Classification of bricks according to constituent raw material:

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

1. Clay bricks:
   1.1 Raw materials:
   a. Alumina
      Alumina is main constituent of every clay. Loam soil (adhesive soil) form a good clay. In absence of sand, pure clay will develop cracks due to shrinkage on drying and burning. A good clay bricks should contain about 20% of alumina.
   b. Silica
      Free silica (sand), if added to clay in suitable proportion makes hard and prevents it from warping and shrinkage on drying. Silica, if present in greater proportion, makes a brick brittle. Silica present in the combined form (aluminum silicate) does not form good bricks, as it will shrink and develop cracks. Both silica and alumina should be in free form.
   c. Lime
      This also should be present in small quantities in the brick earth. It should be in a finely produced condition and it should not be in the form lamps or clods.
      Lime prevents shrinkage of raw bricks. It helps fusion of sand at the kiln temperature. This fused sand will bind the bricks particles fast.
   d. Iron oxide
      A small quantity of oxide of iron (5-6%) is desirable. It helps the fusion of sand like lime. It gives red colure to burn bricks. Excess of iron oxide imparts dark blue or blackish colour 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. This gives a yellow tint to the bricks. But excess of magnesia is not desirable as it tends to produce the decay of bricks.

1.2 Composition of good clay brick:
   A good clay brick should contain the following:
   1. Clay or alumina – Al₂O₃ – 20%
   2. Sand or silica – SiO₂ – 60%
   3. Remaining ingredients, such as:
      - Lime
      - Iron oxide
      - Magnesia
      - Manganese

1-3 Harmful ingredients in clay bricks:
   a. Excess of lime:
      Excess of lime makes the colure of the brick yellow instead of red. Lumps of limestone remaining in the finished brick are undesirable because, when such a brick comes in contact with water, lime will begin to slake. During slaking, lime expands and also generates heat. Due to this, stresses will be produced, which will result in producing cracks in bricks.
   b. Iron pyrites:
      These will decompose and oxide the clay during the burning of bricks. After oxidation a black discoloration will be produced on the bricks, making it look ugly.
   c. Pebbles:
      The presence of pebbles, girt, gravel etc. will be undesirable because they prevent the clay from being mixed well. They prevent the manufacture of smooth and regular, standard bricks. They also spoil the appearance of the bricks. Pebbles, gravel, grit, etc., should be removed before mixing and pugging of clay are done.
e. Organic matter:
This includes leaves, twigs. Etc. of plants, roots, grass, bones of animals etc. These if prevent and burnt along with bricks, produced empty pockets or pores and will produce porous bricks.
f. Alkalis (MgO, K₂O):
   I. It lowers the fusion temperature and melts bricks.
   II. Changes the shape of bricks or get twisted.
   III. These salts have hygroscopic action, they absorb moisture, present in the atmosphere and keep brick damp which is harmful for health and decays the structure.
   \[
   \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 \\
   \text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{KOH}
   \]
g. Salts:
   Salts such as sodium sulphate cause efflorescence.

1.4 Manufacture of bricks:
   Manufacture of clay bricks involves the following operation:
1.4.1 Preparation of clay:
   a. Removal of loose soil:
      The top layer of loose disintegrated soil up to about 20 cm depth has to be removed as this contains a lot of impurities.
   b. Digging, spreading and cleaning:
      Next, the earth has to be dug up. For small quantity, digging may be done manually. For large scale work, it may be done by machine.
   c. Weathering:
      The earth is left to weather for a few weeks, this is necessary to increase the plasticity of soil and improves its quantity.
   d. Blending:
      This refers to mixing the clay, after making it loose and adding any required ingredients to the top of the heap.
   e. Tempering:
      This is necessary to make the clay fully consistent, and fit for molding into raw bricks, by adding the required amount of water to make it plastic.
1.4.2 Molding:
   Molds required for making a brick are made of rectangular blocks slightly large in size (10% larger than the burnt bricks). It is done to allow for the shrinkage of the molded brick on drying and burning. The molding is improved by the following process:
   a. Dry press process:
      In this method, clay is not made sufficiently plastic, but only small amount of water is mixed with clay as to form a damp powder. With plunger machines, this powder is compressed in the mold, in the form of bricks. Such bricks are directly burned, no drying is needed, but care is to be taken during burning where the temperature should be raised gradually.
   b. Stiff mud process:
      In this process the clay is only sufficiently moist to process the required coherence under moderate pressure, which results in economy of time in drying and fuel in burning. Such clay is forced to come out of any opening having dimensions equal to length of bricks, by means of a wire. Hence these 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 molding. Bricks are molded under pressure in a soft mud brick machine, which tempers the clay in its pigging chamber, sands or wets the molds, presses the clay into 4 to 9 molds at a time, strikes off the excess clay, bumps the molds uniformly and dumps the bricks into a pallet. The pallets of bricks are carried away to the dryer as fast as made.
1.4.3 Drying:
   As wet clay bricks come from different brick machine, they contain from 7-50% moisture depend on whether dry press stiff mud or soft mud process has been used moisture in clay may be classified as:
   - Equilibrium moisture: is that moisture in the material which exerts a vapor pressure equal to that exerted by the surrounding air of a given temperature and humidity.
   - Free moisture: is held strongly in the pore spaces.
Most of the free water is removed in the drying process and the remaining moisture during the burning process. Mechanical dryer, who permit of automatic control of temperature, humidity and air velocity, have come into general use. As the free water of the clay body is removed, the clay particles tend to coalesce causing shrinkage. The general effect of such shrinkage is to increase the resistance to moisture flow in the dried layers. If the drying is carried on too rapidly as by means of hot dry air, the moisture is removed from the surface of the solid more rapidly than the interior of the solid so that the surface harden and cracking occur. It is desirable to dry clay with moist air, reducing the drying rate to the point where diffusion of water to the surface can keep up with the vaporization at the surface. The average time necessary for drying clay brick is about 3 days, and the temperature required is from 38 °C to 149 °C.

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

a. Water smoking:
During this period which 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 °C and complete at about 750 °C.
c. Oxidation:
Oxidation begins during the dehydration stage. All combustible matter is consumed, carbon is eliminated, the fluxing materials are changed to oxides, and sulfur is removed.

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

Grade A:
Intended for use in building construction and footing subjected to loads and exposed to severe abrasion by weathering action.

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

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

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

Dimensions:
A good brick shall have standard dimensions as shown below:

```
115cm±3%
24cm±3%
75cm±4%
```

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

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

\[
\text{Compressive strength} = \frac{\text{Load at failure}}{\text{Cross sectional area subjected to load}}
\]
1.6.2 Water absorption:

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

\[
\text{Water absorption} = \left\{ \frac{(W2-W1)}{W1} \right\} \times 100\%
\]

Where

- \( W2 \) – weight of brick after 24 hours in water
- \( W1 \) – weight of dry brick

1.6.3 Effloresce:

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

The effloresce shall reported as:

- Nil – No effloresce visible.
- Slight- A thin deposit of salts on less than 10% of the area of the brick.
- Moderate- A heavier deposit of salts covering between 10-50% of the area of the brick, but no powdering or flaking of the surface.
- Heavy – A heavy deposit of salts covering more than 50% of the area, but no powdering or flaking of the surface.
- Serious – A heavy deposit of salts and some powdering and flaking of the surface.
1.7 Compressive strength, water absorption and effloresce according to Iraqi standard No. 25/1988:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Effloresce</th>
<th>Minimum compressive strength N/mm²</th>
<th>Maximum water absorption %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For one brick</td>
<td>Average for 10 bricks</td>
<td>For one brick</td>
</tr>
<tr>
<td>A</td>
<td>Slight</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>Slight</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

2. **Sand – Lime bricks:**

2.1 Raw materials:

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

2.1.1 Sand

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

a. Contain not less than 70% silica.
b. Well graded between 0.005 – 0.5 mm.
c. Free from impurities such as organic matter, rock, minerals and soluble salts.
d. The percentage of clay not more than 10%
e. Iron compounds not more than 1.5%.
f. Gypsum content not more than 1%.
g. ( CaO + MgO ) not more than 5%.

2.1.2 Lime:

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

a. Activity of lime shall not be less than 83%.
b. The percentage of lime retaining on 75 µm sieves should not be greater than 2%.

2.1.3 Water:

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

2.1.4 Pigment:

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

2.2 Mix proportion:

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

2.3 Manufacture:

a. Sand, lime and pigment are taken in suitable proportions and they are thoroughly mixed with a required quantity of water.
b. The material is then molded in the shape of the bricks under mechanical pressure (150-200 kg/cm²).
c. Bricks are then placed in closed chamber and subjected to saturated steam pressure of about 8.5-16 kg/cm² for 6-12 hours to speed up the interaction between lime and sand. The process is known as autoclaving.

\[
\text{CaO} + \text{H}_2\text{O} + \text{SiO}_2 \rightarrow \text{CaO}_2\text{SiO}_2 . \text{H}_2\text{O} \quad \text{“Tobermorite “ “Hydrous calcium silicate “}
\]

\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2 \text{O}
\]

2.4 Properties of lime sand brick:

a. The raw materials of these bricks do not contain any soluble salt. Hence the trouble of effloresces does not arise.
b. If plaster is to be provided on sand lime bricks, the quantity of mortar required will be less as bricks are uniform in size and shape.
c. These bricks are hard and strong.
d. These bricks are uniform in colour and texture.
e. Sand lime bricks are used for ornamental work.

3. **Concrete bricks:**

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

![Brick Dimensions Diagram]

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

3.2 Properties of concrete bricks:
- a. The using of these bricks save time and effort as brick are light in weight and big in size.
- b. These bricks give good bonding with plastering materials used in their construction.
- c. These bricks have accurate size and shape.
- d. These bricks can produced with various bearing capacity according to the cement content used in their production.
- e. The weight of bricks can be controlled by varying the size of openings.