and 6. can be welded, riveted, or screwed; the disadvantages are: easy to be corroded and high cost of repairs.

These characteristics determine that steel is one of the important materials needed by economic construction departments. In construction, the steel structures consisted by steel in various shapes have high security and light deadweight, used for large-span and high-rise structures. However, because every department needs a large amount of steel, the wide use of steel structure is limited to some extent. But though concrete structures have heavy deadweight, the usage of steel is decreased greatly, and it can overcome the corrosion and high cost of repairs of steel. Thus, steel is widely used in concrete structures.



Electric-arc steelmaking furnace

Refinement of Steel from Ore





Bessemer convertor



Open hearth furnace

Non - Ferrous Metals

Aluminium

Uses:

- •Foil wrapping for food products
- •Car body panels
- •Aircraft parts for its lightweight
- •Cans
- •Clips

Properties:

- •Light in weight
- •Malleable and ductile
- •Takes an excellent polish
- •Resistant to corrosion
- •Machines easily
- •Difficult to solder and weld
- •Melting point 658°C

Structure of matter (state of matter):

In general, anything that has mass and takes up space, is called matter.

• Chemical matter is composed of atoms and molecules



DEFINITION OF MATTER CHEMISTRY :

study of the composition, structure, and properties of matter and the changes it undergoes:

The two properties of **MATTER** are: Mass – amount or quantity of matter

Volume – amount of space occupied
Therefore...MATTER is anything that has mass and takes up space.
All matter is composed of atoms
Atom: Extremely small chemically indivisible particle
Atom is Greek for "that which cannot be divided"

There is so many different kinds of matter, which are organized by their composition and properties:

Composition - the types and amounts of atoms that make up a sample of matter

Properties - the characteristics that give each substance a unique identity

PROPERTIES Of MATTER:

Properties of matter allow us to distinguish between substances and classify them ,Can reveal the identity of an unknown substance Divided into two groups:

1. PHYSICAL PROPERTIES

2. CHEMICAL PROPERTIES

PHYSICAL PROPERTY:

Defined as - a characteristic that can be observed or measured without changing the identity or composition of the substance . Example include:

Colour Oder Taste Size Physical state (liquid, gas, or solid) Boiling point Melting point Density

Physical properties used to describe matter can be classified as:

1)Extensive – depends on the *amount* of matter in the sample

- e.g. Mass, volume, length, height, amount of energy, etc.

2)Intensive – depends on the *type* of matter, not the amount present

- Hardness, density, boiling point, melting point, colour, ability to conduct electricity, etc.

CHEMICAL PROPERTIES:

Defined as - ability or inability of a substance to combine with or change into one or more other substances i.e. ability of a substance to undergo a chemical reaction

Example include: Charcoal burning in air, iron rust, Decomposition of wood.

CHEMICAL PROPERTIES

Consider terms such as:

burn, rot, rust, decomposition, ferment, explode, oxidize, corrode, grow, precipitate, gas formation and digest.

STATES OF MATTER

Matter can be classified according to its physical state and its composition

•Physical State: Solid ,Liquid, Gas

•Classification into different states based upon:

- 1. Particle arrangement
- 2. Energy of particles
- 3. Distance between particles

•State of matter is dependent on temperature and pressure of the surroundings



SOLIDS

- 1 Has a definite shape and volume
- 2 True solids have very rigid, ordered structures, in fixed positions i.e. high density.
- 3 atoms held tightly together, therefore incompressible
- 4 Atoms move through vibration only, therefore small thermal expansion.

Solid



LIQUIDS

- 1- Has a definite volume, atoms are not widely separated, therefore high density and small compressibility.
- 2- no definite shape i.e. follows the shape of its container.
- 3- Atoms move rapidly enough to slide over one another i.e. ability to flow.
- 4- Small thermal expansion.



GASES

1- Also known as vapour

2- No fixed volume or shape, conforms to the volume and shape of its container

- 3- Atoms far apart i.e. low density and can be compressed
- 4- moving at high speeds, colliding with container, moderate thermal expansion



CHANGES IN MATTER

All matter can undergo physical and chemical changes

Physical change – occurs when a substance alters its state (phase change), but does not change its chemical composition

E.g. Grinding, cutting.

Phase change – transition of a substance from one state to another

depend on temperature and pressure , E.g. Boiling, freezing, melting, and condensing.

Physical changes can be classified as reversible or irreversible. Phase change depend on Temperature and Pressure Affects:

Phase change depend on Temperature and Pressure Affects:

- Particle arrangement
- Energy of particles
- Distance between particles

•Phase change is either an exothermic or endothermic process Exothermic – heat is given off i.e. Removal of E

Endothermic – absorption of heat i.e. Input of E

•Phase changes include: melting, evaporation/ boiling, condensation, freezing, sublimation and reverse sublimation

CHANGES OF STATE

Melting - solid to liquid Freezing - liquid to solid Evaporation/ boiling - liquid to gas Condensation - gas to liquid Sublimation - solid to gas Reverse Sublimation - gas to solid



CLASSIFICATION OF MATTER

- All matter is composed of atoms
- All matter can be classified or identified as either pure substances or mixtures
- **Substance** kind of matter that cannot be separated by any physical process
- Pure substances are considered as either elements or compounds.
- **Element** : 1. a substance that cannot be broken down into simpler substance by physical and chemical reaction.
 - 2. Consists only of one kind of atom.
 - 3. Building blocks for other substances

Compound :

- 1. a substance that consists of two or more elements chemically bonded
- 2. Compound is always composed of the same elements, in the same proportion by mass represented by a formula e.g. NaCl, H2O.
- 3. Most of matter in the universe exists as compounds.
- 4. Compounds can be synthesised or decomposed

Synthesis – combination of elements to form compounds

Decomposition – splitting of compounds into their individual elements

Mixture :1. combination of two or more substances in which each substance retains its individual properties

Therefore, substances ARE NOT chemically combined, just mixed physically.

2. Mixtures can be separated by physical methods.

3. Mixtures can either be classified as: Homogeneous, Heterogeneous.

Destructive and Non-Destructive Testing

Destructive Testing requires destroying the specimen in order to measure the property. Often requires a specially prepared specimen. (e.g. Tensile test). Destructive testing is called mechanical testing.

Non-Destructive Testing (NDT) measures attributes of the specimen without damaging it. Does not normally need a prepared specimen. Typically used to find flaws inside a part. (e.g. X-ray, Ultrasound)

1. Tensile test

Purpose of tensile testing:

Generally a tensile test is designed to be run until the sample fails or breaks under the load. The values that may be measured from this type of test like tensile strength, ultimate strength, elongation, modulus of elasticity, yield strength, Poisson's ratio, and strain hardening. The measurements taken during the test reveals the characteristics of a material while it is under a tensile load.

Types of materials

Nearly all materials can be tested in tension include metals, plastics, woods, polymers and textiles. Materials with high compressive strength values have relatively low tensile strength, such as brick and aerospace composites. These are not generally tested in tension as their applications do not normally require them to withstand tensile loads.

Tensile specimen

A tensile specimens is a standardized sample cross-section. It has two shoulders and a gage (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area. Specimen of a standard shape (dog-bone) and dimensions (prepared according to *ASTM*).





Tensile Testing Machine

Tensile test machines are universal testing machines specially configured to evaluate tensile strength of specimens. Each tensile test machine is configured to your testing needs by our application engineers with the correct controller, grips.



Procedure of Tensile Test

1- Care is to be taken to ensure that the specimens did not have any notching or cracks from manufacturing or any surface defects that would adversely affect the tensile tests.

2- Before loading the specimens in the machine, the computer system connected to the machine was set up by inputting the necessary information of gauge length and width of the specimen. The computer system was then prepared to record data and output necessary load-deflection graphs.

3- The specimens were loaded into the machine, and a tensile test was performed. The data was recorded electronically

A tensile load is applied to the specimen until it fractures. During the test, the load required to make a certain elongation on the material is recorded. A load elongation curve is

plotted by an x-y recorder, so that the tensile behaviour of the material can be obtained. An engineering stress-strain curve can be constructed from this load-elongation curve by making the required calculations. Then the mechanical parameters that we search for can be found by studying on this curve

المعادلة هنا. A typical engineering stress-strain diagram and the significant parameters

1- Stress σ = P/Ao (Load/Initial cross-sectional area)

2- Strain $\varepsilon = 1/10$ (Elongation/Initial gage length)

3- *Elastic Region:* The part of the stress-strain curve up to the yielding point.

4- Elastic deformation is recoverable. In the elastic region, stress and strain are related to each other linearly.

Hooke's Law: $\sigma = E \varepsilon$

The linearity constant E is called the elastic modulus which is specific for each type of material. 5- *Plastic Region:* The part of the stress-strain diagram after the yielding point.

6- Maximum point of the stress-strain diagram (σ UTS), necking starts.

 $\sigma \text{UTS} = \text{Pmax}/\text{Ao}$

7- *Yield Strength* is the stress level at which plastic deformation starts. The beginning of first plastic deformation is called *yielding*. It is an important parameter in design.

Problem

The following data were recorded during the tensile test of a 14mm diameter mild steel rod. The gage length was 50 mm.



Strain

Load	Elongation	Load	Elongation
	(mm)	(1)	(mm)
0	0	46 200	1.25
6 310	0.010	52 400	2.50
12 600	0.020	58 500	4.50
18 800	0.030	68 000	7.50
25 100	0.040	59 000	12.5
31 300	0.050	67 800	15.5
37 900	0.060	65 000	20.0
40 100	0.163	65 500	Fracture
41 600	0.433		

Plot the stress-strain diagram and determine the following mechanical properties:

(a) proportional limits; (b) modulus of elasticity; (c) yield point; (d) ultimate strength; and (e) rupture strength.

Area, $A = 0.25\pi(142) = 49\pi \text{ mm}^2$

Length, L = 50 mm Strain = Elongation/Length Stress = Load/Area



Stress-Strain Diagram

(not drawn to scale)

PL = Proportional Limit

- EL = Elastic Limit
- YP = Yield Point
- US = Ultimate Strength
- RS = Rupture Strength

Compression Test

A compression test is any test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, "squashed", crushed, or flattened. The test sample is generally placed in between two plates that distribute the applied load across the entire surface area of two opposite faces of the test sample and then the plates are pushed together by a universal test machine causing the sample to flatten. A compressed sample is usually shortened in the direction of the applied forces and expands in the direction perpendicular to the force. A compression test is essentially the opposite of the more common tension test.

Purpose of Compression Tests

The goal of a compression test is to determine the behaviour or response of a material while it experiences a compressive load by measuring fundamental variables, such as, strain, stress, and deformation. By testing a material in compression the compressive strength, yield strength, ultimate strength, elastic limit, and the elastic modulus among other parameters may all be determined. With the understanding of these different parameters and the values associated with a specific material it may be determined whether or not the material is suited for specific applications or if it will fail under the specified stresses.

Types of Compression Testing materials:

Typically materials subjected to compression testing have a compressive strength generally accepted to be high and a tensile strength (e.g tensile test) that is considered to be of a lower value. Almost all materials can experience compressive forces in one way or another depending upon their application, but the most common materials are composites, concretes, wood, stone, brick, mortars, grouts, polymers, plastics, foam and metals among many others.

Shape of the specimen: The shape of the machine to be used for the different materials are as follows:

(i) For metals and certain plastics: The specimen may be in the form of a cylinder

(ii) For building materials: Such as concrete or stone the shape of the specimen may be in the form of a cube.





Data:

Compressive strength and modulus are two useful calculations.

Compressive strength(σ)= $\frac{\text{maximum compressive load}}{\text{minimum crosssectionalarea}}$

Compressive modulus $= \frac{\text{change in stress}}{\text{change in strain}}$



Figure 1: Compression and Tension stress-strain curves for (a) GCI and (b) Concrete

Timber (wood)

على الرغم من استحداث مواد صناعية جديدة في مجال البناء ما زال الخشب ينفر د بمكانة متميزة بين مواد البناء بسبب منظره الطبيعي وخفة وزنه وسهولة تشكيله وتجميعه ومقاومته للأحمال وعزله للصوت والحرارة، هذه الأسباب جعلت الخشب مادة البناء السائدة لقرون طويلة لكن بدأت بالانحسار بسبب نقص الكميات المتاحة منها وارتفاع أسعارها، اما عيوبه فهي قابليته للاحتراق وتعرضه لمهاجمة السوس وتحلله بفعل البكتريا وتغير الرطوبة.

Uses of timber:

(i) Used in the form of piles, posts, beams, lintels, door/window frames and leaves, roof members etc.

(ii) Used for flooring, ceiling, panelling and construction of partition walls.

(iii) Used for form work for concrete, for the timbering of trenches, centring for arch work, scaffolding, transmission poles and fencing.

(iv) Used in wagon and coach building, marine installations and bridges.

(v) Used in making furniture of agriculture implements, sports goods, musical instruments, well curbs, mortar bodies, carts and carriages, railway sleeps, packing cases etc.

Classification of trees:

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

a. Endogenous

b. Exogenous:

a. Endogenous trees:

Timber from these trees has very limited engineering applications. Example of endogenous tress is:

Palms: because of their long, straight stems are sometimes locally used as piles

Bamboo: Is used structurally to a considerable extent.

b. Exogenous

Exogenous trees are outward growing trees. Horizontal section of such tree contains several rings which are nothing but annual rings. These rings can be used to predict the age of tree. Most of the exogenous trees are useful for many engineering purposes.

Exogenous trees are sub classified into following types.

1. Conifers

2. Deciduous

Conifers (soft wood)

Conifers are soft wood producing trees which are also called as ever green trees. The timber of these trees is light coloured, light in weight, low dense and poor against fire.

Examples: Pine, Fir, redwood, spruce, deodar, cedar etc.

أشجار رخوة - :وتستعمل للأعمال الأنشائية والأعمال التي تصبغ بأصبًاغ دهنية. Deciduous (hard wood)

أشجار صلدة - بوتستعمل لأغراض الزخرفة والزينة والأماكن آلتي يتطلب فيها مقاومة عالية.

Deciduous trees are hard wood producing trees. The leaves of this type of trees are generally broad in size and they fall in autumn and grow in spring. Deciduous trees are most suitable for constructional purposes. Timber of deciduous trees is dark coloured, dense, heaviest and good against fire.

Examples: Maple, Mahogany, Oak, teak, walnut, babul etc.

Structure of wood



Characteristics of good timber

The principal characteristics of timber of concern are strength, durability and finished appearance.

- 1. Narrow annual rings, closer the rings greater is the strength.
- 2. Compact medullary rays.
- 3. Dark colour.
- 4. Uniform texture.

- 5. Sweet smell and a shining fresh cut surface.
- 6. When struck sonorous sound is produced.
- 7. Free from the defects in timber.
- 8. Heavy weight.
- 9. No woolliness at fresh cut surface.

الصفات العامة للأخشاب General properties of wood

نحصل على الاخشاب من الأشجار القائمة داخل الغابات بصورة رئيسية وتحتوي على ماء تختلف درجة تشبعها لذا يجب تجفيف الاخشاب قيل استعمالها سواء كان خشب منشور او من الرقائق الخشبية او حتى من بعض الاخشاب المستديرة مثل أعمدة المناجم او أعمدة البريد.
 للخشب القابلية على امتصاص الرطوبة من الهواء والجو والاحتفاظ به.
 ليمكن تشغيل الخشب لأشكال عديدة باستعمال الات ومعدات بسيطة.
 ليمكن تشغيل الخشب لأشكال عديدة باستعمال الات ومعدات بسيطة.
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 ليمكن تشغيل الخشب لأشكال عديدة باستعمال الات ومعدات بسيطة.
 ليخرض معين.
 الخشب كأي مادة عضوية يتعرض للقرض والحشرات الثاقبة حفارات)عند تعرضه للطروف البيئية الملائمة لنشاط الكائنات الدقيقة.
 الخشب يعد مادة احتراق قابلة للاشتعال.
 ليمن الخشب بتعدد الخواص الطبيعية والميكانيكية ليس فقط داخل الأنواع بل أيضا داخل.
 يمتن الخشب بتعدد الخواص الطبيعية والميكانيكية ليس فقط داخل الأنواع بل أيضا داخل.

أهم العوامل المؤثرة في تحمل الخشب **1. سرعة النمو** - :ان تباعد الحلقات السنوية في مقطع الخشب يدل على سرعة نمو الشجرة وهذا يعني تحمل ضعيف لهذه الاخشاب وأحسن مّثال لّذلك هي الاخشاب الرخوة على اختلاف أنو اعها. استقامة الالياف - : إن اخشاب الاعمال الانشائية تكون غالبا بمقطع بحيث تكون الالياف متجهة نحول طول اللوحة وان أي اختلاف بين اتجاه الطول في اللوحة والالياف لابد وان يؤثر في قوة تحمل الخشب. 3. تكون الاخشاب المجففة خفيفة الوزن إذا ما قورنت ببقية مواد البناء الاخرى وبالتالي يمكن التعامل بها ونقلها الي مسافات بعيدة بتكاليف اقل 4. يكون تأثير درجات الحرارة على الخشب وتمدده قليل اذ ان التغير في ابعاد ومقاييس الخشب يكون اساسا من الرطوية. 5. يمتا ز الخشب بخاصيته القليلة في نقل الصوت والحرارة والكهرباء وهذه الخواص لازمة وضرورية ومرغوبة في بعض الاستعمالات اهمها خاصية العزل الحراري ا و الكهربائي والصوتي. . طبيعةً مادة الخشب متباينة الخواص أي له ترتيب محوري غير متكامل على اتجاهات محاور الخشب الثلاثة الأساسية (العرض القطر – المماس) بخلاف المواد المعدنية مثل الحديد التي ليس لها ترتيب محوري. 7. الخشب يمتص الصدمات والاهتز إزات أفضل من اي مادة اخرى-8. الخشب لا يصدأ ولوغمر تحت مياه البحر لفترة طويله فهوأيضا مقاوم لفصل القلويات والاحماض المخففة. 9. الخشب لا بتبلور مثلما بحدث في معظم المعادن عندما يتكرر تعرضها لأحمال وجهد معاكس.

10. الخشب يختلف عن الخرسانة بأنه يتميز بخاصية تماسك خاصة عند تعرضه الى درجات الحرارة العالية
11. ان وجود العقد يضعف الخشب وخصوصا عندما تكون العقد في الأماكن التي تقاوم قوى الشد حيث من المستحيل الحصول على الخشب بمقاطع كبيرة دون وجود العقد.
12. تحدث بعض العيوب في الخشب عند قطع الأشجار وتعتبر نقاط ضعف تؤثر على تحمل الخشب واهمها:
(تعرج الالياف – التشققات الحلقية – التشققات القطرية – العقد الخشبية – الرضوض – الانكماش التعفن.)
13. محتوى الرطوبة :تزداد مقاومة الخشب عندما يخدما يجف وسبب هذه الزيادة هو نقصان الرطوبة.

أنواع الخشب (Types of wood (Timbers) أنواع الخشب

يصنف الخشب الى نوعين أساسيين هما- : **1. الخشب الطبيعي - : Natural wood** تقسم الاخشاب في الطبيعة الى فصيلتين **A. فصيلة الاخشاب الصلدة** ويستعمل في اعمال النجارة خارج الدور ويكون خشبها ثقيل الوزن نسبيا وداخلها مثل خشب الصاج والبلوط والجاوي والزان. **B. فصيلة الاخشاب الطرية** وتكون خفيفة الوزن ويستعمل في الاعمال التجارية داخل الدور

كابواب الغرف والشبابيك ومن هذه الاخشاب الصنوبر والأرز والسرو.

Artificial (manufactured) wood : الخشب المصنع. 2

اهم الاخشاب المصنعة التي تستخدم في الاعمال التجارية

A . الواح معاكس : (Ply Wood) يصنع خشب المعاكس من القشرة وهي الطبقة التي تستخرج من سيقان الأشجار وتلصق عدة قشرات بعضها مع بعض بعد معالجتها بنوع من الغراء بحيث تكون الياف الطبقة الواحدة متعاكسة ومتعامدة مع الياف الطبقة التي تليها ثم تكبس بمكابس خاصة تحت ضغط عال . تستعمل الواح المعاكس في الاعمال البنائية لعمل الدواليب والابواب الداخلية او تغليف الجدران والاثاث كما تستعمل في الاعمال الانشائية لعمل هياكل قوالب الصب.

B .الواح الياف (الماسونايت Masonite wood):

تصنع من تقطيع الخشب ومعالجته كيمياويا وتحويله الى عجينة تدفع بين دلافين ساخنة ثم يضغط افقيا لعمل صفائح دقيقة الالياف متماسكة ومتجانسة التركيب وبسمك يتراوح بين 9 - 4 سم يعمل أحد اوجهه املسا لماعا والوجه الاخر خشنا، يعالج في بعض الآحيان بمواد دهنية لزيادة مقاومته للماء والرطوبة تستعمل الواح الألياف في صناعةً الأبواب الرخيصة كونها اقل سعرا من الواح المعاكس واكثر تجانس في تركيبها وغير قابلة لانفصال الألياف او الطبقات منها كما في الواح المعاكس.

C .الواح نشارة (الخشب المضغوط): Compressed wood الخشب اذ تعالج بأصباغ ومواد كيمياوية تصنع هذا الالواح من نشارة الخشب الناتجة من معامل الخشب اذ تعالج بأصباغ ومواد كيمياوية لتتحول الى عجينة قابلة للكبس لتكوين الواح بأبعاد قياسية وتستعمل هذه الالواح في الأبواب والقواطع الداخلية التي لا تتعرض للخارج بشكل مباشر.

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 sub microscopic capillaries of the cell walls.

Fibre Saturation point:

The moisture content at which all free water is removed (i.e. cell cavities empty) while the cell walls are filly saturated. Changes in moisture content below the fibre saturation point are associated with shrinkage and swelling, as well as variation in strength and elastic properties and other properties. Fibre 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. 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.

Seasoning of wood:

تجفف الاخشاب قبل استعمالها للتخلص من الرطوبة الزائدة واتمام انكماشها قبل استخدامها حيث يحسن التجفيف من مقاومة الاخشاب للأحمال ويقلل اصابتها بالفطريات كما يقلل من وزنها عند النقل،

هناك ثلاث طرق للتجفيف هي- :

تحفيف الخشب

a. تجفيف طبيعي Natural seasoning :

يستخدم هذا النوع من التجفيف لمعظم الاخشاب الانشائية حيث تعرض الاخشاب للهواء والشمس وذلك برصف الاخشاب بصورة مائلة مع ترك فواصل بينها تسمح بتخلل الهواء وترك الاخشاب تحت مظلة تقيها المطر.

: Artificial seasoning تجفيف صناعي. b

يستخدم هذا النوع من التجفيف للأخشاب المستعملة في الأثاث والارضيات والقواطع وذلك برصف الخشب بنفس الطريقة السابقة في مقصور ات مقفلة تعرف بالفرن ذي المقصورة او في عربات تتحرك خلال فرن يسمى الفرن المتتالي وفي هذه الافران يدفع الهواء على الخشب فتتز ايد درجة الحرارة وتتناقص الرطوبة تدريجيا وفق برنامج معين يضمن عدم تعرض الاخشاب لإجهادات داخلية كبيرة او التواءات نتيجة جفاف سطحه بسر عة بينما داخله لا يزال رطب.

Seasoning process:

There are two principle methods of seasoning timber:

a. Natural seasoning: This consists of stacking the timber in 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 an 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.

By artificial seasoning, timber is seasoned with in 4-5 days. Here also different methods of artificial seasoning are there and they are as follows.

- 1. Water Seasoning
- 2. Seasoning by Boiling
- 3. Chemical seasoning
- 4. Kiln seasoning
- 5. Electrical seasoning
- 1. Water Seasoning

Water seasoning is the process in which timber is immersed in water flow which helps to remove the sap present in the timber. It will take 2 to 4 weeks of time and after that the timber is allowed to dry.

1. Seasoning by Boiling

Seasoning of timber is also achieved by boiling it in water for 3 to 4 hours. After boiling timber is allowed to drying. For large quantity of timber boiling is difficult so, sometimes hot steam is passed through timber logs in enclosed room. It also gives good results. The boiling or steaming process develops the strength and elasticity of timber but economically it is of heavier cost.

2. Chemical Seasoning

In case of chemical seasoning, timber is stored in suitable salt solution for some time. The salt solution used has the tendency to absorb water from the timber. So, the moisture content is removed and then timber is allowed to drying. It affects the strength of the timber.

3. Kiln Seasoning

In this method timber is subjected to hot air in air tight chamber. The hot air circulates in between the timber logs and reduces the moisture content.

4. Electrical Seasoning

In the method of electrical seasoning timber is subjected to high frequency alternating currents. The resistance of timber against electricity is measured at every interval of time.

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

DEFECTS IN TIMBER:

عيوب الخشب هي الحالة غير الطبيعية او غير المنتظمة في الخشب التي تقلل من قيمته التجارية ومكانته وتشغيله واستعماله ومظهره ولا يوجد أي خشب خام خالي من العيوب، واهم عيوب الخشب هي :

1. تعرج الألياف : Twisted Fibres in Timbers

تحدث هذه الحالة نتيجة نمو الأشجار منحنية بتقوس كبير ونتيجة ظروف نمو شاذه تجعل الالياف تنمو بصورة متموجة او حلزونية او متقطعة مع محور الشجرة وهذه الاخشاب تكون عرضة للانبعاج عند تجفيفها لذلك تستبعد في اعمال الانشاءات.



Twisted fibres

2. التشققات الحلقية : Ring shakes

وهي تشققات تسبب انفصالًا بين الحلقات السنوية وقد يمتد بطول جذع الشجرة وهذه التشققات تصاحب اجهادات الشد التي تنشأ في بعض الألياف نتيجة نمو الشجرة منحنية بتقوس كبير.

3. التشققات القطرية : Radial shakes

و هي تشققات داخلية في الاتجاه الطولي للجذع.

4. العقد الخشبية Knots in Timber

تعرف العقدة بانها قاعدة فرع مدفون في جذع الشجرة ويتناسب حجمها مع حجم الفرع والعقد تعتبر أجزاء قوية مشبعة بالصموغ تعترض نسيج الجذع وقد تنفصل اثناء تجفيف الخشب ووجود العقد يشكل صعوبة في تشغيل الخشب وكذلك فان المواد الصمغية تجعل تغطيتها بالطلاء صعبا



5. Upsets: Upsets, a defect of timber in which the fibbers of wood are crushed and compressed by fast blowing winds or inappropriate chopping of tree.



Upset