Brick:

A brick is rectangular in shape and of size that can be conveniently handled with one hand. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete.

A brick is building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to unit composed of clay, but it is now used to denote any rectangular units laid in mortar. A brick can be composed of clay-bearing soil, sand and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are *fired* and *non-fired* bricks.

Classification of bricks according to constituent raw material:

1. Clay bricks
2. Lime – sand bricks
3. Glass brick
4. Concrete bricks

1. Clay bricks:

One of the oldest building material brick continues to be a most popular and leading construction material because of being cheap, durable and easy to handle and work with. Clay bricks are used for building-up exterior and interior walls, partitions, piers, footings and other load bearing structures.

Clay brick are essentially made of clay which has some specific properties.

- The Plasticity behavior when it mixed with water.
- Clay particles fuse together when subjected to high temperature.
- Economical and easily available.

Raw materials:

a. Silica (SiO_2)

Free silica (sand) is a main constituent, 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.

b. Alumina (Al_2O_3)

Alumina is one of a main constituent of every clay. Loam soil (adhesive soil) forms 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.

Alumina absorbs water and renders the clay plastic. If alumina is present in excess of the specified quantity, it produces cracks in brick on drying. Clays having exceedingly high alumina content are likely to be very refractory. Both silica and alumina should be in free form.

C-Lime ($CaCO_3$):

Normally constitutes less than 10 percent of clay. 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 on drying. 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 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:

Rarely exceeding 1 percent affects the colour and makes the brick yellow. 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:

For the preparation of bricks, clay or other suitable earth is moulded to the desired shape after subjecting it to several processes. After drying, it should not shrink and no crack should develop. The clay used for brick making consists mainly of silica and alumina mixed in such a proportion hat the clay becomes plastic when water is added to it. It also consists of small proportions of lime, iron, manganese, sulphur, etc. The proportions of various ingredients are as follows:

Silica 50–60%
Alumina 20–30%
Lime 10%

Magnesia < 1% Ferric oxide < 7% Alkalis < 10%	Less than 20%
Carbon dioxide Sulphur trioxide Water	Very small percentage

***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. Excess of Lime in brick clay has the following Effects:

1. In carbonated form, lime lowers the fusion point.
2. Excess of lime causes the brick to melt and the brick looses its shape (dimensional changes).
3. Red bricks are obtained on burning at considerably high temperature (more than 800°C) and buff-burning bricks are made by increasing the lime content.

B. Iron pyrites (FeS_2):

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.

D- 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.

E- Alkalis (MgO , K_2O):

1 .It lowers the fusion temperature and molts bricks

2. Changes the shape of bricks or get twisted.

3. These salts have hygroscopic action, they absorb moisture, present in the atmosphere and keep brick damp which is harmful for health and decays the structure.

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

$$K_2O + H_2O \longrightarrow 2\,KOH$$

F-Salts:

Salts such as sodium sulphate cause efflorescence. Efflorescence is the migration of a salt to the surface of a porous material, where it forms a coating. The essential process involves the dissolving of an internally held salt in water, or occasionally in another solvent. The water, with the salt now held in solution, migrates to the surface, and then evaporates, leaving a coating of the salt.

G. Corboaceous :

Corboaceous materials in the form of bituminous matter or carbon greatly affects the colour of raw clay. Unless proper precaution is taken to effect complete removal of such matter by oxidation, the brick is likely to have a black core.

H. Sulphur:

Sulphur is usually found in clay as the sulphate of calcium, magnesium, sodium, potassium or iron, or as iron sulphide. Generally, the proportion is small. If, however, there is carbon in the clay and insufficient time is given during burning for proper oxidation of carbon and sulphur, the latter will cause the formation of a spongy, swollen structure in the brick and the brick will be decoloured by white blotches.

I. Water: A large proportion of free water generally causes clay to shrink considerably during drying, whereas combined water causes shrinkage during burning. The use of water containing small quantities of magnesium or calcium carbonates, together with a sulphurous fuel often causes similar effects as those by sulphur.

1.4 Manufacture of clay brick:

Manufacturing First, let's go through the manufacturing process of bricks. Thereafter the cost implications of changing bricks size can be understood more easily. The fundamentals of clay brick manufacturing haven't changed much over time, except for the basic advancements that made brick plants more efficient and improved the quality of the bricks. Other improvements include:

- Complete knowledge of raw materials & their properties
- Better control over the firing process
- Improved kiln designs 38
- Advanced Mechanization

The manufacturing of clay bricks start with the selection of raw materials. Clay, being the main material, is found almost everywhere here on earth. But the clay founded in different areas all have different properties, sometimes clay in the same batch will have different properties. The selection of this abundant raw material will have no impact on the question of size. Moving along, the selected clay then gets mixed with water, the clay is formed in the desired shape, dried and lastly fired (sometimes bricks gets fired more than once). Figure 1 here below, shows a diagrammatic representation of how clay bricks are manufactured.

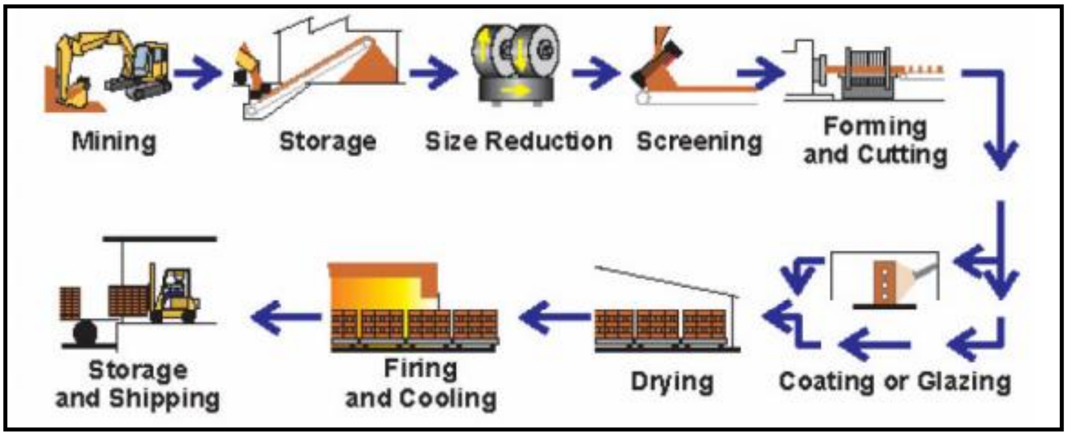


Fig. 1: Diagrammatic representation of the manufacturing process.

Clearly, the only stage during manufacturing, where the size will be a relevant issue, is when they are formed into their desired shape. In ancient Egypt times, clay were forming by using their hands, but this changed with the invention of brick making machines in the 19 th century, where the majority of manufacturing of clay bricks in America, are machine made.

Manufacture of clay bricks involves the following operation:

1.4.1 Preparation of clay:

a. Removal of loose soil:

The soil used for making building bricks should be processed so as to be free ofgravel, coarse sand (practical size more than 2 mm), lime and kankar particles, organic matter, etc. About 20 cm of the top layer of the earth, normally containing stones, pebbles, gravel, roots, etc., is removed after clearing the trees and vegetation. 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. After removing the top layer of the earth, proportions of additives such as fly ash, sandy loam, rice husk ash, stone dust, etc. should be spread over the plane ground surface on volume basis. The soil mass is then manually excavated, puddled, watered and left over for weathering and subsequent processing. The digging operation should be done before rains.

c. Weathering:

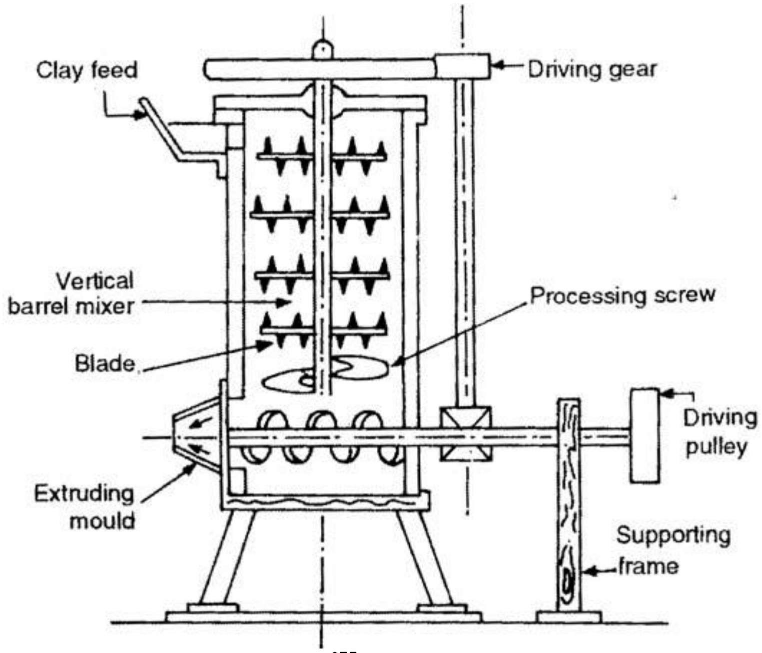
The earth is left to weather for a few weeks, this is necessary to increase the plasticity of soil and improves its quantity. Stones, gravels, pebbles, roots, etc. are removed from the dug earth and the soil is heaped on level ground in layers of 60–120 cm. The soil is left in heaps and exposed to weather for at least one month in cases where such weathering is considered necessary for the soil. This is done to develop homogeneity in the mass of soil, particularly if they are from different sources, and also to eliminate the impurities which get oxidized. Soluble salts in the clay would also be eroded by rain to some extent, which otherwise could have caused scumming at the time of burning of the bricks in the kiln. The soil should be turned over at least twice and it should be ensured that the entire soil is wet throughout the period of weathering. In order to keep it wet, water may be sprayed as often as necessary. The plasticity and strength of the clay are improved by exposing the clay to weather.

d. Blending:

The earth is then mixed with sandy-earth and calcareous-earth in suitable proportions to modify the composition of soil. Moderate amount of water is mixed so as to obtain the right consistency for moulding. The mass is then mixed uniformly with spades. Addition of water to the soil at the dumps is necessary for the easy mixing and workability, but the addition of water should be controlled in such a way that it may not create a problem in moulding and drying. Excessive moisture content may effect the size and shape of the finished brick. 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. Tempering consists of kneading the earth with feet so as to make the mass stiff and plastics (by plasticity, we mean the property which wet clay has of being permanently deformed without cracking). It should preferably be carried out by storing the soil in a cool place in layers of about 30 cm thickness for not less than 36 hours. This will ensure homogeneity in the mass of clay for subsequent processing. For manufacturing good brick, tempering is done in pug mills and the operation is called *pugging* Pug mill consists of a conical iron tube as shown in Fig 2. The mill is sunk 60 cm into the earth. A vertical shaft, with a number of horizontal arms fitted with knives, is provided at the centre of the tube. This central shaft is rotated with the help of bullocks yoked at the end of long arms. However, steam, diesel or electric power may be used for this purpose. Blended earth along with required water, is fed into the pug mill from the top. The knives cut through the clay and break all the clods or lump-clays when the shaft rotates. The thoroughly pugged clay is then taken out from opening provided in the side near the bottom. The yield from a pug mill is about 1500 bricks.



Pug mill

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:

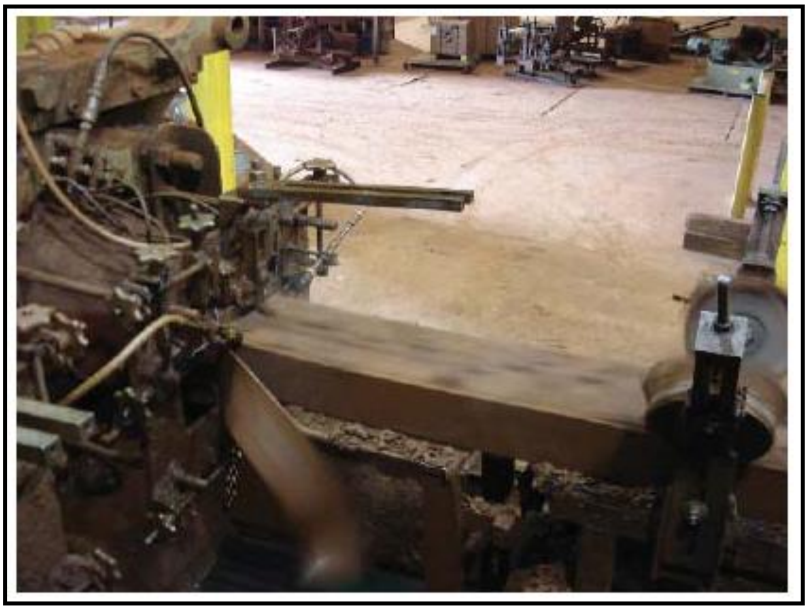


Fig. 3: Molding of clay bricks

After mining, clay is extruded through a die and trimmed to specify dimensions before it is sent to the firing chambers. Figure 2 shows a example of the molding procedure.

The 1 st step in the forming process produces a homogeneous, plastic clay mass, figure 3 shows how this is achieved by adding water to the clay (As found on TN). This happens in a mixing chamber with one or more revolving shafts each with blade extensions. Here after, the forming begins, there are basically 3 principal processes of bricks clay bricks into their desired shape. These, will be discussed later:

Fig. 4: Clay mixing with water

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.

As shows in figure 5, water in the range of 10 to 15 % is mixed with the clay. After plugging, the clay then is sent to a de-airing chamber. This chamber maintains a vacuum of 375-725mm of mercury. This process removes air bubbles and air holes that formed during the mixing process. The clay then gets extruded through a die which produced a long column of clay, which will be separated by a cutter to form the individual bricks. After the clay is extruded, different coatings could be added on the bricks to enhance some properties (like textures and glazes). The die and cutter spacing are a bit bigger than what the end bricks desired size will be, as the normal shrinkage that occurs during the firing and drying process. Drying shrinks clay bricks from 2 to 4 percent, while firing shrinks bricks from 2.5 to 4 percent, this result to a total shrinkage of 4.5 to 8 percent of the extruded size. (90% of bricks in America are made this way)

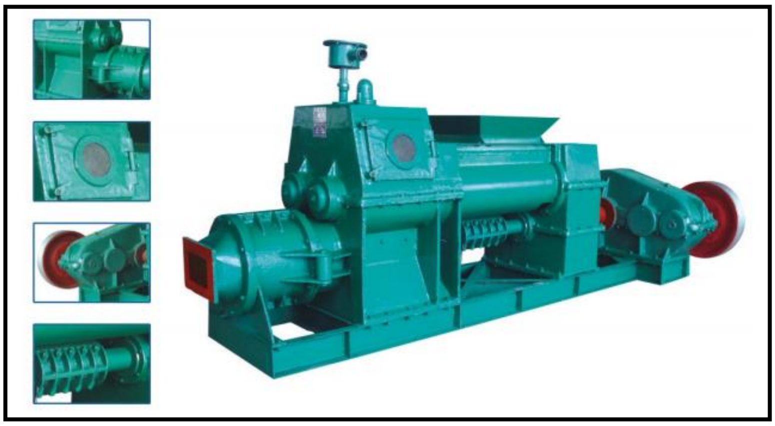


Fig. 5: Clay brick extrusion machine (CBM 26/08)

C- ***Soft mud process:***

This process is used where the clay is too wet; clays are mixed with 20-30 % water and then put into brick moulds. 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:

i. **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.

ii. **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 ºC to 149 ºC.

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 ºC to 175 ºC.

b. Dehydration:

Dehydration consists of expelling chemically combined water by breaking down the clay molecules. It begins at about 425 ºC and complete at about 750 ºC.

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. This is achieved at about 300 – 900 ºC.

d. Vitrification: when extensive fluxing occurs and the mass becomes tight, solid and nonabsorbent; leading to a deformed shape.

1.5. kilns

There are several different types of kiln but they can be allocated to two main categories.

- ***Intermittent kilns*:** These are static, usually small kilns and are used for firing small batches of products eg. Special shapes.
- ***Continuous kilns*:** For large scale production continuous kilns are more economical and are capable of turning out large quantities of bricks at a steady constant rate.

There are two main types of continuous kiln Chamber and Tunnel

1. Chamber kiln : In its simplest form a chamber kiln is an annular tunnel divided off into chambers (usually 12-20). A section of the kiln (about 4-5 chambers) is being fired at any one time. The firing is drawn round the kiln with chambers being lit in front of the firing and the chambers behind are allowed to go out. Bricks are loaded into the kiln in front of the fire and pre-heat for 1-2 days before the fire reaches them. The bricks then fire for 2-3 days. Once the fire has passed, the bricks cool before being removed from the kiln. They are then replaced with fresh dry bricks awaiting the fire's next circuit.

2. Tunnel kiln : In a tunnel kiln dry bricks are loaded onto a fireproof trolley or kiln car. This then travels very slowly through the kiln. Typical schedule through the kiln from end to end is 3-4 days but variations occur depending on production schedules.

1.6 Classification of clay bricks in accordance with Iraqi standard No. 25 / 1988:

Bricks used in construction works are classified into three grades:

Grade A:

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

Grade B:

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

Grade C:

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

Appearance:

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

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

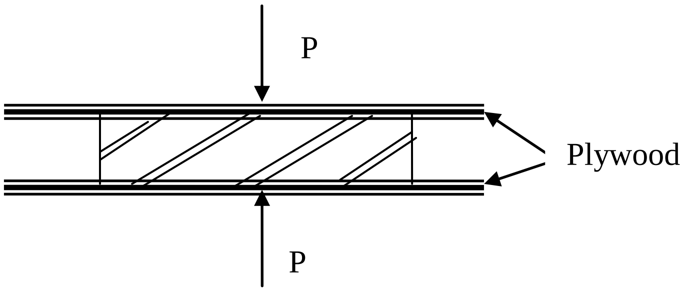
1.7 Properties of bricks:

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.

1.7.1 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.

Compressive strength in (Mpa) = Load at failure (KN) / Cross sectional area subjected to load (mm^2)



1.7.2 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 ºC to 115 ºC for about 48 hours. Next the specimen shall be completely immersed in clean water for 24 hours. Each specimen shall then be removed, the surface water wiped off with a damp cloth and the specimen weight.

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

Where: W2 – weight of brick after 24 hours in water (gm)

W1– weight of dry brick (gm)

1.7.3 Effloresce:

Efflorescence is a powdery deposit of salts which forms on the surface of bricks and mortar. It is usually white but efflorescence can be yellow, green or brown. A temporary efflorescence is particularly common on new brickwork as soluble salts are transported to the surface of the brickwork by water.

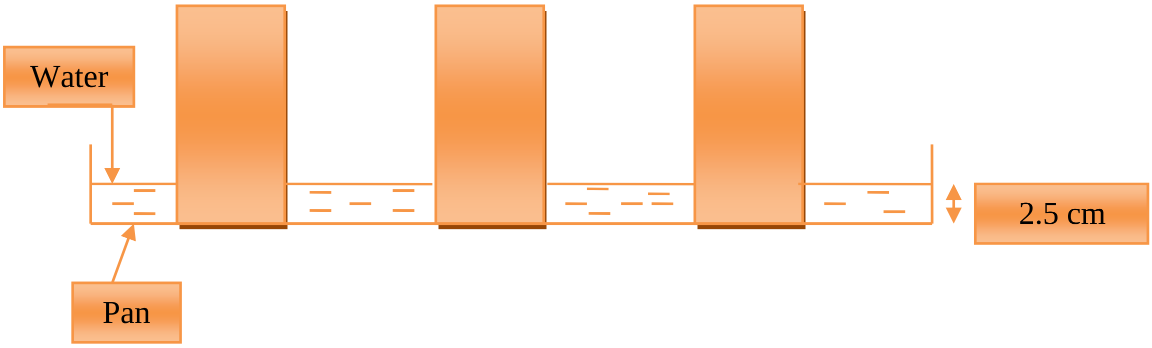
Efflorescence can occur from a variety of sources. New bricks contain minimal, if any, soluble salts, but mortar and concrete have relatively high soluble salt contents. Ground waters that are naturally saltbearing can be drawn into base brickwork. A faulty or bridged damp-proof course will allow the salts to migrate up the wall. Render that has been applied over a damp-proof course can also allow salt to migrate up the face of the brickwork. Water allowed to enter uncovered cavity walls during construction is also likely to cause efflorescence, so brickwork must be protected from water entry during construction.

Efflorescence on new brickwork may be unsightly, but it will not cause damage unless it persists for a long time. Persistent efflorescence should be taken as a warning that water is entering the wall through faulty copings, damp-proof courses or pipes. If allowed to continue unchecked, the salts carried to the face of the wall may eventually attack the bricks and cause deterioration.

Remedy: Laying dry bricks and providing good ventilation to speed up the drying process after the bricks have been laid can minimise efflorescence. Forced ventilation and heating of the premises may be necessary to ensure drying during cold winter months. The best removal method is simply to brush off the deposit with a stiff dry bristle brush after the wall has dried out.

Efflorescence on brickwork

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



The effloresce shall report as:

1. Nil – No effloresce visible.

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

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

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

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

1.8 The characteristics of good clay brick:

The essential requirements for building bricks are sufficient strength in crushing, regularity in size, a proper suction rate, and a pleasing appearance when exposed to view.

- ***The shape and size:*** The bricks should have uniform size and plane, rectangular surfaces with parallel sides and sharp straight edges.

- ***Colour:*** The brick should have a uniform deep red or cherry colour as indicative of uniformity in chemical composition and thoroughness in the burning of the brick.

- ***Textue and compactness***: The surfaces should not be too smooth to cause slipping of mortar. The brick should have precompact and uniform texture. A fractured surface should not show fissures, holes grits or lumps of lime.
- ***Hardness and soundness:*** The brick should be so hard that when scratched by a finger nail no impression is made. When two bricks are struck together, a metallic sound should be produced.
- ***Water absorption:*** should not exceed 20 per cent of its dry weight when kept immersed in water for 24 hours.
- ***Crushing strength: should*** not be less than 10 N/mm2.
- ***Brick earth:*** should be free from stones, kankars, organic matter, saltpetre, etc.

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

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