

CLAY BRICKS

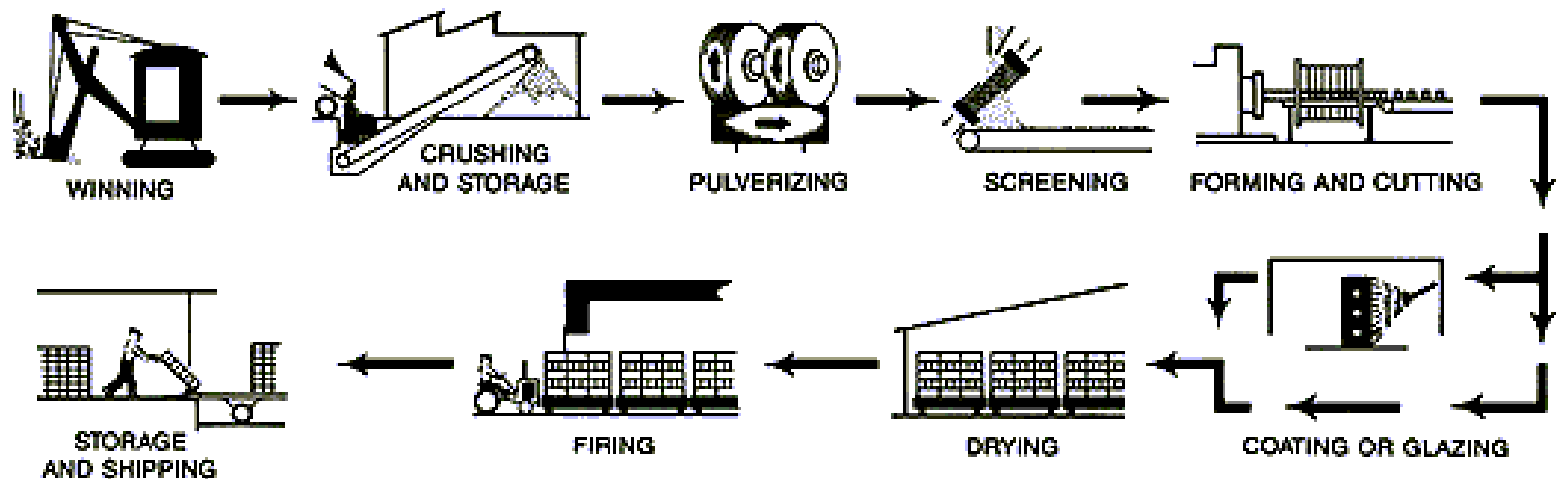


Composition of Clay

- Clay → $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Impurities (CaO...)}$
- Clay is cohesive so can be shaped when wet. (sand is non-cohesive.)
- Pure Clay → Kaolin → $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$

Manufacturing Process

- Clay bricks are made after a series of manufacturing processes.



Manufacturing Process

- 1) Preparation of Raw Material (excavated & ground)
- 2) Forming or shaping (mixing with water to a plastic condition to obtain the desired shape)
 - Stiff-mud, Soft-mud, Dry press processes
- 3) Setting and drying
- 4) Glazing → provides a thin & smooth coat on the surface. Firing or burning → in kilns above 950°C
- 6) Cooling → rate of cooling affects brittleness, color & shape.

Stiff-Mud Process (Extrusion)

- The clay is mixed with just enough water to produce plasticity (~ 12 - 15% water by weight)
- The clay is extruded through a "die" producing a horizontal column of clay which passes through an automatic cutter
- Cutter-wire spaces and die sizes should be precisely calculated to compensate for shrinkage during drying and firing
- As the clay column leaves the die, textures or surface coatings may be applied
- The green bricks (not solidified yet!) are then stacked with care to allow sufficient airspace between them to create even coloring and uniform strength during drying and firing

Extrusion Process



Extrusion Die



Brick column left the die



Bricks are cut with wires



Individual bricks are separated and stacked



Final Product

Soft-Mud Process (Forming)

- In this process, the clay contains too much water to be extruded ($\sim 20 - 30\%$ water by weight)
- Instead of extrusion, individual molds (often wood) are utilized, and are lubricated with either oil, water or sand to prevent the clay from sticking to the mold
 - If sand is used, grains with a maximum diameter of .5mm are sprinkled on the mold surfaces after being immersed in water
 - If oil is used, it will be absorbed by the brick and burned during firing
- The soft-mud process can be carried out by hand or by machine.

Dry-Press Process



- This process is adaptable for clays of very low plasticity ($< 10\%$ water by weight)
- Instead of wooden molds, the clay is formed with steel molds and is put under high pressure to create a very compact, dense brick
- Hydraulic or compressed air-rams generate pressures ranging from 3.5-10 MPa

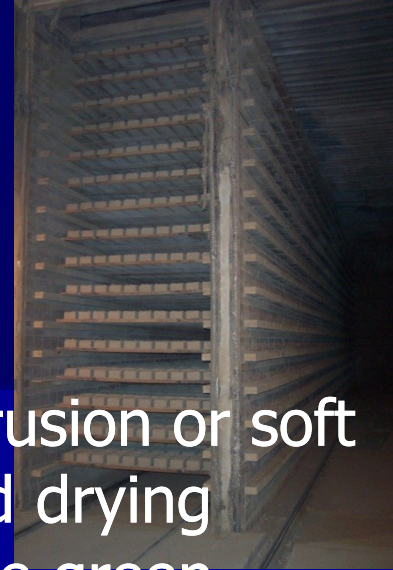
Drying

- After molding the brick unit through either extrusion or soft mud process, bricks go through the setting and drying stage. Before they enter the kiln to be fired, the green bricks must be correctly dried. (40-200 °C at 24-48 hrs)
- The moisture must be minimized to prevent certain defects and shrinkage from happening when fired at extreme heat in the kiln. Shrinkage can cause the bricks to crack.

Soft-mud process



Stiff-mud process



Firing / Burning



- Firing, one of the most specialized steps in the manufacture of brick, requires from 40 to 150 hr. depending upon kiln type and other variables.
- The two general types of kilns are tunnel and periodic kilns.
- A periodic kiln is one that is loaded, fired, allowed to cool and unloaded, after which the same processes are repeated.
- In a tunnel kiln, units are similarly loaded on special cars which pass through various temperature zones as they travel through the tunnel. The heat conditions in each zone are carefully controlled and the kiln operates continuously.

Firing / Burning

The fusibility of clay causes it to become hard, solid and of relatively low absorption when properly fired. Firing consists of:

- Water smoking $\sim 200^{\circ}\text{C}$ \rightarrow evaporation of free water
- Dehydration $\sim 450^{\circ}\text{C}$ - 750°C \rightarrow evaporation of chemically bound water
- Oxidation $\sim 450^{\circ}\text{C}$ - 950°C \rightarrow oxides are formed
- Vitrification $\sim 950^{\circ}\text{C}$ - 1200°C \rightarrow low melting components liquify and fill the pores

Firing / Burning

Fusing takes place in three stages:

- 1) Incipient fusion, that point when the clay particles become sufficiently soft that the mass sticks together;
- 2) Vitrification, when there is extensive fluxing and the mass becomes tight, solid and non-absorbent; and
- 3) Viscous fusion, the point at which the clay mass breaks down and tends to become molten.

The key to the firing process is to control the temperature in the kiln so that incipient fusion and partial vitrification are complete but viscous fusion is avoided.

Cooling

- After the temperature has reached the maximum and is maintained for a prescribed time, the cooling process begins. 48 to 72 hr are required for proper cooling in periodic kilns; but in tunnel kilns, the cooling period seldom exceeds 48 hr.
- Because the rate of cooling has a direct effect on color and because excessively rapid cooling will cause cracking, cooling is an important stage in the firing process.

Defects in Bricks

- Defects are sometimes formed because of:
 - Unsuitable chemical composition
 - Improper mixing of clay, sand & water
 - Improper shaping
 - Improper burning

Defects in Bricks

- Lime Pops: Small lumps of CaO →they may hydrate to form Ca(OH)_2
- Blisters: Tiny holes occurring on the surface due to incomplete mixing or improper shaping.
- Laminations: Occurs on the extruded sections of some hollow bricks
- Cracks: - Composition
 - Improper drying before burning
 - Rapid cooling
 - Too much sand→lack of cohesion
- Warping: During drying it may warp.
- Softness & Low Strength: Under burning

Properties of Bricks

- All properties of brick are affected by composition of the raw materials and the manufacturing processes. It is for this reason that most manufacturers blend clays to reduce the possibility of impurities from one clay source affecting the overall quality of the finished product.
- The properties that most concern the users of brick are 1) durability, 2) color, 3) texture, 4) size variation, 5) compressive strength and 6) absorption.

Properties of Bricks

- Porosity and Absorption is affected by chemical composition, proper mixing and shaping and the degree of burning

$$\%Absorption = \frac{\textit{Weight of water absorbed}}{\textit{Weight of the dry clay product}}$$

Porosity affects the strength and durability of the brick. Higher porosity (or higher absorption) leads to lower strength and lower durability.

Properties of Bricks

- Strength is also affected by the factors affecting porosity

For strength tests → capping is done with cement mortar

- Strength of brick → 80-200kgf/cm²
- Strength of wall → further affected by mortar and workmanship
- Strength of wall < brick strength

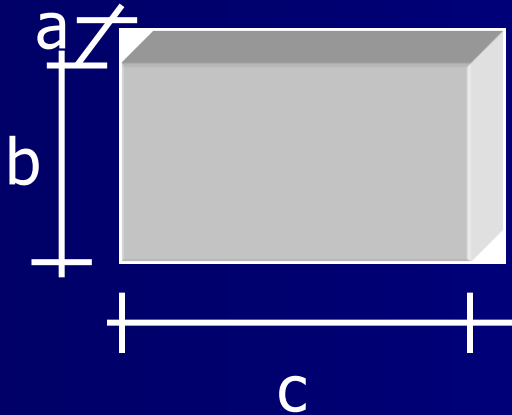
Properties of Bricks

- The compressive strength of brick or structural clay tile is an important material property for structural applications. Typical Brick Strengths obtained from manufacturers in US.

Unit Type		Mean Unit Compressive Strength, psi (Mpa)	Standard Deviation of Compressive Strength, psi (MPa)
Solid brick	Forming Method	Extruded	11305 (77.9)
		Molded	5293 (36.5)
	Raw Material ¹	Fire clay	15346 (105.8)
		Shale	11258 (77.6)
		Other ²	9169 (63.2)
Hollow Brick ³		6736 (46.4)	2447 (16.9)
Structural clay tile ³	Vertical coring	10057 (69.3)	5578 (38.5)
	Horizontal coring	5119 (35.3)	2067 (14.3)

Properties of Bricks

- Unit weight



$$Y = \frac{W}{V} \rightarrow \begin{array}{l} \text{Total} \\ \text{volume} \\ V = a.b.c \end{array}$$

CLASSIFICATION OF BRICKS

1) X-Section

- Solid
- Vertically perforated
- Horizontally perforated

2) Size

- Standard (190x90x50)
- Modular (190x90x85)
- Block (larger)

3) Use

- Facing
- Paving
- Sewer
- Fire

