BUILDING A WIDER HORIZON CEC WITH LABOUR

Greentech Knowledge Solutions Pvt. Ltd.

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Manual for Trainers

Brick Kiln Workers Skill Development

PKT Greening the Earth

NB Institute for Rural Technology

Manual for Trainers: Brick Kiln Workers Skill Development

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Module 1: Introduction to Brick Industry

1.1 General History of Burnt Clay Bricks in India

At a basic, functional level, brick is a building material that is used to make walls, pavements, and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote any rectangular units laid in mortar. Bricks made from clay and fired in a kiln are called burnt clay bricks. Burnt clay bricks are the most popular and widely used bricks globally.

Globally, it is estimated that 1500 billion burnt clay bricks are produced annually. China, South Asia, and South-East Asia are the major burnt clay brick producing regions in the world. This region produces around 87% of the total bricks produced globally. China is the largest producer with annual production of around 800 billion bricks/year, followed by India which produces around 250 billion bricks/year.

Burnt clay brick production enterprises are at large, tradition-bound enterprises in many parts of the world. It is a booming industry as the demand for bricks is increasing almost universally due to increasing population, economic growth, and urbanization.

1.2 History of Burnt Clay Brick making

It is believed that the art of brick making originated, more than 5000 years ago, in large river valleys that were home to some of the earliest civilizations. One of the reasons for this was the abundance of riverine clay, the basic raw material for bricks. It is perhaps no coincidence that the earlier evidence of brick making comes from sites located along the Nile in Egypt; along the Euphrates and Tigris in ancient Mesopotamia, and the rivers, Indus and Ghaggar for the Indus Valley Civilization.

Excavations at Indus Valley cities of Mohenjo-daro, Harappa, Mehrgarh, and Rakhigarhi have revealed evidence of the use of ceramic or fired bricks as early as 3000 BC. One of the key characteristics of the ancient cities of Indus Valley is the precise dimensions of their bricks. All Indus Valley bricks were in the same ratio of 1:2:4 but came in different sizes. A common size was 7 cm high × 14 cm wide × 28 cm long. Bricks were laid in rows or 'courses', end to end and crossways, using wet mud as cement to stick the bricks together. The walls thus built were so strong that many have been standing for over 4000 years.

The skills and expertise required for making sturdy terracotta bricks have been thriving across the centuries in the Gangetic plains. The terracotta temples of Bishnupur, Bankura District in West Bengal, are a standing testament to this long tradition.

Figure 1: The terracotta brick temples of Bishnupur, West Bengal (1600–1737)[1];

1.3 Benefits of Burnt Clay Brick

Burnt clay bricks are the most popular material for the construction of walls globally. The main benefits of burnt clay bricks are:

- Economical (Raw material is locally available at affordable prices in majority of high population regions)
- Hard and durable (properly fired bricks have long life)
- Good compressive strength for ordinary construction
- High fire resistant
- Good thermal insulation properties
- Different colours and different surface textures are possible
- Structures made from good quality bricks require low maintenance cost
- Demolishing of brick structures is easy, bricks are Reusable and Recyclable

1.4 Different Types of Burnt Clay Bricks

1.4.1 Solid burnt clay bricks

Solid burnt clay bricks are the most common types of bricks. Usually in India, they are made through manual moulding process. Solid burnt clay bricks can also be made using soft mud moulding machine or using an extruder. The typical sizes of such bricks are:

- 230 mm x 115 mm x 75 mm having fired brick weight of around 3 kg/brick (Uttar Pradesh & Rajasthan)[2]
- 254 mm x 127 mm x 75 mm having fired brick weight of around 3.5 kg/brick (West Bengal & Tripura)[3]

[1]Source: Wikipedia Commons

[2]9 inch x 4.5 inch x 3 inch

Figure 2: hand moulded solid brick

Figure 3: Soft mud moulded solid brick

Figure 4: Extruded solid bricks

1.4.2 Perforated and hollow burnt clay bricks

Perforated Bricks:

In practice, the perforated bricks, usually having 3 to 10 holes, are manufactured. The holes pass through its width and these bricks have perforations up to 20% - 25% of the gross volume. Generally, in a particular region, the perforated bricks are of the same size as that of solid bricks manufactured in that region. Bricks having higher volume of perforation, are lighter in weight in comparison to solid burnt clay bricks.

Various types of perforated bricks are shown below:

---

[3]10 inch x 5 inch x 3 inch


Figure 5: Perforated Bricks

Hollow blocks:

In hollow blocks, the volume of perforations is greater than 25 % of the gross block volume, and usually the perforations are laid along the bigger length/dimension of the block. Three sizes of hollow blocks are commonly produced: (i) 400 x 200 x 200 mm[4] (ii) 400 x 150 x 200 mm[5] and (iii) 400 x 100 x 200 mm[6].


Figure 6: Hollow Blocks

1.5 Brick Industry in India: Overview of Current Scenario

As per estimates[7], there are over two lakh brick kilns operating in the country which produces about 220–280 billion bricks a year, placing India as the second largest producer of bricks in the world after China. Table 1 provides the data on number of kilns, brick production, and resource consumption; which establishes the fact that the brick industry in India is quite energy intensive and account for a sizable share of coal consumption in the country.

Table 1: Brick Production and Resource Consumption by Indian Brick Industry

1	Total number of brick kilns	1,90,000 - 2,80,000

[4]Approx. 16 inch x 8 inch x 8 inch

[5]Approx. 16 inch x 6 inch x 8 inch

[6]Approx. 16 inch x 4 inch x 8 inch

[7]A study conducted jointly by The Energy and Resources Institute (TERI) and the Punjab State Council for Science and Technology (PSCST) during 2013–2015

1.a	Clamp kilns[8]	1,47,000 - 2,32,000
1.b	Bull's Trench kilns	42,000 - 47,000
1.c	Others	500 - 1,000
2	Annual brick production	220 - 280 billion
3	Annual coal consumption	29 - 35 million tonne (MT)
4	Annual biomass consumption	12 - 16 million tonne (MT)
5	Annual top-soil consumption	400 - 500 million m^3
6	Annual water consumption	200 - 235 million m^3

Most of these brink kilns are found in the rural and peri-urban areas. The availability of fertile alluvium soils in the Gangetic plains of North India makes the fringe areas of North Indian cities be dotted with brick kilns. Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal are the major brick producing states in this region, together accounting for about 65% of the total brick production in the country. As most of the operations are manual, it is estimated that about 10 million workers are employed across the industry in India.

1.6 Future Prospects of Brick Industry and Opportunities for Workers

Government of India is trying to provide housing for all Indian families by 2022. This would entail, construction of 2-3 crore new houses. In addition to housing, new offices, shops, commercial buildings are being constructed. It is estimated that the demand for bricks will at least double in next 15 years.

The brick industry is changing in India. To reduce the amount of fuel used for firing of bricks and also to reduce air pollution, improved technologies like zigzag kilns are being adopted. More and more enterprises are using machines for clay winning and mixing. Use of machines like extruders and soft mud moulding machines is also increasing. Small trucks, electric vans, fork-lifts, are now increasingly being used for material handling. On regulatory front also, there has been increasing push for compliance with stricter environment regulations, compliance with labour regulations, and formalization of the industry. It is hoped that in coming years the brick industry will move from the traditional production to more modern industry which will have reduced environmental impacts, better product quality, and improved working conditions for the workers. This will happen through upgradation of technologies and operating practices, and therefore, the modern brick industry will require trained workers. This training program is

[8]The estimate of the number of clamp kilns in operation can vary significantly depending upon the market demand. Clamp kilns are not registered and are not members of any industry associations.

Source: Kumar S. 2016. Resource Efficient Bricks: Benefits of Producing Clay-fired Bricks. New Delhi: The Energy and Resources Institute.

designed to equip workers with basic skills in brick making. It is expected that the trained workers will have excellent work opportunities in the Indian brick industry.

1.7 Points to remember

1. Burnt clay bricks are economical, durable and are high fire resistant.
2. Perforated bricks have perforations up to 20% - 25% of the gross volume and thus they are lighter in weight in comparison to solid burnt clay bricks.
3. In hollow blocks, the volume of perforations is greater than 25% of the gross block volume, and usually the perforations are laid along the bigger length/dimension of the block.

Module 2: Introduction to Brick Making Process

2.1 Introduction to Brick Making Process

Brick Making Process

The production of common burnt clay bricks consists mainly of five operations.

i) Soil winning
ii) Soil-mix preparation
iii) Moulding
iv) Drying
v) Firing

A brief description of these operations (as practiced in India) is provided below.

2.1.1 Soil Winning

Brick making process starts with mining of soil or soil winning. In India, mostly surface soils from agriculture fields are used for brick making, though in some cases silt from water bodies such as rivers and ponds is also used. In case of agriculture soils, the soil winning operation is carried out either manually or through mechanical excavators. The excavation depth is shallow and is generally kept to less than 2 m.

Figure 7: Soil Winning – Manual or by excavator

2.1.2 Soil-Mix Preparation

During soil-mix preparation, water is added to the soil and after water addition the typical moisture content of the mix is about 25-35% by weight. At this stage, fuels such as rice husk, saw dust, powdered coal, fly ash etc. can also be added to the soil. The fuels added to the soil during soil preparation are referred as *internal fuels*. The soil, water and fuel are mixed into a homogenous mass. Traditionally, the mix preparation used to be done manually or by pug-mill. Now-a-days various kinds of mixing machines are also being used of soil-mix preparation.


Figure 8: Soil mix preparation – Manually and by pug-mill

2.1.3 Moulding

During moulding, the clay mass is transformed into the shape of the brick. Moulding of bricks can be done either manually or by using machines. In the manual method or *hand moulding*, a clot of the prepared soil-mix is thrown to fill a wooden or metallic mould, excess soil is scraped off and the brick is de-moulded. In mechanized moulding bricks are shaped using soft-mud moulding machine, extruders and semi-dry brick presses.

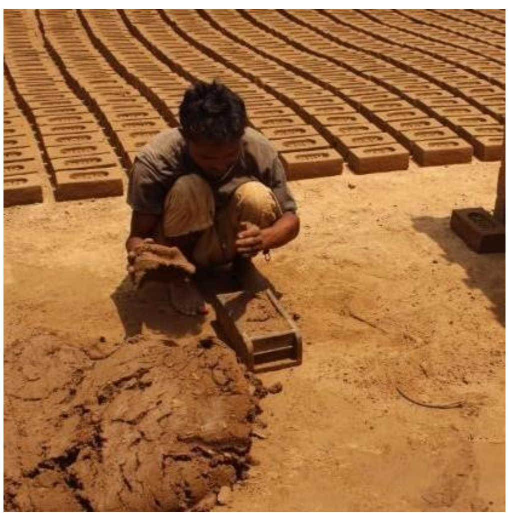



Figure 9: Manual and mechanized moulding of soft-mud bricks

2.1.4 Drying

Freshly moulded green bricks (the unbaked bricks are referred to as *green bricks*) contain about 25% moisture by weight. The bricks are left in the open (initially spread on the ground and later stacked in layers) for drying. The combined action of the sun and wind removes the moisture in the bricks. The moisture content in green bricks at the end of drying can range from 5% - 15% by weight. The final moisture content and the time taken for drying depend on the local weather conditions. In India, mostly open drying is practiced. Drying under shed is practiced in large brick plants as well as in brick kilns located in regions which receive rainfall throughout the year. In some of the large brick plants, artificial drying, i.e. drying achieved using hot air/gases from the kiln or burning additional fuel is employed. Artificial drying is usually faster and have better control on drying.


Figure 10: Natural and artificial drying of bricks

2.1.5 Firing

The brick firing process consists essentially of increasing the temperature of the bricks progressively over a period of time, holding it at a peak temperature (of about 1000 ^{o}C), and then cooling back to the ambient temperature.

Bricks are fired in kilns and fuel is burned in them to provide necessary energy for heating and completing chemical reactions in bricks. Fuel is fed into the kiln by hand (using small hand shovel) or using mechanical stokers. In India most of the brick kilns are fired using solid fuels.


Figure 11: Hand-fed and stoker-fed firing of brick kiln

Generally, the firing operation consumes the largest amount of energy in the brick making process. It accounts for almost all the fuel used in brick making, and consequently, all the combustion related air pollution in brick making. Further, the cost of fuel for firing bricks is the single largest cost in brick production, which accounts for 30%-50% of the total production cost.

Figure 12: Fired bricks in the kiln

2.2 Points to remember

1. During soil winning the excavation depth is generally kept to less than 2 m.
2. During soil-mix preparation, water is added to the soil and after water addition the typical moisture content of the mix is about 25-35% by weight. At this stage, fuels such as rice husk, saw dust, powdered coal, fly ash etc. can also be added to the soil.
3. In mechanized moulding bricks are shaped using soft mud moulding machine, extruders and semi-dry brick presses.
4. The moisture content in green bricks at the end of drying can range from 5% – 15% by weight.
5. The cost of fuel for firing bricks is the single largest cost in brick production, which accounts for 30%-50% of the total production cost.

Module 3: Layout of a Brick Making Plant

3.1 Layout of a brick making plant

Layout of a brick making plan consists of distinct areas. These are:

- Clay storage
- Clay preparation
- Moulding area
- Drying area and drying brick storage
- Kiln
- Coal storage and coal crushing
- Fired brick storage

The different areas and the flow of material in a brick plant is shown in figure below:

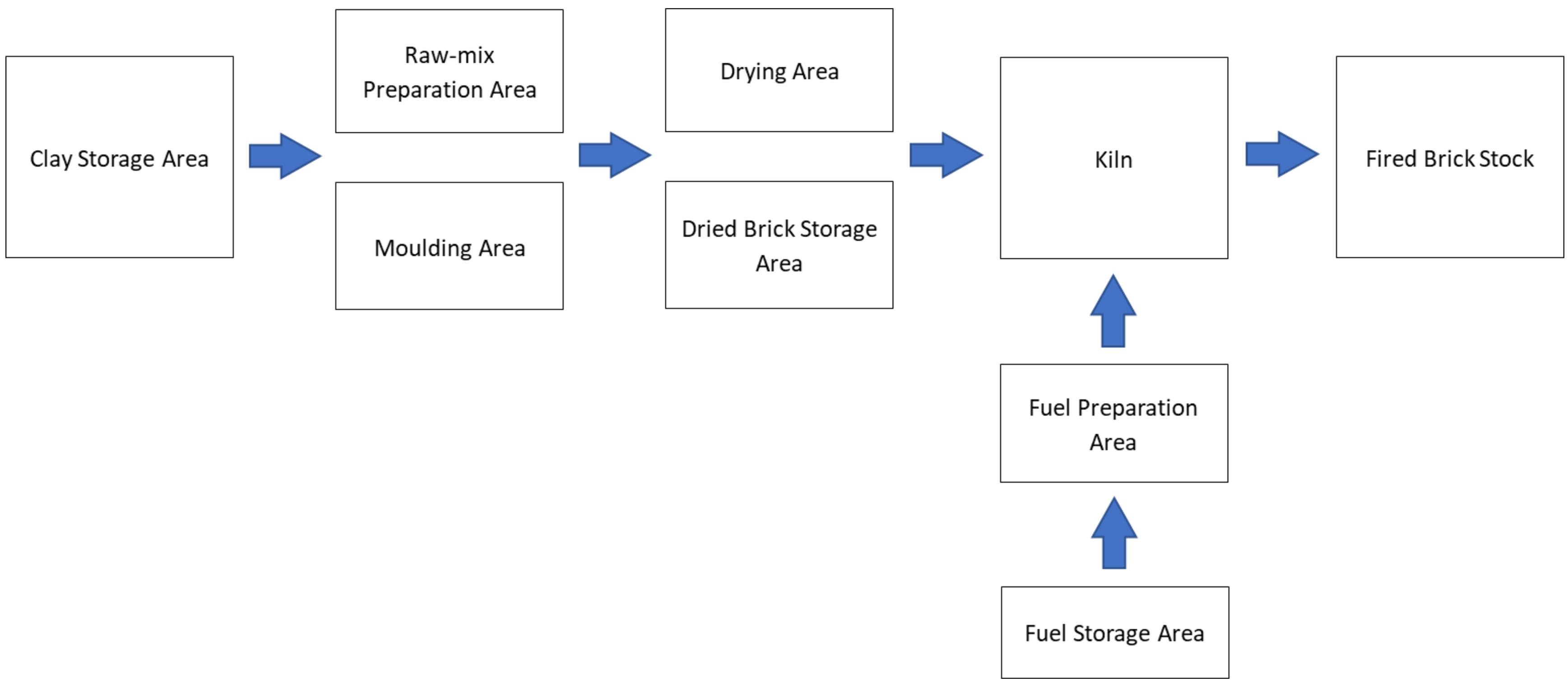


Figure 13: Layout of a brick making plant

3.1.1 Clay storage area

Clay is stored in open in heaps adjacent to the area where raw-mix is prepared and moulding of bricks is carried out.

Figure 14: Clay storage area

3.1.2 Raw-mix preparation area:

In this area, clay is mixed with water to prepare the raw-mix. Sometimes there is more than one type of clay, or additive like fly ash or internal fuel that needs to be mixed. Mixing is done either manually or through a pug mill or mechanical mixers. In case, pug-mill or mechanical mixers are used, usually the raw-mix is prepared centrally and then transported to the moulding area using handcarts, tractors, etc.

Figure 15: Raw mix preparation area

3.1.3 Moulding area:

This is the area where moulding of bricks is carried out. In hand-moulding, this occupies largest area in a brick field. The ground of the moulding area should be level and plain, it should also have good drainage to prevent water logging in the moulding area. Mechanized moulding requires large space to install machines for crushing of lay-mix, sanding the mould, filling of mould with clay-mixture, releasing and handling of freshly moulded bricks.


Figure 16: Moulding area

3.1.4 Brick drying area:

After moulding, bricks can be dried naturally or artificially. In natural drying brick are dried in a single layer by placing them on a flat ground under the sun. After the initial drying is over, the bricks are organised in brick hacks for further drying. Brick hacks are located adjacent to the moulding area.


Figure 17: Drying area

Artificial drying involves blowing air or hot gases through the brick stacks. It is mostly required and economically justified for large scale production of bricks.

3.1.5 Dried brick storage:

In some of the kilns, either a covered storage or a temporary storage is created to store the dried bricks, before they can be transported to the kiln for firing. Rains or clouds interrupts the drying of bricks, and during those days, dried green bricks from the storage are used for uninterrupted operation of the kiln.

Figure 18: Dried brick storage area

3.1.6 Kiln

Firing of bricks is carried out in the kiln. Sufficient circulation space as well as storage space for stacking fired bricks is generally left around the kiln

Figure 19: Zigzag Kiln and Tunnel Kiln

3.1.7 Fuel storage

Fuel, usually coal, is the most expensive raw-material and it should be stored carefully. Ideally, the floor of the fuel storage area should be paved, and a shed should be provided. Fuel storage is usually situated not very far from the kiln.

Figure 20: Fuel storage in a kiln

3.1.8 Coal crushing area

Coal crushing area is used to crush the coal.

Figure 21: Coal crushing area

3.1.9 Fired brick storage area

Area around kiln is generally used for storage of fired bricks. The fired bricks are sorted and stored as per the quality.

Figure 22: Fired brick storage area

3.2 Concept of Brick quality

3.2.1 Parameters used for assessment of brick quality

Size: All the bricks should be regular and uniform. Good quality bricks shouldn't exceed the following tolerances in size – in length they shouldn't exceed 4 mm, and in width and height 2 mm.

Shape: Shape should be uniform of quality bricks. Edges of them should be sharp, straight and right angle.

Colour and metallic ring of bricks: Well brunt brick always have uniform colour. It can be red, cherry or copper-coloured. Well-burnt bricks give metallic ringing sound when struck with one another.

Surface finish: Good quality brick surface should be free from cracks, flaws, air holes and any defect or impurities. Broken surface of good quality bricks should show uniform, compact and fine structure.

Compressive Strength: Compressive strength of good quality bricks in north India is generally above 100 kgf/cm^2. Crushing strength is tested in laboratory.

Water absorption: Good quality bricks should not absorb water more than 20% of its dry weight when soaked 24 hours in cold fresh water.

3.2.2 General classification

Bureau of Indian Standards lays down requirements for classification, quality, dimensions and physical requirements of common fired-clay bricks in IS-1077:1992. This standard classifies bricks based on their average compressive strength as shown in the table below.

IS 1077:1992 Common Burnt Clay Building Bricks – Specifications		
Class Designation	Average Compressive Strength Not Less Than	
	N/mm^2	Kgf/cm^2 (approx.)
35	35.0	350
30	30.0	300
25	25.0	250
20	20.0	200
17.5	17.5	175
15	15.0	150
12.5	12.5	125
10	10.0	100
7.5	7.5	75
5	5.0	50
3.5	3.5	35

It also specifies values for other physical requirement like water absorption, efflorescence, dimensions and shape and size of frog.

Customarily, bricks fired in a kiln can be classified broadly under four categories: overfired, well fired or Class-I, under fired, and broken bricks.

Overfired: These are the over fired bricks. These bricks have been exposed to high temperatures within the kiln. Because of excessive firing shrinkage they have smaller final size, usually they also not straight and have got disfigured. They have high density and can be used to replace stone aggregates.

Figure 23: Over-fired bricks

Class-I bricks: Class-I bricks are well fired/baked bricks with optimum firing shrinkage and gives metallic ringing sound when struck with one another.

Figure 24: Class-I bricks

Under-fired bricks: Underfired bricks have undergone some or no firing shrinkage. They have low strength as well as do not have good weather resistance. Usually these bricks are classified as Class-II and Class-III bricks.

Figure 25: Underfired Bricks

Broken bricks: Bricks which are broken. The breakage in bricks can be due to faulty clay selection, improper clay-mix preparation, moulding defects, drying cracks, and cracks occurring during firing as well as improper loading of bricks in the kiln.

Figure 26: Broken bricks

3.3 Points to remember

1. All the bricks should be regular and uniform.
2. Well brunt bricks always have uniform colour. It can be red, cherry or copper-coloured. Well-burnt bricks give metallic ringing sound when struck with one another.
3. Good quality brick surface should be free from cracks, flaws, air holes and any defect or impurities.
4. Good quality bricks don’t absorb water more than 20% of its dry weight when soaked 24 hours in cold fresh water.

Module 4: Work Organization in Brick Making

4.1 Work Organization in brick making (Different types of workers and their tasks)

The brick manufacturing industry in India is labour intensive, employing up to 10 million workers. There are different types of brick workers engaged in a brick kiln.

(i) **Workers involved in moulding of bricks:** These workers are known as paatla (Gujarat), pathaiwala or pather (North India). Their work involves mixing clay with water and shaping it into bricks that are then sun dried. These workers arrive at the worksite about a month before the kiln firing is initiated.


Figure 27: Moulding of bricks

(ii) **Workers involved in transporting dry green bricks to the kiln**: This process is generally called bharai in North India. In this process, sun-dried bricks are shifted for stacking in kilns for baking. The bricks are usually transported using a cart (animal/ mechanical).


Figure 28: Transportation of bricks

(iii) **Workers involved in arranging bricks in the brick kiln**: Bricks are arranged in kilns for firing by workers known as "stackers".

Figure 29: Stacking of green bricks

(iv)**Workers involved in feeding the fuel and managing the fire in the kiln**: These workers are commonly called as Jalaiya or Jalai-wala. There work involves feeding the fuel and managing the firing process in the kiln.

Figure 30: Firing of bricks

(v) **Workers involved in unloading fired bricks from the kiln**: These are commonly known as Nikasi. They remove the fired bricks from the kiln, transport it and stack them under different categories around the kiln.

Figure 31: Unloading of bricks

Module 5: Basic Occupational Health and Safety

5.1 Occupational Health and Safety Matters

Section 7A of Chapter 2 of Factories Act 1948 specifically mentions that "Every Occupier (Employer) shall ensure health, safety and welfare of the workers". It stipulates several measures aimed at ensuring safety of workers at workplace. Some significant ones are as follows:

- Maintenance of sufficient supply of wholesome drinking water, sufficient latrine and urinal facilities and adequate and suitable facilities for washing
- First Aid boxes equipped with the prescribed contents are also to be provided in every factory
- A notice containing abstract of the Factories Act and Rules made there under, in English and local language should be displayed prominently.
- Names and address of Factories Inspector and certifying Surgeon should also be displayed on notice board
- Notice of any accident causing disablement of more than 48 hours, dangerous occurrence and any worker contracting occupational disease should be informed to Factories Inspector.

Although occupational health issues and occupational safety issues are not the same, however, they are complementary to each other. A healthy workplace is by definition also a safe workplace, but a safe workplace is not necessarily also healthy workplace.

Safety Hazard	Health Hazard
Working conditions where harm is immediate and extreme to the worker	Working conditions which will lead to illness
Leads to injury on the body like cuts or bruises	Caused by prolonged exposure to harmful chemicals or other substances. May lead to long term diseases and/or death
Is associated with poorly maintained machinery or dangerous equipments	Cause is difficult to ascertain as there is generally a long gap between exposure and resultant disease

5.1.1 Issues of concern

The main issues of concern of Occupational Health and Safety in brick kilns in India include:

- High temperature due to burning of coal used in the kilns
- Used of banned materials like plastic, tyre, etc. as fuel
- 12 hours shift of moulding job leading to greater risk of high-level musculoskeletal damage and exposure to hazards

- Infrequent job rotations and ergonomic concerns
- Minimal usage of protective safety gear
- Inappropriate living conditions at the workplace such as low ceiling houses, lack of ventilation
- Lack of separate toilets for men and women in the brick kilns
- Operation of unsafe kilns

5.1.2 Impact of hazardous occupation on women

Typically, a pair or couple (man & woman) are employed in production of bricks by hand. Transportation of red bricks is done by headload and mostly women are assigned to this work. Generally, 9 to 12 bricks are carried at a time as head load, which causes health problems. Exposure to hazardous substances and working conditions can affect woman's reproductive health. For instance, turning soft bricks is a job which is done by women workers where they are required to squat and turn the bricks. This constant squatting can not only result in ergonomical problems such as back ache and other muscular disorders but can also lead to reproductive health problems. Occupational hazards can also seriously affect a developing embryo or foetus and can have adverse effects on the development of a baby or child.

5.2 Safe Drinking Water

Water is a fundamental human need. Each person on Earth requires at least 20 to 50 liters of clean, safe water a day for drinking, cooking, and simply keeping themselves clean.

Polluted water isn't just dirty – it's deadly. Some 1.8 million people die every year of diarrheal diseases like cholera. Tens of millions of others are seriously sickened by a host of water-related ailments – many of which are easily preventable.

The United Nations considers universal access to clean water a basic human right, and an essential step towards improving living standards worldwide. Water-poor communities are typically economically poor as well, their residents trapped in an ongoing cycle of poverty. Safe drinking water should be provided by the employer in the brick fields to avoid poor health or epidemics in the kilns.

5.3 Sanitation

Water is obviously essential for hydration and for food production – but sanitation is an equally important, and complementary, use of water. A lack of proper sanitation services not only breeds disease, it can rob people of their basic human dignity.

5.3.1 Importance of Sanitation:

Proper sanitation facility is needed to:

- Protect and promote health
- Keeping disease carrying waste and insects away from people, toilets and homes
- Break the spread of diseases
- Prevent spreading of waterborne diseases
- Improve the health and quality of life
- Protect the environment against pollution
- Keeping disease carrying waste and insects away from the environment
- Prevent environmental pollution (air, soil and emission)
- Prevent contamination of water resources (surface and ground water)

Adequate provisions should exist to guarantee the safety and security of workers, and of women workers in particular. Security and lighting should be available in the brick kilns while working at night. Separate toilets for men and women facilities should be provided for this.

5.4 First Aid

First aid is the immediate treatment or care given to a person suffering from an injury or illness until more advanced care is provided or the person recovers. First Aid boxes should be labelled and placed where it is visible clearly so that it can be used immediately when required. The first-aid box should contain with the following prescribed items:

Figure 32: First aid box with prescribed items should be placed at a suitable place[9]

First Aid Basic Care:

- Antiseptic wipes (BZK-based wipes preferred; alcohol-based OK)
- Antibacterial ointment (e.g., bacitracin)
- Compound tincture of benzoin (bandage adhesive)
- Assorted adhesive bandages (fabric preferred)
- Butterfly bandages / adhesive wound-closure strips
- Gauze pads (various sizes)
- Nonstick sterile pads
- Medical adhesive tape (10 yd. roll, min. 1" width)
- Blister treatment
- Ibuprofen / other pain-relief medication
- Insect sting / anti-itch treatment
- Antihistamine to treat allergic reactions
- Splinter (fine-point) tweezers
- Safety pins
- First-aid manual or information cards

Wraps Splints and Basic Coverage

- Elastic wrap
- Triangular cravat bandage

[9] Image Source: www.alibaba.com

- Finger splint(s)
- SAM splint(s)
- Rolled gauze
- Rolled, stretch-to-conform bandages
- Hydrogel-based pads
- First-aid cleansing pads with topical anesthetic
- Hemostatic (blood-stopping) gauze
- Liquid bandage

Tools and Supplies

- Knife (or multi-tool with knife)
- Paramedic shears (blunt-tip scissors)
- Safety razor blade (or scalpel w/ #15 or #12 blade)
- Cotton-tipped swabs
- Standard oral thermometer
- Irrigation syringe with 18-gauge catheter
- Medical / surgical gloves (nitrile preferred; avoid latex)
- CPR mask
- Small notepad with waterproof pencil or pen
- Medical waste bag (plus box for sharp items)
- Waterproof container to hold supplies and meds
- Emergency heat-reflecting blanket
- Hand sanitizer
- Biodegradable soap

5.5 Workplace hazards at brick kiln site and their Potential effects

Certain work environments, like brick kilns, have greater risks of injury and illness due to the nature of work being carried out and the nature of the hazards at the workplace. Suitable measures should be taken to mitigate threats. Hazards present at brick kilns site may include:

Hazard	Effects
Over exertion from manual material handling practices and excessive force, poor posture, high frequency/duration of tasks involving lifting, pushing or pulling.	Strains, permanent back injuries, sprains and muscular damage to back, upper and lower extremities. Excessive physical and mental fatigue can cause errors leading to secondary incidents.

Hazard	Effects
Slips, trips and falls on walking and working surfaces, equipment, tools or materials, caught in or struck by or against fixed or mobile equipment.	Abrasions, cuts, contusions, lacerations, punctures, fractures, amputations and chemical burns.
Inhalation of airborne particulate matter from raw materials including crystalline silica, clay, lime, iron oxide, nuisance dusts and gases (CO, SO2, NOx).	Range from irritation (nuisance particulate) to chemical burns (burnt lime or other alkaline raw materials) to chronic effects such as decreased pulmonary function, lung disease, pneumoconiosis - silicosis, tuberculosis and allergies.
Radiant heat, high temperature work environments.	Physiological strain, heat stress or thermal burns, reproductive problems.
Heavy metals particulates or fumes (lead, cadmium, chromium, arsenic, copper, nickel, cobalt, manganese or tin).	Heavy metal toxicity, reproductive problems.
Long or unusual working hours.	Smoking, drug abuse, stress related disorders, workplace violence, drinking water, place of eating/ living, poor sanitation conditions (stagnant water, Insect breeding), Animals (monkeys, snakes etc.).

5.6 Points to remember

The following gives the general safety precautions to be taken according to the working area:

a) Moulding

- Avoid continuously working in squatting position for very long hours.
- It is advised to use specially designed moulding table to make bricks.
- Always ensure arrangement of clean drinking water near moulding area to avoid dehydration especially during summers.
- Avoid working bare foot in open space during moulding to prevent hazards like skin infections, injury, snake bite etc.
- Compulsory provision of first-aid box.

b) Loading of green-bricks in the kiln

- Avoid carrying green bricks on head. It is safe to lift small number of green bricks using specially designed "loader helmet".
- Use safety shoes while transporting/loading green-bricks to avoid foot injuries.
- Avoid dehydration by drinking water at regular intervals.

- Specially designed hand-carts or mechanized carts must be used for transporting of bricks.
- Wear helmet, shoes, eye gear, mask and hand-gloves while loading bricks in the kiln to avoid various potential physical and chemical hazards.

c) Firing of bricks

- Avoid dehydration by drinking plenty of water at regular intervals.
- Always wear masks to avoid chemical hazards from coal dust, smoke and ash dust.
- Wear safety shoes, hand-gloves and protective clothing to avoid health hazards due to high heat stress while working near firing zone.
- Minimize scattering of coal dust into the atmosphere while loading fuel into the storage bins placed at firing zone.
- Always wear protective mask while spreading ash dust over the brick-setting.
- Compulsory provision of first-aid box.

d) Unloading of bricks

- Wear safety gloves while unloading fired bricks to avoid thermal and physical hazards.
- Wear eye gear, safety shoes and mask to safeguard from ash dust and brick pieces while unloading.
- Instead of lifting bricks on top of head, use hand-driven or mechanized cart to take fired bricks out of the kiln.
- Beware of sudden collapse of brick setting while removing fired bricks out of the kiln.
- Compulsory provision of first-aid box.

Module 6: Soil or Clay

6.1 Components of Soil

6.1.1 Clay

Clay grains are always smaller than 2µm. They differ from other grains in their chemical composition and physical properties. Clay very often assumes a platy elongated shape. Their specific surface is infinitely greater than that of rougher round or angular particles.

Presence of a recommended amount of clay is a must in any brick making activity. It imparts the workability and strength in green bricks. It also helps in binding the coarser particles with each other during the vitrification process and contributes to achieve the fired brick strength.

6.1.2 Silt

The grain size of silt ranges from 0.002 mm to 0.063 mm. From the physical and chemical point of view the silt component is virtually identical to the sand component, the only difference being one of size. Silt gives soil the stability by increasing its internal friction. The films of water between the particles grant a certain degree of cohesion to silty soil.

Presence of silt is of utmost importance in brick making. It acts as a mediator between sand and clay by reducing the plasticity content and preventing high shrinkage cracks during drying process.

6.1.3 Sand

The grain size of sand is greater than 0.063 mm (63µm). However, for good quality brick making, sand particles coarser than 2 mm are not suitable. Sand is often made up of particles of free silica (SiO_2) or quartz (polymorphic transformation of silica).

Sand (lesser than 30%) is also essential in brick making, since it helps in opening up the fine-clay structure and making it workable for manual moulding.

6.2 Grain size distribution of soil and its technical importance

The grain size distribution in soil distribution refers to the relative proportion of sand, silt and clay, irrespective of chemical or mineralogical composition. They have a decisive quality influence depending on the selected firing technology. Sandy soils are called coarse-textured, and clay-rich soils are called fine-textured.

Workability and drying behaviour of the clay body are especially determined by the content of fractions of less than 2µm. Fine grained clays generally have high drying shrinkage rates.

6.2.1 Requirements of brick making

For making bricks, the raw-material should have a specific composition of different types of grain sizes. The distribution of grain size suitable for brick making are given below in the table.

Table 2: Distribution of grain size suitable for brick making[10]

S. No.	Elements/components	Grain size	Recommended value
1	Clay	< 0.002 mm (2μm)	20% - 35%
2	Silt	0.002 mm – 0.063 mm	25% - 45%
3	Sand	0.063 mm – 2 mm	20% - 45%

6.3 Colours of Soil

Soil colour is a result of various chemical processes acting on soil. These processes include the weathering of geological material, the chemistry of oxidation-reduction actions upon the various minerals of soil, especially iron (Fe_2O_3), calcium (CaO) and manganese (MnO_2), and the biochemistry of the decomposition of organic matter. Other aspects of earth science such as climate, physical geography, and geology all influence the rates and conditions under which these chemical reactions occur.

Soils tend to have distinct variations in color both horizontal and vertical layers.

- Iron (Fe_2O_3), gives - red colour to the soil,
- Calcium (CaO) gives - whitish colour and
- Manganese (MnO_2) give - black colour to the soil.

The characteristic colour of a soil depends on the amount of mineral present. For example, a soil with 6% iron can give a dark yellow colour instead of characteristic red if the calcium content is more than 2%.

6.4 Soil Test Methods

There are mainly two methods to determine the parameters of the soil for brick making:

- Practical field test (low cost methods)
- Complex laboratory analysis

[10] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

6.4.1 Field tests

There are a few basic field tests that an experienced brick maker should master. Although indicative, a good professional will always derive the correct conclusion out of the field-based tests. Few prevailing field tests are:

1. Smearing test

Take some loose soil from the possible brick making soil and put an appropriate amount of water into it in order to make a sticky paste.

After the soil is saturated with water, mix the soil paste by hand. Try to make a ball with this soil. Roll the moist ball in the hand enough so that the ball is dried out a little bit.

Pinch out a little bit of the soil with the thumb and the index finger and smear on the thumb by the index finger at one go. The smearing should be done as fine as possible.

During this process feel for any coarse particles. After the smearing, if the soil does not form a smooth and thin layer, then the soil is sandy. If the thin soil layer is shiny and evenly spread out over the thumb, then the soil is plastic in nature.

Figure 33: Smearing test[11]

Let the thumb dry out. After drying, if the soil layer falls off easily or can be removed then the soil is sandy or silty in nature with probably low plasticity. However, if the soil sticks to the thumb and index finger after drying then it is plastic in nature.

[11] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

2. Ball test

Take a handful of soil and put some water in it. Water should be enough to make the soil moist and make a dough by hand.

With the hand and fingers mix the soil and water thoroughly. After uniform mixing try to make a ball out of the soil.

Figure 34: Ball test[12]

Observe the smoothness of the surface of the ball. For plastic soils the surface will be shiny and uniform. For sandy soils the surface will be dull and rough. Also, with sandy soils it will be difficult to make a round shaped ball.

3. Wet ball test

Immediately after the ball is reasonably well formed, drop the ball from a height of at least 1 meter. Take care that the surface on which the ball is dropped is leveled and clean – preferably a concrete surface or a hard surface. It is advisable to not perform the test on a wet or loose surface. Observe the ball on the floor. If the ball retains its shape with little amount of deformation at the bottom only, then the soil is plastic and clayey in nature. However, if the ball flattens out upon hitting the floor, then the soil is sandy in nature.

4. Dry ball test

Repeat the tests by making balls and dry them under atmosphere or under a small open fire. Cool the balls and repeat the test. If the ball cracks into many pieces after contact with the

[12] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

floor, then the soil is sandy in nature. However, if the ball breaks into two to three pieces then the soil is clayey and plastic in nature.

5. Sedimentation test

This process is also known as 'Bottle Test' for determining the proportion of clay and sand particles in the soil.

- Fill one-fourth quantity of the glass beaker with the required soil.
- Add half teaspoonful of salt (to accelerate the deflocculation process) into the soil.
- Add water to about 50% above the soil level.
- Let the water percolates to the bottom. Then stir the soil and water mixture vigorously with a spoon for at least 2 minutes.

Figure 35: Sedimentation test[13]

- Pour the stirred slurry into a measuring cylinder.
- Add some more water in the beaker and drain off the entire soil into the measuring cylinder.
- Repeat the process of adding more water in the beaker until it is totally empty.
- While pouring the soil into the measuring cylinder ensure that no soil is sticking to the sides of the measuring cylinder to avoid distortion of proportions.
- Place the measuring cylinder on a level platform and allow it to stand for at least 12 hours or until the water becomes clear at the top.

As soon as the water is clear in the cylinder, there will be distinct granulation layers which represent the fineness/plasticity or coarseness/non-plasticity of the taken sample.

[13] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

- Firstly, measure the height of the bottom most visible layer which is classified as sand and calculate the percentage of sand.
- Secondly measure the topmost visible layer which is classified as clay and calculate the percentage of clay. The layers between the top (clay) and bottom (sand) represents the silt content of the soil sample.

6. Soil shape test

Take some loose soil from the possible brick making soil and put an appropriate amount of water into it in order to make a smooth soil ball with one hand only. If after repeated attempts a round ball cannot be formed, then the soil is sandy. During this process, if water is released out of the ball then the soil is silty/sandy. However, if after a few attempts, a good, smooth and round ball is formed, then the soil is semi plastic to plastic in nature.

Figure 36: Soil shape test[14]

Wash hands with water. If washing is easy, then the soil is silty/sandy with low clay content. However, if after repeated washing, soil is sticking into the palms then the soil is clayey in nature. After washing, if the soil still sticks to the corners of the finger nails then the soil has probably a very high clay content.

7. Lime test

Lime is one of the most dangerous minerals for brick making. The presence of lime needs to be detected during the initial soil testing stage only. It does not affect the green brick quality. However, after firing if the lime nodules containing fired bricks are kept in the open, it absorbs water from the atmosphere and expands, thereby bursting the solid brick.

[14] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

The following method describes a simple field test of determining whether the soil contains lime or not.

Figure 37: Lime test[15]

Take a lump of soil from the required area or depth from the selected brick making soil. Look for soil lumps which have white spots in them.

Take a representative soil sample. Ground the soil into a loose form by hand. Place a small amount of soil in the Petri dish without pouring any amount of water in it.

Take a small amount of acid (e.g. toilet cleaner) by a tube/pipe and put it over the soil sample in the Petri dish. Observe the reaction it creates. Lime is present if the reaction causes effervescent (type of melting) or bubbling action.

If the soil does not show any effervescent, repeat the test with a separate soil sample.

6.5 Points to remember

1. Workability and drying behaviour of the clay body are especially determined by the content of fractions of less than 2µm. Fine grained clays generally have high drying shrinkage rates.
2. The characteristic colour of a soil depends on the amount of mineral present.
3. An experienced brick maker should master all the field tests for soil-mix such as smearing test, ball test, sedimentation test and lime test.

[15] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

Module 7: Soil Mix Preparation (Pugging)

7.1 Excavation of soil and storage

The main sources of soil for brick making are agriculture fields, and silts from rivers, ponds, and lakes, etc. The fertile topsoil of agriculture fields is an important resource and its indiscriminate use will have adverse impact on the agriculture productivity in future, especially in the regions where depth of fertile soil is less. With expected increase in the brick demand, the requirement of raw material (soil) will also increase. Therefore, efforts should be made to utilize alternate sources of raw materials and reduce the dependency on agriculture topsoil. Some of the potential options can be:

- Utilizing the alternate sources of soil such as silt from rivers, lakes and ponds.
- Utilizing waste as raw material (mixing it in some proportion with clay) such as flyash, fuel-ash from industrial boilers, etc.
- Producing hollow and perforated bricks which consumes less clay.

Storage of soil: There should be adequate storage of soil depending upon the production capacity of the kiln. The storage of soil is important/beneficial in many ways:

- It helps in balancing-out the fluctuations in supply of soil which can happen because of various reasons such as bad weather, unavailability of labour, transport strike, etc. The storage of soil ensures un-interrupted supply of raw material for brick production.
- In case of two or more different types of soil are received, it is necessary to thoroughly cross-mix the soils to get a consistent composition.
- Storage also helps in 'opening up' or 'ageing' of soil. In the course of the opening–up process, the water loosens, surrounds and penetrates into the soil lump enabling it to soften and break into smaller pieces. At the same time, the water enveloping the particles ensures adequate cohesion and mobility i.e. the actual source of plasticity/ductility.
- Clay Weathering: Weathering means letting weather, i.e. natural agencies like sun, wind, rain, frost, etc., act on soil / clay stored / kept in the open. It improves the workability and homogeneity of the material. Disintegration of larger particles is caused by alternate expansion and contraction due to action of solar heat and cold, which increases the plasticity of the material. Air helps in oxidation / decomposition of certain minerals like iron pyrites. Rain removes soluble salts by washing. Ageing allows slow penetration of water between clay particles and results into uniform water distribution. Souring involves bacterial action. Bacteria present in the clay break down organic matter releasing amino acids which flocculate mineral particles increasing strength of the body.

7.2 Pugging of raw materials

7.2.1 Importance of Pugging

Pugging of raw materials ensures homogeneity of soil with various additives. Before the pugging process care should be taken to remove systematically all foreign particles e.g. stones, brick bats, plastic, wood etc., presence of which will cause cracks in the green bricks during drying and firing process, and also reduces the strength of the fired bricks.

Figure 38: Defect in brick making[16]

7.2.2 Methods of pugging

Both manual and mechanized pugging are generally practiced for preparing the soil-mix for moulding.

- In manual pugging process, the soil is dug out and after some crushing, is spread out on the ground (50 to 100 mm deep). The soil is watered, turned over with hoes or spades, and left to soak overnight. This soaking process, known as "tempering", allows chemical and physical changes to take place in the clay, thus improving its moulding characteristics. The mixture of soil and water is then pugged manually by foot. The workers puddle the clay by treading in it, mixing and working the water in. The total volume of clay must be trodden systematically. The mix should not be too dry as it will be difficult to move the feet up and down repeatedly. On the other hand, if it is too wet, it will not be suitable for moulding.

[16] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

- In mechanized pugging, the moist soil is usually dug out from the storage and fed directly into the pug mill while the required quantity of water to achieve the needed consistency is added manually during the pugging process.

To achieve the best quality of green bricks, 'Mechanized Pugging' is required. The advantages of mechanized pugging are:

- Soil is properly mixed.
- Good homogeneity of the soil-mix can be achieved.
- Supports uniformity in shape and size of green bricks.
- Increases the green brick strength.
- Reduces considerable labour drudgery thereby increase in productivity

7.2.3 Pug Mill - An introduction to pugmill

Pugmill is a machine used for uniform mixing of soil for green brick making. Two types of pugmill are available:

1. Horizontal
2. Vertical

A pug mill consists of a barrel (cylindrical trough) which is incorporated with the replaceable blades mounted on the main shaft. The main shaft rotates with the help of a worm gear which is attached to it at the top. The shaft speed is maintained between 7 to 9 revolutions per minute. The worm gear is coupled with the gearbox which is then directly connected to the diesel engine or electrical motors by means of belt pulley system.

Figure 39: Pugmill

The shaft when rotates along with the blades, crushes and mixes the soil lump inside the barrel. Below the barrel, openings are provided through which the pugged soil is squeezed out. The output is about 15-20 tonne of soil per day, with 8 operating hours. However, the output of pugged soil can be fine-tuned by increasing or decreasing the speed of the shaft or by varying the number of openings at the bottom of the Pugmill.

Now-a-days, a variety of mixers are being used for pugging of soil in the brick fields – ranging from small single shafts mixers to advanced double shaft mixers.

7.2.4 Pugging process

The pugging process varies from place to place and there are several practices followed for pugging of soil. I one of the proper practices for pugging, two or more trenches are dug near to the Pugmill location.

The stored soil is transported and unloaded into the trench and then leveled manually. During the leveling process the bigger lumps of soil are manually crushed into smaller size and the foreign materials such as stone, grass roots are also removed manually. In case internal fuel (generally saw dust or coal dust) is being used, then a quantified amount of internal fuel is sprinkled on the levelled soil and mixed manually. The water is then sprinkled on top of it. This process is repeated for each lot/batch of soil unloaded into the trench. The soil in the trench is usually aged for 48 hours. This 'well aged soil' is fed into the Pugmill for mixing. Aged soil from different trench can be used alternately for pugging.

Figure 40: Soil preparation tank[17]

7.3 Clay Preparation Equipment

Clay Preparation Machinery:

Box Feeder: It is a type of surge bin consisting of a rectangular chamber of one or more compartments fitted with an intermittently moving slat-conveyor or rubber belt base usually operated by a pawl and ratchet and a rotating digger for constant discharge. Speed of the moving base can be adjusted.

Figure 41: Box feeder

Belt Conveyor: It is an endless moving belt running flat or troughed on the understructure. Belts are of rubber, plastic, textile, wire or steel.

[17] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

Figure 42: Belt conveyor

Smooth Roller: It has a pair of smooth rollers mounted on horizontal spindles carried in bearing on a heavy cast iron or steel frame. Soil / clay particles are broken down between the rollers by pressure. The rolls move in opposite directions and sometimes at different speeds to increase shear.

Double Roll Crusher: It is constructed of two rolls which are checkered. Crushing operation is performed by pressure and shear between the rolls.

Double Shaft Mixer: It has two horizontal shafts fitted with flat blades inclined in the direction of material flow running in a double trough. The adjustable blades lift and cascade the material over itself giving the mixing action and propel it along to the discharge end.

Double Shaft Mixer–Cleaner: Its construction is very similar to that of the double shaft mixer except that it has a movable screen fitted at the end of the mixing trough. Clay discharged by the mixer blades passes through the screen which retains the impurities like leaves, roots, shells, lime nodules, gravel, etc. The screen is intermittently moved laterally and cleaned.

Impactor: It consists of one or two horizontal cylinders fitted with fixed breaker bars. The bars hit the clay, breaking it up and throwing it against plates, bars or other elements or against each other breaking it further down.

Pan Mill: In a dry pan mill, the pan rotates and axes of the mullers remain stationery whereas in a wet pan mill, the pan is stationary and the mullers rotate about their axis in the pan. The perforations in the base are usually in the form of slots. Comminution and mixing is by weight of mullers and by shearing.

7.4 Issues related to quality of pugging

How to check proper mixing of pugged soil?

Take a handful of pugged soil and check for the presence of soil lumps within it. If soil lumps are present, then either the soil has not been aged properly or the pugging process is made too fast.

Consequences of improper mixing

Improper mixing not only causes crack in the green bricks during drying and firing process (major cause of breakage) but also reduces the strength of the fired bricks.

How to check the correct proportion of water in pugged soil?

Take a handful of pugged soil and form a ball by hand of roughly 5 cm in diameter. Place the wet ball on a hard and even surface. If the amount of water is correct the ball will remain in shape. However, if the water content is high then the ball sags and deforms.

Consequences of insufficient water

Less quantity of water in the soil will result in a dry mix and most likely result in the presence of dry soil lumps. Too much dry soil will exert an excessive pressure on the shaft and its blades which might even result in broken blades. Moulders will reject a too densely pugged soil with less water due to difficult mouldability.

Consequences of excessive water

There are two main consequences of excessive water addition, namely:

- It reduces the friction between the soil layer and the inside surface of the metal barrel due to a thin film of water present. This results in slipping of the entire soil lump inside the barrel and hence no output of mixed soil is generated.
- It results in a too wet soil mass that cannot be properly moulded. Excessive amount of water in a de-moulded brick also results in deformation due to sagging.

7.5 Points to remember

1. The soil in the trench must be aged for at least 48 hours. This 'well aged soil' is fed into the Pugmill for mixing.
2. Remove all foreign particles e.g. stones, brick bats, plastic, wood etc., presence of which will cause cracks in the green bricks during drying and firing process.

3. If soil lumps are present, then either the soil has not been aged properly or the pugging process is made too fast.
4. Improper mixing not only causes crack in the green bricks during drying and firing process but also reduces the strength of the fired bricks.
5. Insufficient water in the soil will result in a dry mix and most likely result in the presence of dry soil lumps.
6. Excessive amount of water in a de-moulded brick also results in deformation due to sagging.

Module 8: Moulding

8.1 Moulding Process

Moulding is the process by which the prepared soil is formed into the shape of a brick. At various places 'moulding' process is also termed as 'shaping' process. There are two methods of moulding namely –

- Manual or Hand moulding
- Mechanized moulding (e.g. soft mud moulding, moulding through extrusion, etc.)

It has often been thought that machine-made bricks are of better quality than hand-made bricks. However, if hand-moulding is carried out with care, it can also result in good quality bricks. Furthermore, in most of the developing countries where manual labour is relatively cheaper, hand-made production is economically more competitive than the machine-made bricks.

The choice of moulding or shaping method should take into consideration the following – capital cost and expected life of equipment; maintenance and spares service; availability and cost of fuel (including reliability of electricity supply); scale of production in relation to raw materials supply; and market demand at time of installation and throughout the planned life of the installation.

8.2 Manual Moulding

Manual moulding of bricks is generally done by workers sitting in squatting position. In an improved system manual moulding can be done in standing position where bricks are moulded and demoulded on a moulding table. This arrangement requires an assistant moulder to supply raw material at the table and to carry moulded bricks from the table to the drying area. Central Building Research Institute (CBRI) has designed and developed a special "hand-moulding table" that enables production of bricks of accurate shape and size to be moulded by any brick moulder of average skill.

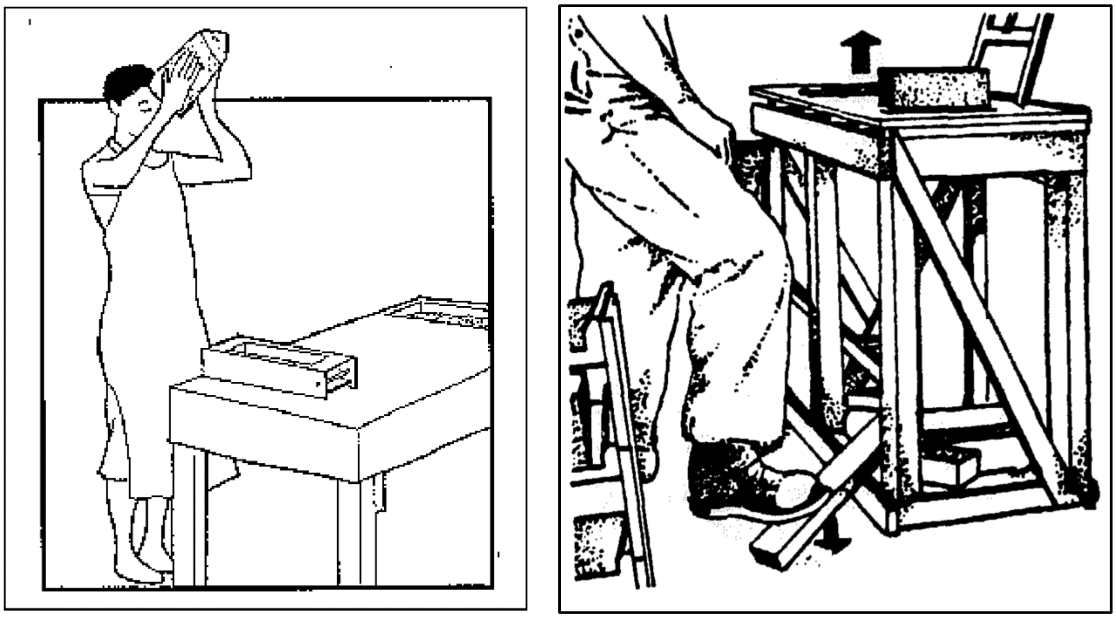


Figure 43 (a[18] & b[19]): Manual moulding on moulding table

8.2.1 Accessories/equipment required for manual moulding

Manual moulding is a tedious task, which requires skill and some special equipment to execute. Moulding accessories can be categorized according to the moulding process:

Spade: This is used to dig the soil and prepare moulding area.

Wheelbarrow: A simple cart made of either wood or metal for carrying the prepared soil up to the moulding area.

Levelling Ring: It is a circular metal ring which is used to level the ground.

Broom: This is used to clean the moulding area.

Mould box: This is used for moulding/shaping of green brick.

Bow Cutter/Metal strip: The bow cutter is a simple instrument used to cut the excessive soil from the top of the mould box. After the wedge of soil is thrown into the mould, the excess soil over the mould needs to be removed and the top surface should be smoothened. The bow cutter cuts and smoothens simultaneously as it moves along the top of the mould.

Cleaning Tool: If the wedge is not covered properly with releasing agent, or if it was not thrown correctly into the mould, the soil will stick to the sides of the mould. It will then be necessary to

[18] Image Source: Village-Level Brickmaking, GATE-1993

[19] Image Source: Small-Scale Brickmaking, ILO-1984

clean the stuck soil from the mould with a cleaning tool after the green brick is removed. Apart from this after repeated mouldings, soft soil tends to fill the sharp corners of the mould and the depressions of the frog. This imparts a rough finish to the green brick.

To take care of this and ensure a smooth and sharp finish to the green brick a cleaning tool is required by which the stuck soil is cleaned off from the mould. A simple sharp blade is required to take out soil from the depressions. A flat blade is required to clean the soil sticking to the mould sides.

Generally, by experience, after approximately 10–15 mouldings the mould needs to be cleaned. In case soil has hardened and it is not possible to clean with the cleaning tools, the mould should be dipped in water and cleaned thoroughly. After each such cleaning, the mould is sprinkled with releasing agent for further fresh mouldings.

Water Bucket: Wooden mould boxes are dipped into the water bucket after the end of moulding to prevent cracking of the wood.


Spade


Wheelbarrow


Broom


Levelling Ring


Mould box


Bow Cutter


Cleaning Tool


Water Bucket

Figure 44: Instruments required for moulding[20]

8.2.2 Mould box

It is the rectangular wooden box with which the brick is formed. In some places metal moulds made of mild steel (MS) or aluminium sheets are also used. Usually the mould is reinforced on the outer surface of the corners by metal angles. Sometimes the inner surface of the mould is lined with a thin metal sheet to minimize wear and tear. The wooded surface of the mould is extended beyond the rectangular section to provide better handling of the mould box. As the freshly made green brick shrinks during drying and firing, the mould size should be bigger compared to the fired brick size.

Figure 45: Types of moulds: Wooden Mould and metallic mould

[20] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

SHRINKAGE RATES AND MOULD SIZES

Fired brick size: 230 mm x 110 mm x 65 mm

Shrinkage rate	Interior mould dimensions		
	Length	Width	Height
5%	242 mm	116 mm	68.5 mm
6%	245 mm	117 mm	69 mm
7%	247 mm	118 mm	70 mm
8%	250 mm	120 mm	70.5 mm
9%	253 mm	121 mm	71.5 mm
10%	256 mm	122 mm	72 mm

Figure 46: Shrinkage rates and mould sizes[21]

To achieve the 230 x 110 x 65 mm fired brick size the mould must be designed as follows:

Assuming shrinkage rate of the soil as 10%
and final length of fired brick (L2) is 230 mm
Length of fired brick (L2) =
Length of mould (L1) - 10% of L1
⇒ 230 = L1 - 0.1L1
⇒ L1 = 256 mm (230/0.9 = 256)
Thus length of the brick mould = 256 mm

Assuming shrinkage rate of the soil as 10%
and final width of fired brick (W2) is 110 mm
Width of fired brick (W2) =
Width of mould (W1) - 10% of W1
⇒ 110 = W1 - 0.1W1
⇒ W1 = 122 mm
Thus width of the brick mould = 122 mm

Assuming shrinkage rate of the soil as 10%
and final height of fired brick (H2) is 65 mm
Height of fired brick (H2) =
Height of mould (H1) – 10% of H1
⇒ 65 = H1 – 0.1H1
⇒ H1= 72
Thus height of the brick mould = 72 mm

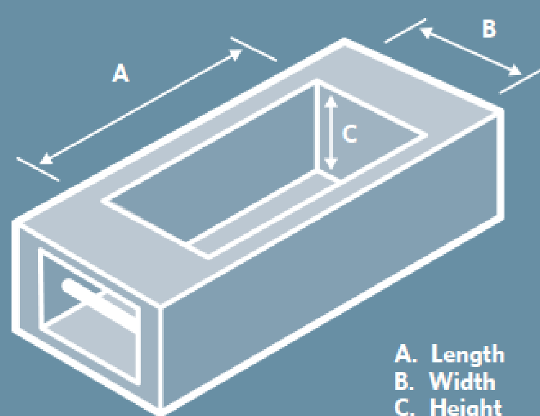


Figure 47: Sample calculation for sizing of mould box[22]

[21] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

[22] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

The Frog

The frog in all types of moulds is made from wood. It is used to form a cavity or a trademark of a brick producer on the longer surface of the brick. It also allows the brick to dry faster and gives the brick a form, which improves its adherence to cement mortar during construction.

Releasing Agent

The releasing agent is a fine, non-plastic, dry material which prevents the soft soil from sticking to the sides of the mould and also helps the green brick to slide easily out of the mould.

8.2.3 Manual moulding process

The various steps involved in manual or hand moulding of bricks are described below:

Step 1: Moulding area preparation

Moulding area is the place where the green bricks are shaped and de-moulded. Before the start of moulding, considerable time and effort needs to be spent for preparing the ground for de-moulding.

Figure 48: Preparation of moulding area[23]

The grass or other vegetation should be removed, and the ground should be leveled as flat as possible with the help of a spade. The ground should be cleaned so that there are no other foreign particles such as roots and stones on it.

Step 2: Transportation of prepared soil

[23] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

The pugged soil is transported to the moulding yard generally by wheel barrow. The soil is transported and unloaded at the different areas of the moulding yard as per the convenience of the moulders.

Step3: Soil maturation

The pugged soil is stored in individual moulders working yard in such a way that it provides an additional 24 hours ageing time. The soil is cut in a longitudinal manner roughly 80 cm width and 40-50 cm height and covered with a plastic. Once moulding work starts, moulder uncovers the plastic as little as possible to enable access to the soil for preparing the dough.

Step 4: Dough preparation

Dough is a lump of pugged soil which is rolled over the releasing agent to decrease the adhesiveness between the dough and the mould box. The dough preparation requires skill in order to cut the correct amount of soil from the stored pile. Too much cutting of soil implies unnecessary waste of energy as well as wastage of processed soil. Too little soil implies adding soil in the mould with the risk of creating a texture.

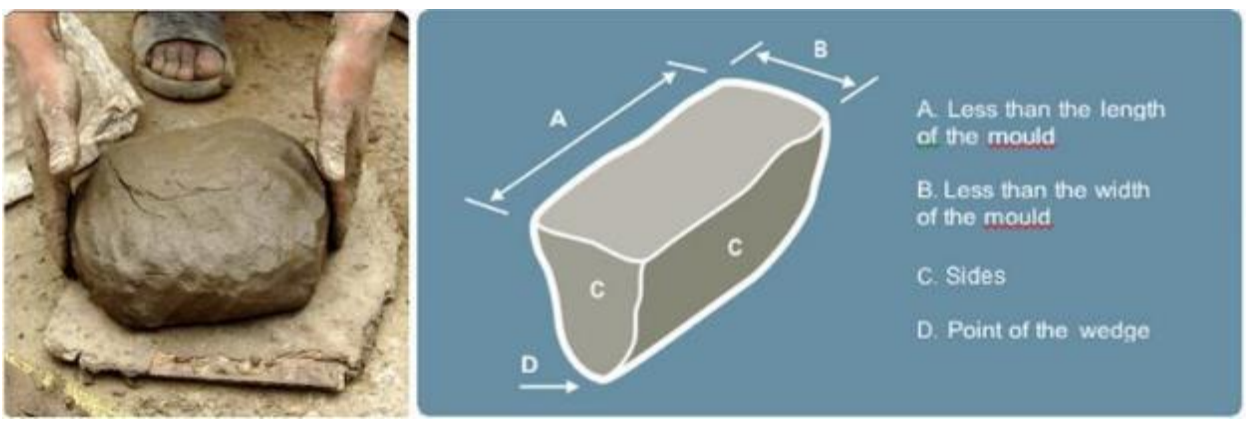


Figure 49: Shape of clay wedge[24]

Step 5: Forming of wedge

The wedge is a triangular shape of soil having a length slightly shorter than the mould length. When the wedge has been coated evenly with the releasing agent, it is thrown into the mould with force.

Step 6: Throwing of wedge into the mould box

After the preparation of the wedge it is thrown into the mould box. To generate a natural force, it is usually thrown from approximately a height of 30-40 cm above the mould. The art of good

[24] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

moulding is to get the correct angle and force of throwing the wedge into the mould. The shape of the wedge is very important. When thrown, it should enter the mould and strike the bottom of the mould first without touching the sides. To do this, the length and the width of the throwing wedge should be slightly less than the length and width of the mould. When the wedge is made and thrown correctly, the soil will spread out along the bottom of the mould first, before filling the sides of the mould. The releasing agent prevents the clay from sticking to any part of the mould and as a result allows the green brick to easily slide out of the mould. When the wedge is poorly made or thrown, the brick will not slide out of the mould easily. This happens because the mould has cut off the releasing agent from the side of the wedge causing the exposed soil to stick to the mould.

Figure 50: Throwing of wedge into the box[25]

Step 7: Compaction of dough

After the wedge is thrown into the mould box with force, it is compacted by hand. Care should be taken not to produce excessive pressure at a particular region. This makes the brick irregular in shape.

Step 8: Cutting of excessive dough and levelling

Once the dough is compacted the excess soil on the top of the mould must be removed and cut by bow cutter. Care should be taken that the cutting is straight and in a horizontal line. Excessive pressure should not be used during the cutting since this will cut the dough in an irregular and concave manner thereby reducing the thickness of the brick.

[25] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

Step 9: Releasing and levelling

After the soil is properly compacted in the mould, the green brick is de-moulded in the moulding yard. For de-moulding, the mould containing the green brick is inverted on the ground and the mould box is pulled upward gently. Rough or irregular pulling of mould box destroys and bends the corner of the green brick. After the brick is de-moulded onto the ground, it is pressed gently on the top, by the bottom of the mould. This ensures that all corners are straightened, and the edges are sharp.

Step 10: Cleaning of mould

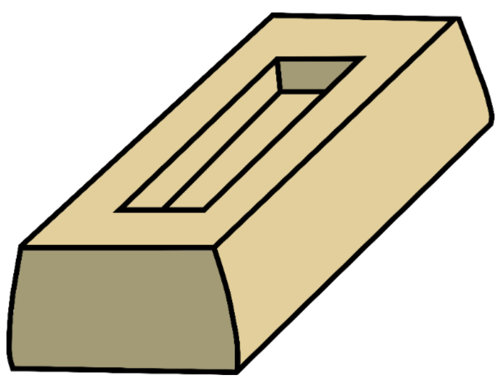
Moulds should be cleaned after forming of roughly 10 to 15 bricks. If the mould is not cleaned regularly, the finish of the green bricks decreases.

Once moulding work is completed the wooden box must be dipped into water and left overnight until the next moulding. This ensures that no cracks will develop, the box keep its correct shape and increases its life span.

8.2.4 Hand-moulding defects and possible remedial measures

The following is a list of defects that might occur during hand-moulding of bricks, the possible reasons of the faults, and some suggestions to correct them:

1. **The brick is mis-shapen with the base larger than the top.**



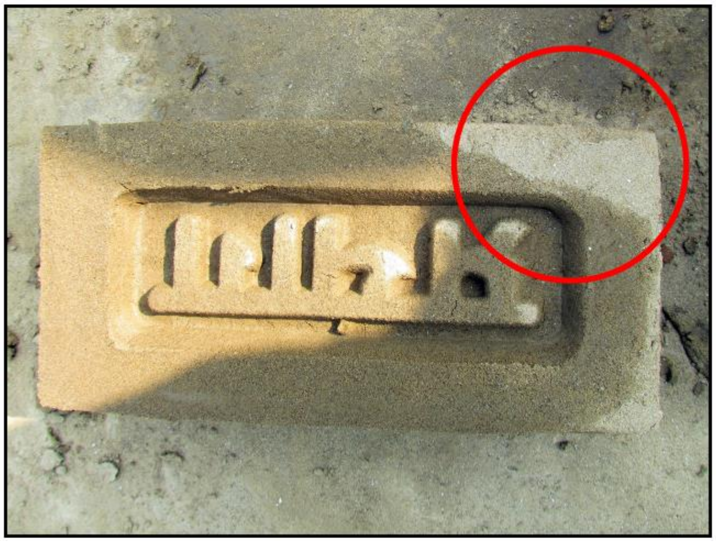
Reasons:

- The prepared soil-mixture used to make the brick was too soft (because of excess water in soil-mixture), so the bottom spread as a result of pressure from the material above.

Suggestions:

- Use appropriate amount of water when preparing the soil-mixture.

2. **The brick does not have well-made corners or missing corners at the top.**



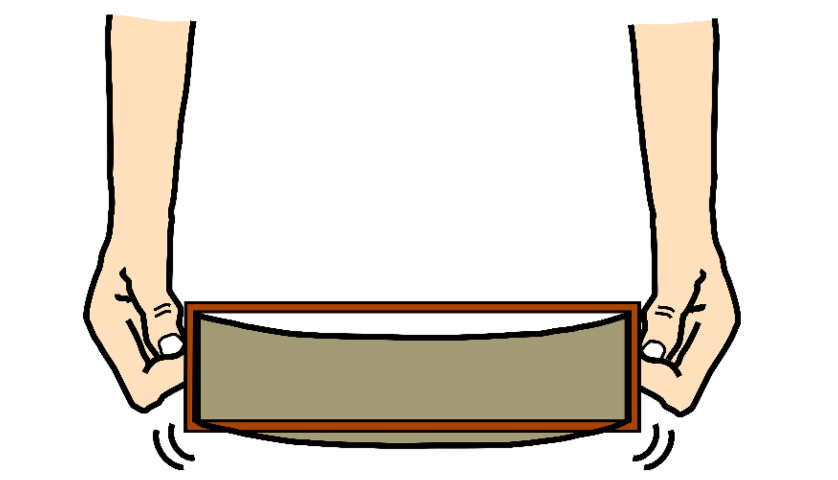
Reasons:

- The moulder failed to press enough soil-mixture into the mould box to fill it completely.
- The wedge was not thrown into the mould with enough force to fill the corners of themould completely.
- The moulder did not remove the sand/soil lump stick at the corners of the mould.

Suggestions:

- Throw the wedge into the mould with more force and compact it uniformly into the mould box to fill the corners.
- After throwing the wedge into the mould box, knock the mould on the floor to ensure that the soil fill the mould completely.
- The mould needs to be cleaned regularly after 10 – 15 mouldings by scraping off the excess sand/soil stick at the inside surface.

3. Brick sticks to the mould making it difficult to remove from the mould.



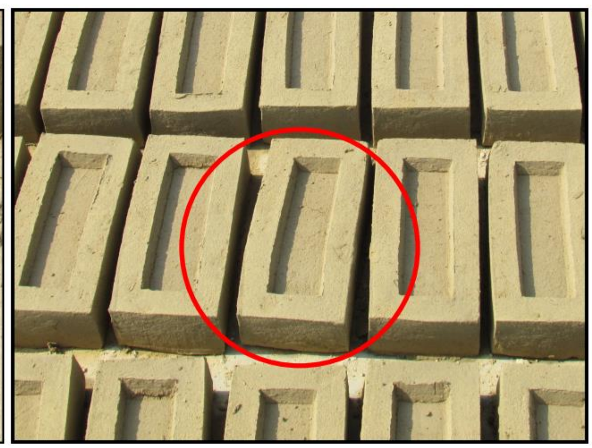
Reasons:

- The mould box was not well coated with the sand and the soil-mixture stuck to the inside surface of the box.
- The proportion of clay was too high in the soil-mixture resulting in the mixture sticking to the mould surface.
- Too much water was used to prepare the soil-mixture.
- The wedge was thrown with too much force.
- The wedge was not thrown well and a part of it was cut off when it entered the mould. The exposed clay stuck to the side of the mould.

Suggestions:

- Sprinkle the sand uniformly on the all the surfaces of the mould box.
- Increase the amount of soil containing high sand content in the soil-mixture.
- Use appropriate amount of water in preparing the soil-mixture.
- Use a little less force when throwing the wedge into the mould.
- Check that the wedge can enter the mould without touching the sides of the mould and then throw it correctly into the mould.

4. The brick is misshapen with distorted edges.



Reasons:

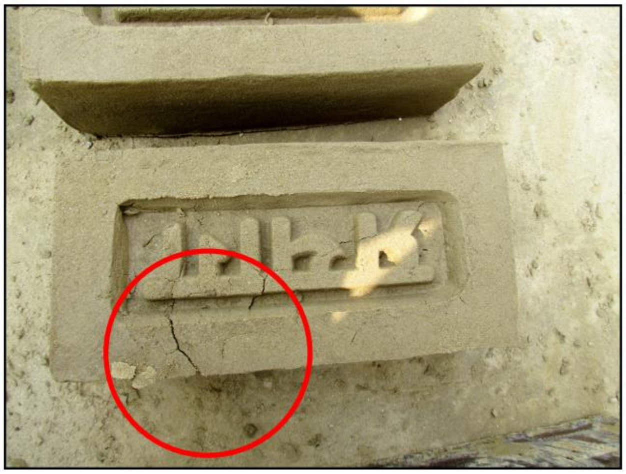
- The moulder failed to sprinkle the inside of the mould uniformly with the sand.
- While de-moulding, the mould box was not lifted properly.
- The proportion of sand was too high in the soil-mixture resulting in the distortion of edges.

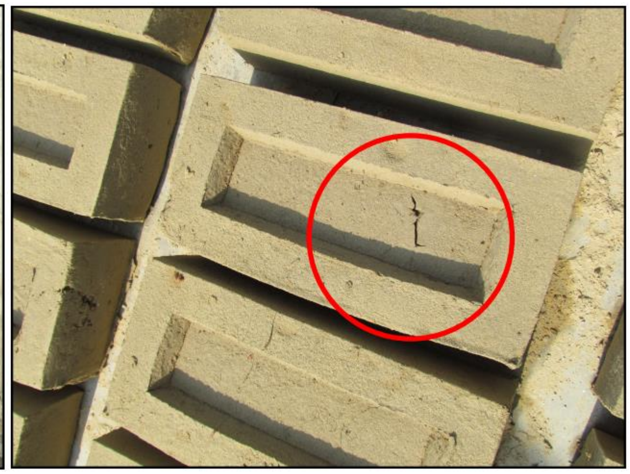
Suggestions:

- Sprinkle the sand uniformly on the all the surfaces of the mould box.
- While releasing the green brick ensure that the mould box is lifted straight upwards.

- Increase the amount of soil containing high clay content in the soil-mixture.

5. **The brick has small cracks.**





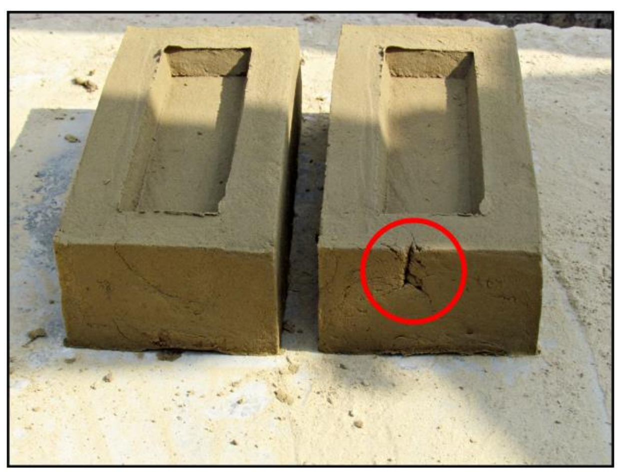
Reasons:

- The soil-mixture is contaminated with impurities like pebbles, brick pieces, grass, plastic, paper etc.
- After de-moulding the bricks were placed on uneven or bumpy ground.

Suggestions:

- Always check the soil-mixture for any impurities in it.
- Level the moulding ground evenly using metal ring after sprinkling some water to it.

6. **The brick has deep gap on side or top surfaces.**



Reasons:

- A joint is formed at one end of the wedge while rolling the soil lump to form the wedge. If the moulder forms the wedge in such a way that the while throwing the wedge into the mould box the joint goes at the bottom or side surfaces of the mould box, a wide crack an form at the sides or top of the moulded brick.

Suggestions:

- Form the soil wedge in such a way that the joint comes at the top of the wedge. Consequently, when moulder throws the wedge into the mould box the joint comes at the top which can be removed while scraping the excess soil from the top of the box.

7. The brick has long lamination cracks or pieces of soil fallen off the sides of the brick.

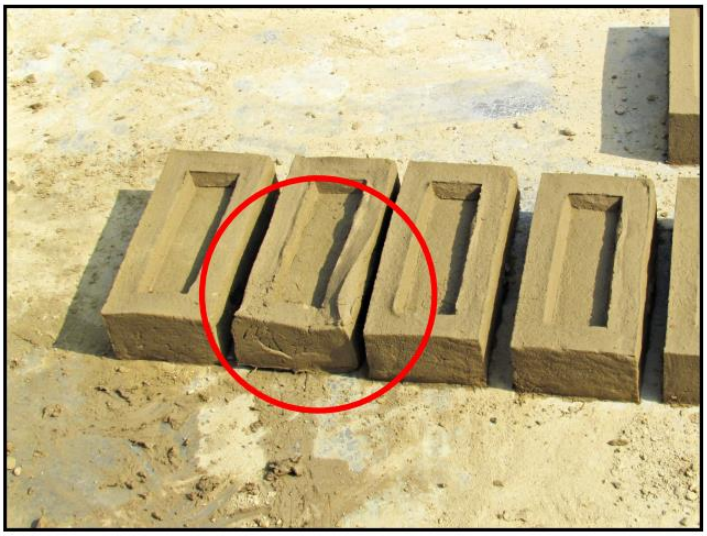
Reasons:

- This is caused when a piece of soil-mixture with sand covering its surface is inadvertently mixed with fresh soil-mixture to prepare the wedge. The film of sand separates the soil on either side of it so the brick tends to split at this point during drying or firing.

Suggestions:

- Ensure that the wedge's soil is homogeneous before throwing it into the mould box.

8. The brick has multiple distortions.



Reasons:

- The soil-mixture is too soft because too much water was mixed during the mixture preparation stage.
- The clay proportion in the soil-mixture is too high.

Suggestions:

- Use less water during soil-mixture preparation.
- Increase the amount of soil containing high sand content in the soil-mixture and experiment with different proportions.

8.3 Mechanical Moulding

Mechanical moulding of bricks is mainly done through soft mud moulding machines or extruders. A short introduction of these mechanized processes is discussed below:

8.3.1 Moulding through soft mud moulding machine

Soft alluvial clays, such as those suitable for hand-moulding, may be processed by the soft-mud process. One of the smallest machines available produces approximately 14,000 bricks per day. This particular machine, originally made in the United Kingdom as the Berry Machine, was bought up by another company which is now producing it in the Netherlands. It has a horizontal pugmill followed by a set of cams which force moist clay through the side of the containing barrel into a quartet of iron-clad wooden moulds. To prevent clay from sticking, moulds are sanded. This can be done by hand. The whole process is fairly labour-intensive. The pugmill section alone could be used to prepare clays for hand-moulding.

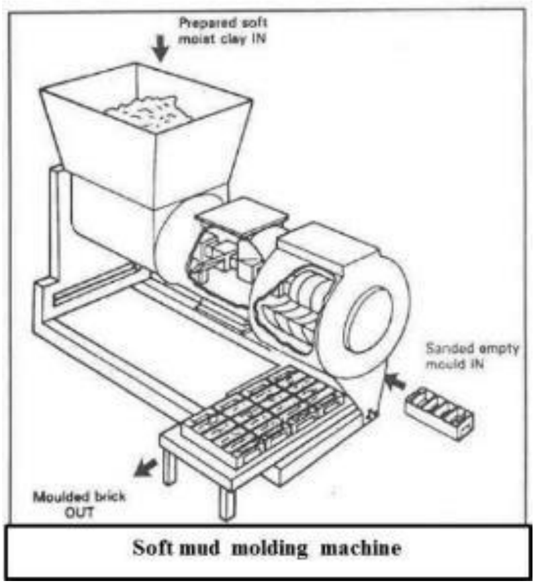


Figure 51: Schematic of a soft mud moulding machine

8.3.2 Moulding through Extruder:

In soft-extrusion process, a body of maximum plasticity is used, the moisture content being 20 to 30 per cent. The body is extruded with the help of a pug mill through a die into a column of plastic clay. The die forms the outer dimensions of the product. The column is then cut into bricks by taut wires of a cutting machine. Stiff-extrusion is carried out with a body containing between 12 and 20 per cent moisture.

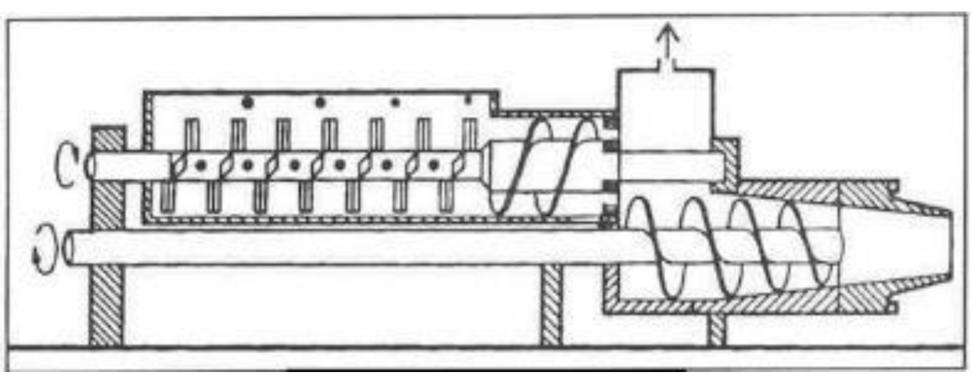


Figure 52: A de-airing extruder

Components of De-airing Extruder:

De-airing extruder is among the most commonly used shaping machine in the heavy clay industry today. Its individual components are described below in brief.

- **Twin-shaft Mixer:** It consists of an open U-shaped trough in which two shafts fitted with several paddles rotate in opposite directions. Limited amount of water (generally less than 2%) and/ or internal fuel can be added here. The paddles knead the raw-mix intensely and force it to move through a perforated plate fitted at the end of the mixer into vacuum chamber.

- **Vacuum Chamber:** The prepared and mixed clay enters the vacuum chamber by passing through the perforated plate. A cutter is fitted after the perforated plate to cut the noodles into small cylinders or the holes are made divergent to break open the surface of the emerging clay. These operations increase the specific surface (surface per unit mass) of the material to aid effective vacuum application. A vacuum pump fitted externally to the chamber creates the vacuum. At least 90% vacuum is maintained for high de-airing efficiency. De-airing removes the entrapped air in the clay body making it stiffer, homogeneous and increasing its yield point. Increase in yield point makes the extruded material withstand the tensile loads during subsequent cutting and handling better.

- **Auger:** Auger is functionally divided into 3 zones - charging zone, compression zone and work zone.

  The de-aired material is first taken-up by the charging zone with the help of paddles or rollers, which prevent the material from sticking to the lining of the vacuum chamber. Length of the charging zone is normally one third of that of the auger. Reliable functioning of the paddles or rollers is extremely important for high and dependable throughput. To increase the capacity of the charging zone, its pitch is kept about 50 % greater and diameter about 10 to 20 % larger than the subsequent zones (which are confined within a closed cylinder).

  At the start of the closed cylinder, the compression zone begins. The loose body is progressively compressed in this zone and air entrapped in it is sucked back into the vacuum chamber. Speed of the body's forward movement decreases with increase in its compression. When the auger channel gets completely filled with the body, the work zone begins.

  Fully compacted clay is pushed forward in the work zone.

- **Pressure Head:** It is the connecting piece between the auger and the die. At its entry end, its cross section is circular while at its exit end, it is rectangular. The pressure head converts the rotating flow of clay into an axially advancing one and compensates for differences in output between the outer rim of the auger and its hub. It feeds clay uniformly into the die.

- **Die:** Shaping is completed in the die. The function of the die is to ensure –
  i. Constant velocity of paste across its entire cross section,
  ii. Smooth and faultless column surface and
  iii. Desired dimensions of the column.

  For producing perforations and hollows in the extruded column, cores of desired shapes and sizes are introduced inside the die (around which the paste flows) which is fitted to die in the desired configuration with the help of braces. It is very important to prevent deflection/ wear of the cores to maintain dimensional accuracy of the extrudate.

8.4 Points to remember

1. The moulding area must be levelled carefully using metallic ring. After every four to five de-mouldings level the area again to produce good quality green-bricks.
2. Keep the pile of clay-mixture on a plastic sheet (instead of putting directly on the ground) and also cover it from all sides with plastic sheet to prevent early drying.
3. Remove any hard lumps of soil, roots, dead vegetation, stones, limestone nodules etc. from the pile of clay-mixture.
4. Ensure that the mould box is sprinkled with releasing agent (sand) uniformly at its inside surface.
5. When the clay clot is thrown it should enter the mould and strike the bottom of the mould first without touching the sides. This ensures swift de-moulding of bricks.
6. While throwing the clot in the mould, always ensure that the joint formed in the clot comes at the top so that it can be removed while scrapping the excess soil from the top of the mould.
7. While de-moulding, lift the mould straight upwards and gently tap the top of the de-moulded brick by the mould's bottom to straighten its corners and to keep the edges sharp.
8. Check the mould regularly for any lump of clay sticking inside it especially, at the corners. After approximately 10–15 mouldings the mould needs to be cleaned for any lump of clay stick inside the mould box.
9. After dusting the inside of the mould with sand, knock the mould on the ground to shake-off any loose sand from the internal surfaces of the mould.
10. Do not use too much water to clean the mould as the excess water is absorbed by the clot making the clay too soft, resulting in the production of disfigured green-bricks.

Module 9: Drying

9.1 Importance of Drying

It is very important to dry bricks before firing process, because:

- In order to obtain the high strength and water-resistant properties of ceramic materials, the bricks must be burnt in a kiln to a high temperature. The bricks are piled up one on top of another, approximately 20 bricks high. Thus, the bricks at the bottom must be strong enough to carry the weight of those above. The freshly moulded green brick may not be able to bear the weight of even one more brick without showing some distortion. When a certain amount of moisture has dried out, and the brick clay is approximately at the critical moisture content, the bricks become "leather-hard". They are then sufficiently rigid and strong for handling and stacking.
- During the drying process, the bricks shrink. It is preferable that this shrinkage takes place before bricks are piled high for burning, lest the shrinkage causes the whole setting of bricks to become unstable, or to collapse within the kiln.
- Even after the "leather-hard" condition has been reached, there is much more water to be dried out of the bricks. If this is not done, the water in the bricks nearest to the heat source will evaporate and condense on cold bricks away from the heat source. These bricks will then absorb the water and get spoilt.
- Another risk is that water remaining in green bricks may turn to steam if the heat rises too quickly. This steam will build up pressure within the bricks, causing them to rupture. To minimise the risk, bricks should be as dry as possible before being put into the kiln;
- Within the kiln, any water remaining in the green bricks will only be driven out by burning expensive fuel. Fuel costs may thus be reduced if the maximum of water is removed through natural drying.

9.2 Principles of Drying

Drying in brick making commonly refers to the process of thermally removing the moisture from freshly moulded green bricks to yield a dried product. Thermal removal of moisture can be attained either through artificial heating (using hot air in a dryer) or though atmospheric/ natural drying (exposure to sun rays). In most of the brick kilns in India, natural drying is practiced.

During drying process, initially the moisture from the surface of the green bricks get evaporated. Then the moisture from the inner part (core) of the green bricks gradually move towards the outer surface and then get evaporated.

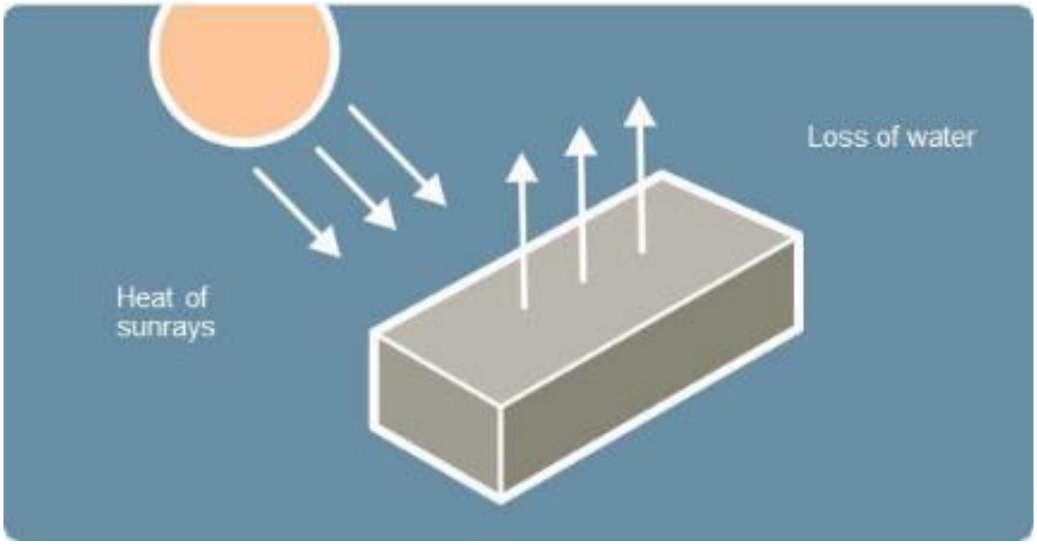


Figure 53: Sun drying of bricks[26]

9.3 Factors affecting drying

The following factors affect the drying rate of a brick. In most of the cases two or more factors contribute to the effect.

9.3.1 External factors

Atmospheric temperature

Increased atmospheric temperature (e.g. summer months) results in higher heat input. Hence, during the daytime in summer months highest rates of drying are experienced. Depending upon the climatic conditions, sometimes, the drying rate is so high that outdoor drying of freshly moulded bricks results in drying shrinkage cracks within a few minutes.

Relative humidity

Relative humidity in the atmosphere gives a measure of the moisture content in the atmosphere. The higher the moisture content in the atmosphere, the lesser will be its capacity to absorb moisture from green bricks. Thus, if relative humidity is higher, the drying rate will be less, and vice versa.

Air flow rate

High air flow rate results in higher rate of heat and mass transfer between green bricks and the surroundings. Hence high air flow rate in the surrounding will increase the brick drying rate.

[26] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

9.3.2 Internal factors

Moisture content within the brick

During manual moulding of green bricks the minimum moisture content varies between 25%. to 35%. The moisture content is a factor of the ease of workability of the soil and moulder habits. High moisture content within the green bricks will take a longer time to dry compared to those moulded with lesser water.

Soil characteristics

Soil plasticity and the grain size is an important characteristic to determine the drying time. The finer the grain size the higher will be the plasticity resulting in more closed packing of the grains. This will result in lesser number of open pores or finer size of them. More sandier the soil is, the higher will be the amount of pores and their chances of interconnectivity. Bricks with larger concentration of pores i.e. sandy soils will dry faster compared to bricks made with clayey soil due to enhanced capillary action.

Brick moulding type

Brick moulding patterns also have a role to play in determining the drying rate. The more compact the brick, the lesser will be the number of pores and the water content. Thus, hollow soil blocks dry much faster due to greater surface area exposed to atmosphere and higher area of surface diffusivity

9.4 Stages in drying of green bricks

STAGE 1

The green bricks are laid flat on the surface; the exposed top portion dries out much faster than the surface in contact with the ground.

If at this stage the drying takes place too fast, then there is a risk that the bricks will develop cracks due to differential drying rates between the surface and the part that is in direct contact with the ground.

STAGE 2

After 1-2 days (depending on local atmospheric conditions) the bricks are turned from the flat position to the upright (the smallest surface) position. This will ensure a uniform green brick drying from all directions. During this stage, the maximum shrinkage accompanied by moisture removal occurs and the green brick reaches the 'Leather Hard' condition.

Cracks developed due to non uniform drying are called shrinkage cracks. Sometimes these shrinkage cracks can hardly be seen by the naked eye. These cracks eventually expand during the firing process resulting in cracks during firing and hence loss of strength.

STAGE 3

After the 'Leather Hard' form of the green brick is attained, the bricks are stacked over one another and are left for further drying.The remaining water in the interstitial spaces gets dried over time through the forces of diffusion activated by the dry and relatively hot ambient conditions. It is worthy mentioning here that the removal of water is not any more through capillary action but through diffusion within the soil structure procedure. Completion of this process results in a 'Bone Dry' brick.

Figure 54: Stages of brick drying[27]

9.5 Stacking patterns and its effect on drying

In order to stack the green bricks, they must have attained 'Leather Hard' condition to avoid physical damage (such as fingerprints, corner damages, breaking) and stacking deformation.

The 'Leather Hard' green bricks are lifted and stacked in rows to achieve the final bone-dry stage. The stacking of the 'Leather Hard' green bricks fulfills two major purposes namely:

- Allowing full airflow circulation for complete drying.

[27] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

- Creating space for new moulding.

'Leather Hard' condition is determined physically by the condition when there will be no fingerprints on the green bricks during handling and they can be handled with four fingers of a hand. Also, during stacking they should be able to bear the load of the entire stack without deformation.

Stacking of green bricks requires special attention and only well-trained workers can do it in a well-managed way. Generally, the green brick stacking is done by moulders themselves. Various patterns of stacking are followed. In some parts a herringbone pattern of stacking is made, in some parts honeycomb and in other parts closed packed stacking and in other parts cross stacking. In the cross-stacking patterns, a total height of 10 brick layers are made. This height is also made due to convenience to provide easy access to the top layer for brick transporters.

The stacking must be uniform and a proper air gaps must be provided to ensure a uniform drying pattern. The brick surfaces should never be in contact with each other otherwise this contact will always remain moist. Whatever the stacking pattern applied, there should always be a gap of 3–4 cm between each and every brick for proper airflow.

9.6 Preparation of stacking base

Before start of moulding, it is necessary to construct the stacking base for further drying of the green bricks. The stacking base is generally prepared all along the periphery of the moulding yard.

Before preparation of the stacking base calculate the length needed for stacking of bricks based on the daily production and drying time. Never keep more than two parallel layers. For preparation of stacking base initially clean and level the area. Place at least one layers of fired bricks on the flat surface. Ensure that the fired brick surface is absolutely leveled.

The height of the stacking base should be at least one brick height more than the ground level. This is to ensure that water (from unseasonal rains) does not damage the bottom layers. If the bottom layers are damaged, then the whole stack will fall down. Also keep a plastic sheet ready near each stacking base. During any indication of rains cover the stack with the plastic to protect the green bricks from being damaged.

Figure 55: Drying shed

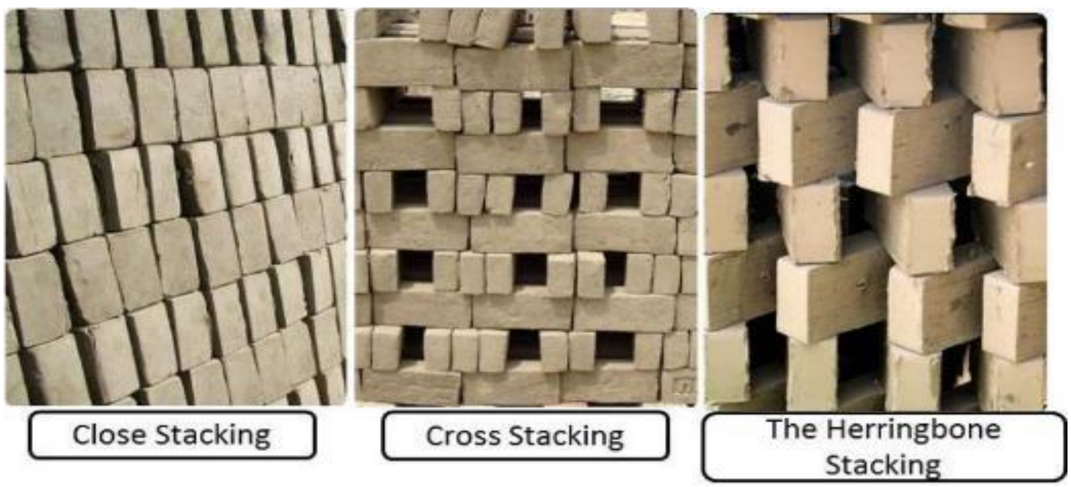


Figure 56: Types of stacking for drying[28]

9.7 Storage of dried green bricks

Green bricks are mainly stored for firing during the rainy season. The driest months for the year must be utilized to produce green bricks in surplus to store it to use during rainy days. During the summer months green bricks dry faster. Thus, the rate of production will be very high. There are three important things to be considered for green brick storage.

- Firstly, the storing pattern should be such that damage due to rain do not occur.
- Secondly, it should be economical and not occupy much space.
- Thirdly, there must be necessary manpower to produce enough bricks for regular consumption and storage.

[28] Source: Green Brick Making Manual, Vertical Shaft Brick Kiln Project, Nepal-2008

For making a storage chamber the number of bricks needed to be stored needs to be known. It is advisable to make a number of small storages rather than a single very large storage. This is done to avoid excess losses due to damage by rain leaking, etc.

Depending upon the dried green brick strength the total stack height of the storage is determined (usually varies between 20 to 30 brick height).

Once the area is calculated, and the site selected for storing, clear the area from any vegetation. After cleaning the land should be leveled properly. Place at least three layers of fired bricks to make the base. The level might be varied so that during rain water does not flow over the green bricks.

Now start placing the green bricks from one corner. Ensure that there should be no gap between the bricks. Always begin stacking of bricks from one side only. If haphazard stacking is done, then there will be the chance of gaps when the stacks meet together.

Initially the stack should be vertical. The height of this type of stacking might vary. Generally, it is half the length of the total stack. After reaching the desired height the stacking of the green bricks should be made in such a way that a sloping roof is made.

Figure 57: Storage of dried green-bricks

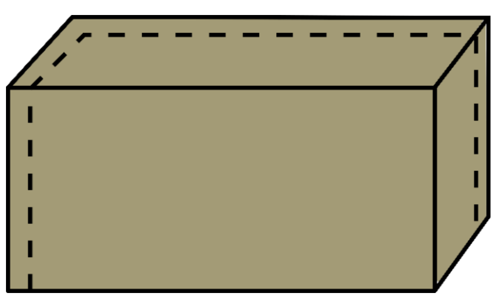
Figure 58: Stack of dried green-bricks covered with plastic cover

After completion of the stack, cover the top with a thick plastic. Be careful that the plastic covers only the top to protect the bricks from rain damage. On top of the plastic put red bricks all along. Alternatively, you can put a layer of burnt coal ash and then a layer of red bricks. This is done to prevent the red bricks from slipping during heavy rains. During monsoon operation keep the green brick stack as airtight as possible.

9.7.1 Drying defects and possible remedial measures

The following is a list of defects that might occur during drying of bricks, the possible reasons of the faults, and some suggestions to correct them:

1. **Dried bricks oversize in all three dimensions.**



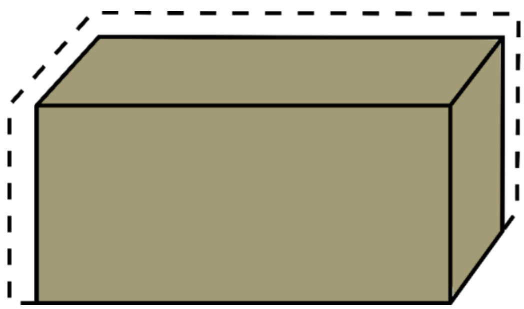
Reasons:

- The fault lies in higher proportion of coarse particles in the soil. The presence of more sand and less clay in the soil will reduce the extent of drying and firing shrinkage of the brick.

Suggestions:

- Conduct the sedimentation test to estimate the proportion of sand and clay in the soil mixture. Increase the amount of soil containing high clay content in the soil-mixture and check with different proportions to find the suitable mixture.

2. Dried bricks undersize in all three dimensions.



Reasons:

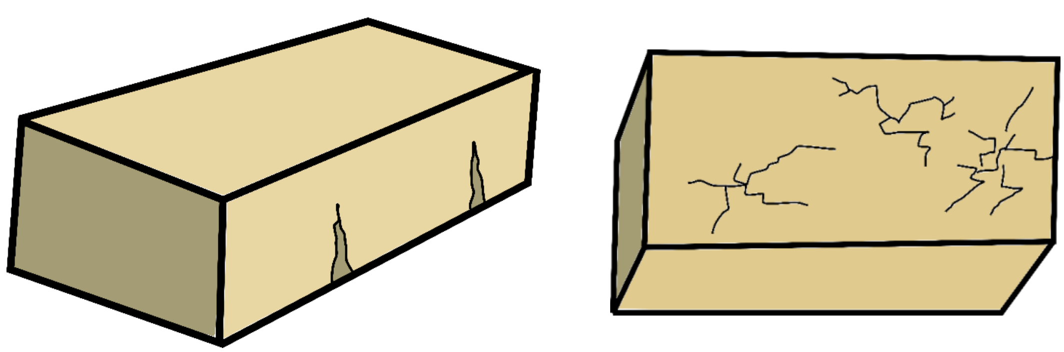
- The fault lies in high proportion of clay content or addition of too much water at the mixing stage.

Suggestions:

- Conduct the sedimentation test to estimate the proportion of sand and clay in the soil mixture. Increase the amount of soil containing high sand content in the soil-mixture and check with different proportions to find the suitable mixture.

- Use appropriate amount of water during soil-mixture preparation.

3. The brick has developed cracks after drying.



Reasons:

- Straight cracks extending at right angles from one of the long faces happen if the drying process is too rapid.
- Multiple surface cracks are normally the result of differential drying shrinkage caused by the presence of lumps of drier material in the soil mixture which do not shrunk as much as the surrounding material.
- There is too much water in the soil-mixture.
- The clay proportion in the soil-mixture is not correct for making bricks.

Suggestions:

- If bricks are laid in the open for drying, cover them with grass or plastic sheet to decrease the rate of drying. If bricks are put in the drying shed, close the openings in the wall to reduce the wind blowing through the shed.
- To avoid the multiple surface cracks, ensure sufficient mixing of the soil before moulding.
- Use appropriate amount of water during dough preparation.
- Increase the amount of soil containing high sand content in the soil-mixture and experiment with different proportions.

9.8 Points to remember

1. To minimize the risk of breakage during firing bricks should be as dry as possible before being put into the kiln.
2. After 1-2 days the bricks are turned from the flat position to the upright position. This will ensure a uniform green brick drying from all directions.
3. The stacking must be uniform and a proper air gaps must be provided to ensure a uniform drying pattern.
4. The brick surfaces should never be in contact with each other otherwise this contact will always remain moist.
5. There should always be a gap of 3–4 cm between each and every brick for proper airflow.
6. It is necessary to construct the stacking base for laying green bricks for drying. The height of the stacking base should be at least one brick high above the ground level. This ensures that water (from unseasonal rains) does not damage the bottom layers.

Module 10: Basics of Firing

10.1 Steps in Brick Firing Process

Green bricks are fired in the kilns to convert a fairly loosely compacted blend of different minerals into a strong, hard, and stable product i.e. fired brick. The firing process determines the properties of the fired brick — strength, porosity, stability against moisture, hardness etc. Depending on the nature of clay and the quality requirements of fired bricks, the firing temperature lies in the range of 600–1100 ^{o}C.

The overall firing process can be categorized in three steps – heating, soaking and cooling.

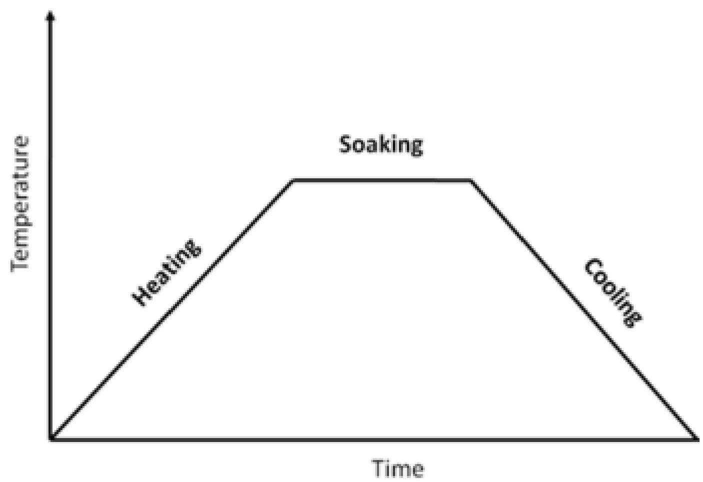


Figure 59: Steps in brick firing process

10.1.1 Heating:

Heating of clay leads to removal of moisture and carbonaceous material, chemical changes, and colour change in the final product. The chemical and physical changes occurring at different temperatures during the clay heating process are represented in the figure below and are explained below.

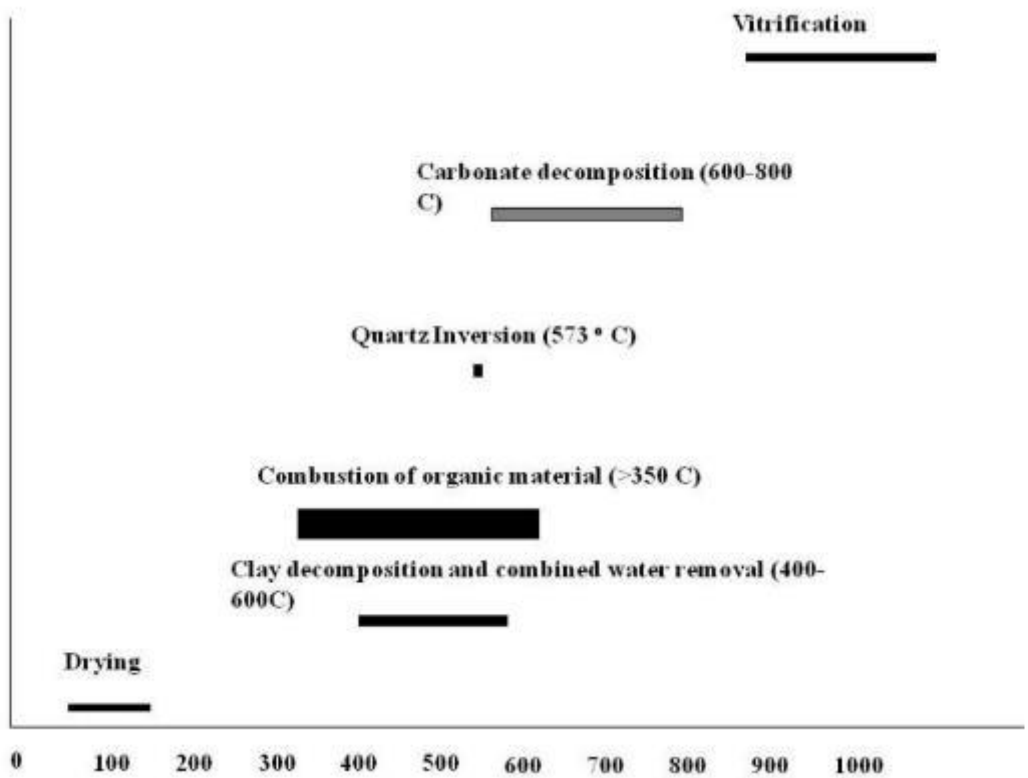


Figure 60: Changes occurring in brick during heating of green bricks

1. **Removal of mechanical moisture:** About 25-30% of water is added to clay during the hand-moulding or extrusion process. While most of the moisture is removed during drying, generally 3-10% moisture still remains with bricks while loaded in the kiln due to different climatic conditions. The first stage of heating involves removal of this moisture (drying). Almost all the mechanically held water is evaporated when temperature of the bricks reaches around 150 ^{0}C. However, the clay still retains its original characteristics.

2. **Combustion of carbonaceous materials:** The clay contains carbonaceous organic matter (plant material such as roots, leaves etc.). The amount of organic matter present in clay varies from place to place. At some places, agricultural residues (wheat straw and rice husk etc.) are added to clay as internal fuel. As green bricks are heated up in the kiln and oxygen (in combustion air) diffuses inside bricks, combustion of the organic matter is initiated at about 400^{o}C. The process is completed when the temperature reaches 700^{o}C.

3. **Decomposition of clay molecules and release of combined water (Dehydroxylation):** Clay material consists of several chemical compounds which have water molecules or hydroxyl groups chemically combined with them. Kaoline is one such compound which is the major component in clay (the chemical formula of Kaoline is $Al_2O_3.2SiO_2.2H_2O$). When clay is heated, it starts decomposing resulting in release of combined water.

4. **Quartz inversion**: Silica, a common constituent of brick making soils, has its crystal structure in the form of α–quartz (alpha–quartz) in nature. At 573^{0}C, its crystal structure changes into from β–quartz (Beta quartz) and this transformation is accompanied by an expansion of volume by around 2%. During cooling, β–α change occurs again at temperature 573 ^{0}C. The heating and cooling rates near quartz inversion temperature have to be controlled to obtain near-uniform temperature throughout the brick and thus avoiding excessive stresses which can lead to crack formation in bricks.

5. **Carbonate and sulphide decomposition:** Carbonates and sulphides present in the clay decompose at 600 – 800 ^{0}C releasing CO_2 and SO_2.

6. **Vitrification:** Vitrification entails partial melting of clay particles at points of contact, to form a glassy bond, which binds the whole mass together and give strength. The extent to which a mass of clay is melted during firing depends on (i) temperature of the clay mass, and (ii) duration of the heat treatment.

   Vitrification of clay approximately commences at around 900 ^{0}C. However, the vitrification temperature depends upon the type of minerals constituting clay, their proportion and particularly on how much fluxing oxides they introduce — ferrous oxide, lime, magnesia and potash. Fluxing oxides are those which bring down the temperature of vitrification. This explains for the wide variations observed in firing temperature, which ranged between 600 – 1100 ^{0}C at different locations.

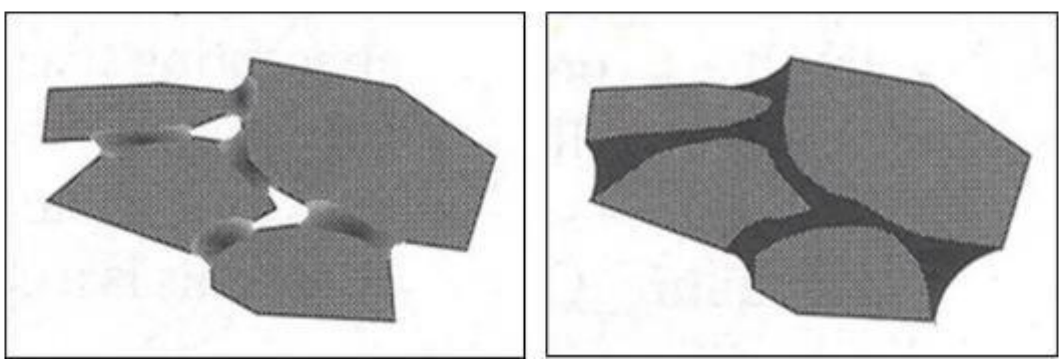


Figure 61: Vitrification of clay

As temperature increases, more melting of clay mass occurs. In practice, the heating must be restricted lest so much liquid forms that the whole brick starts to become distorted under the weight of the higher layers of bricks. In extreme cases, the bricks may get fused together in the kiln.

10.1.2 Soaking:

The bricks are maintained at the finishing temperature for few hours in order to attain uniform vitrification throughout the brick. This process is known as soaking.

10.1.3 Cooling:

During cooling the liquid solidifies to glass, bonding the whole mass together. The cooling rate should be slow to avoid excessive thermal stresses in the bricks, particularly once the quartz inversion temperature (573 ^{0}C) is reached, since shrinkage occurs at this point.

10.2 Introduction to Fuels

10.2.1 Fuels used in brick kilns

In brick kilns, generally solid fuels are used e.g. coal, wood, sawdust, agricultural residue like rice husk, industrial waste and bye-products like used rubber tires, pet-coke, etc. Apart from solid fuels, bricks are also fired from natural gas, diesel, etc.

10.2.2 Relevant fuel properties

The characteristics of fuel that should to be considered for assessing the suitability of a fuel for combustion process are:

1. **Calorific value**

   The calorific value is the measurement of heat or energy contained in the fuel. It is the amount of heat/energy which is released or available for use after complete combustion of a unit amount of fuel. Higher the calorific value, higher is its heat content. It is measured either as Gross Calorific Value (GCV) or Net Calorific Value (NCV).

2. **Volatile matter:**

   Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in fuel. Thus, the volatile matter is an index of the gaseous fuels present. Volatile matter content proportionally increases flame length and helps in easier ignition of fuel.

3. **Fixed carbon:**

   Fixed carbon is the solid fuel left after the moisture and volatile matter are driven off. It consists mostly of carbon but also contains some hydrogen, oxygen, nitrogen and sulphur which are not driven off with the gases. The amount of fixed carbon and volatile combustible matter directly contribute to the heating value of fuel. While volatile matter helps in initiation of the burning, fixed carbon acts as the main heat generator during the burning.

4. **Ash content**

Ash is an impurity that will not burn. Lower the ash content better is the fuel. Higher Ash content reduces the burning capacity and also increases the handling costs. Ash can also cause clinkering and slagging.

5. **Sulphur Content:**

Sulphur content affects clinkering and slagging tendencies. It corrodes metal chimney and other equipment such as induced draught fans etc. and limits the exit flue gas temperature. SO_2 produced due to the combustion of sulphur affects nearby vegetation.

Following table shows properties of some important fuels.

Parameter	Bituminous coal	Saw dust	Coffee husk	Wood chips
Volatile matter %	20-35	65-70	75-77	55-60
Fixed carbon %	40-45	15-20	~3	15-20
Calorific value kcal/kg	4,000-7,000	3,500-4,500	4,300-4,500	3,500-4,500
Ash content %	10-35	5-7	5-7	2-5
Sulphur %	0.5-3	0-0.5	0-0.2	0

Ignition temperature

For fuel to burn, it requires to be heated to a minimum temperature, which is known as ignition temperature of the fuel. Therefore, it is important to know the ignition temperature of the commonly used fuels.

Fuel	Ignition Temperature ^{0}C
Coal	450 – 750
Wood, sawdust	350 – 450

10.3 Basics of Combustion and Combustion Process of Coal

10.3.1 Basics of Combustion

The process of burning of a substance to produce heat is called combustion. The substance which burns to produce heat is in generally called fuel. The prerequisites for the combustion to happen are:

i. Presence of some kind of "Fuel" e.g. wood, coal, petroleum, natural gas etc.
ii. It has to be at the right temperature to ignite. The temperature at which something will ignite is called its "ignition point".
iii. It has to be mixed with an adequate amount of air (Oxygen). Fuel won't burn unless oxygen is present. For something to continue burning, an abundant supply of fresh air is required.

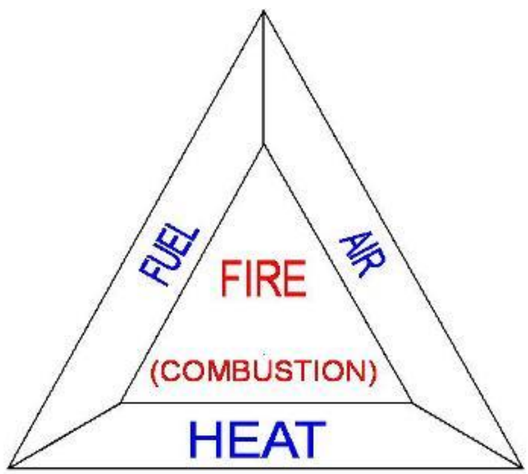


Figure 62: Combustion conditions

Combustion basically refers to oxidation of fuel. Carbon, hydrogen and sulphur present in the fuel combine with oxygen in the air to form carbon dioxide, water vapour and sulphur dioxide. The chemical reactions occurring during the combustion process are as below:

$C + O_2 = CO_2$ + 8,084 kcal/kg of carbon

$2H_2 + O_2 = 2H_2O$ + 28,922 kcal/kg of hydrogen

$S + O_2 = SO_2$ + 2,224 kcal/kg of sulphur

Carbon may also combine with oxygen to form carbon mono-oxide with release of lower amount of heat.

$2C + O_2 = 2CO$ + 2,430 kcal/kg of carbon

If for any reason the air supplied is inadequate, the combustion will be incomplete. Incomplete combustion results in poor generation of heat with some portion of carbon remaining un-burnt and formation of carbon mono-oxide (toxic in nature) instead of carbon di-oxide. The unburnt carbon passes into the atmosphere with flue gases as soot and can cause respiratory problems in the nearby inhabitants.

The objective of good combustion is to release all the heat contained in the fuel. This can be accomplished by controlling the 'three Ts' of combustion – (i) Temperature high enough to ignite the fuel and maintain the ignition, (ii) Turbulence for proper mixing of oxygen and fuel and (iii) Time sufficient for complete combustion.

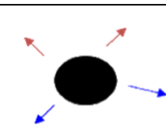
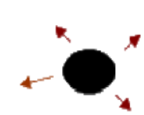
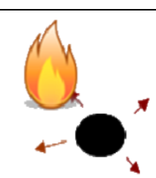
Combustion of Coal

Combustion is defined as the rapid chemical reaction in which chemical energy of fuel is converted into heat. During combustion, carbon, hydrogen and sulphur present in the fuel reacts with oxygen and releases heat. A simple word equation for this chemical reaction is:

Fuel + Oxygen = Heat + Carbon Dioxide + Water

Coal must be heated to its ignition temperature before it can burn. Although the ignition temperature of a substance is essentially constant, the time needed for burning to begin depends on factors such as the size of the fuel particle and the amount of oxygen in the air. A finely divided substance is more readily ignited than a massive one; e.g., sawdust ignites more rapidly than does a log. The vapours of a volatile fuel such as gasoline are more readily ignited than is the fuel itself. The rate of combustion is also affected by these factors, particularly by the amount of oxygen in the air.

The process of combustion of coal consists of four major steps:

1. **Drying**	As the coal is heated; the moisture present in the coal (except inherent moisture) is released in the form of water vapour. By the time the coal temperature reaches 120°C, the drying is over.	
2. **Release of volatile matter**	As the coal particles are further heated, they start emitting volatile gases. This volatile matter release generally starts at a temperature of around 250-300 o C. Most of the gases which are released are combustible gases.	
3. **Combustion of volatile matter**	Volatile gases coming out of the coal particles, mixes with the air and forms a combustible mix, which ignites. The combustion of volatile matter is seen as flames. Wood has in general the highest volatile matter among various solid fuels and therefore has the longest flames.	

4. **Combustion of char**	After all volatile matter is burned out; the coal particle now consists only of carbon (char) and ash. Char ignition temperature is higher compared to that of the volatile matter. In a brickkiln, normally the char combustion takes place once the temperature exceeds 600° C.	

10.4 Different Types of Coal – How to Distinguish Types of Coals

10.4.1 Colour of the Coal

The colour of a coal generally varies from grey to black, depending on the ash content and other impurities present in the coal. Based on the coal colour it is possible to get initial coal quality indicators.

Deep black colour:
Indicates that it is a very good quality coal which has high carbon content, high calorific value and very low ash content.

Light black colour:
Indicates that this is a medium quality coal, having less carbon content and a high ash content.

Grey colour coal:
Indicates that this is a poor-quality coal which has a very low carbon content, low calorific value and a very high ash content.

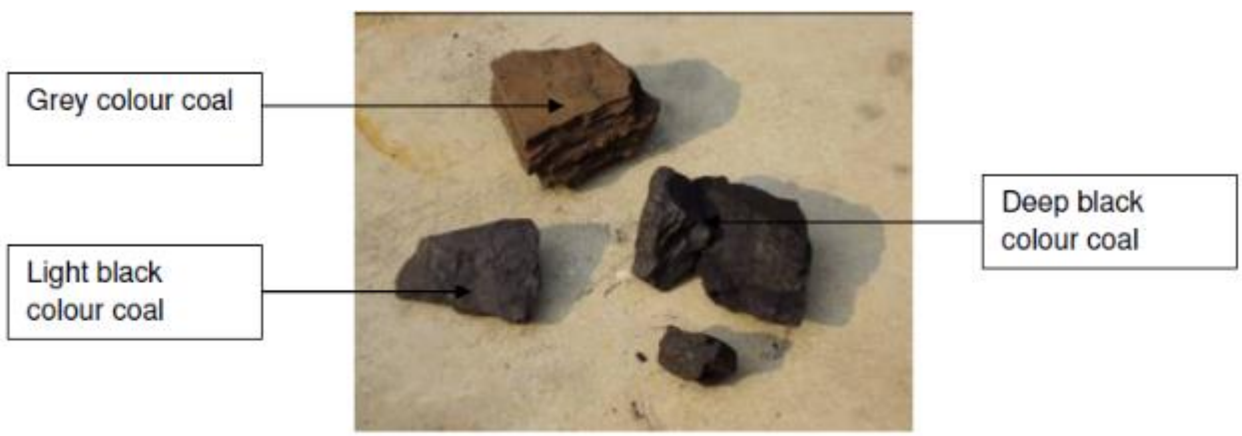


Figure 63: Different colours of coal

10.4.2 Lustre

Lustre is a measure of the shininess of coal. It varies from dull to shiny depending on the calorific value of the coal. Based on the coal shininess it is possible to get initial coal quality indicators.

Shiny lustre:
Indicates that it is a good quality coal having high calorific value and high volatility.

Dull lustre:
Indicates that this is a poor-quality coal having very low calorific value and low volatility.

Figure 64: Lustre of coals

10.4.3 Hardness

Hardness of coal varies from soft to hard.

Soft Coal:
Soft coal means that it can be broken by pressing two hands together. If the same is black in colour and light, then it has high calorific value. However, if the same is brown in colour then it is premature type of coal i.e. lignite or peat.

Hard Coal:
Hard coal means that it cannot be broken by hand. Most often hard coals are also heavy in nature. It has in general low calorific value, very low volatility and high ash content. If its lustre is dull, then it is not very suitable for VSBK operation.

10.4.4 Flame height

The flame of a coal provides useful indicators about the volatile matter present in the coal.

Therefore, it is important to carefully observe the flame properties during the "Field test kit" testing process and to record it. In general, it is experienced that the longer the flame, the higher the volatile matter content of the coal.

High flame

If a high flame during the initial period of burning is observed, then it is probably a 'high volatile coal'.

Low flame

If a low flame or no flame is observed, this indicates a 'low volatile coal'.

Figure 65: Long flame indicating high volatile fuel

10.4.5 Fire colour

During the burning of coal the developing colour of the fire is an indicator of what temperature is reached. Determining the temperature by observing the colour of the fire is sometimes tricky and requires quite some experience. The table below provides some basic indication for fire colour assessment.

Colour		Temperature (°C)
Yellow		<475
Lowest Visible Red		475
Lowest Visible Red to Dark Red		475 to 650
Dark Cherry to Cherry Red		650 to 750
Cherry Red to Bright Cherry Red		750 to 815
Bright Cherry Red to Orange		815 to 900

Dull red

colour code the visible colour will be around dark cherry to cherry red.

Orange red

If the coal burns with a bright orange colour, then the coal is of high calorific value. As per the colour code it belongs to the highest visible colour of bright cherry red to orange.

10.5 Points to remember

1. Depending on the nature of clay and the quality requirements of fired bricks, the firing temperature lies in the range of 600–1100 ^{0}C.
2. The overall firing process can be categorized in three steps – heating, soaking and cooling.
3. For fuel to burn, it requires to be heated to a minimum temperature, which is known as ignition temperature of the fuel.
4. Combustion basically refers to oxidation of fuel. Carbon, hydrogen and sulphur present in the fuel combine with oxygen in the air to form carbon dioxide, water vapour and sulphur dioxide.
5. The colour of a coal generally varies from grey to black, depending on the ash content and other impurities present in the coal.
6. During the burning of coal, the developing colour of the fire is an indicator of what temperature is reached.

Module 11: Types of Brick Kilns

A large variety of kilns are used for firing bricks. These can be classified in several ways, e.g. on the basis of the production process (intermittent and continuous kilns); direction of air flow (up-draught, down-draught and cross-draught kilns); or on the basis of the method of production of draught (natural draught and forced draught kilns).

11.1 Classification based on nature of production process

Depending upon the nature of production process, brick kilns can be classified as intermittent kilns and continuous kilns. The classification is represented in figure below:

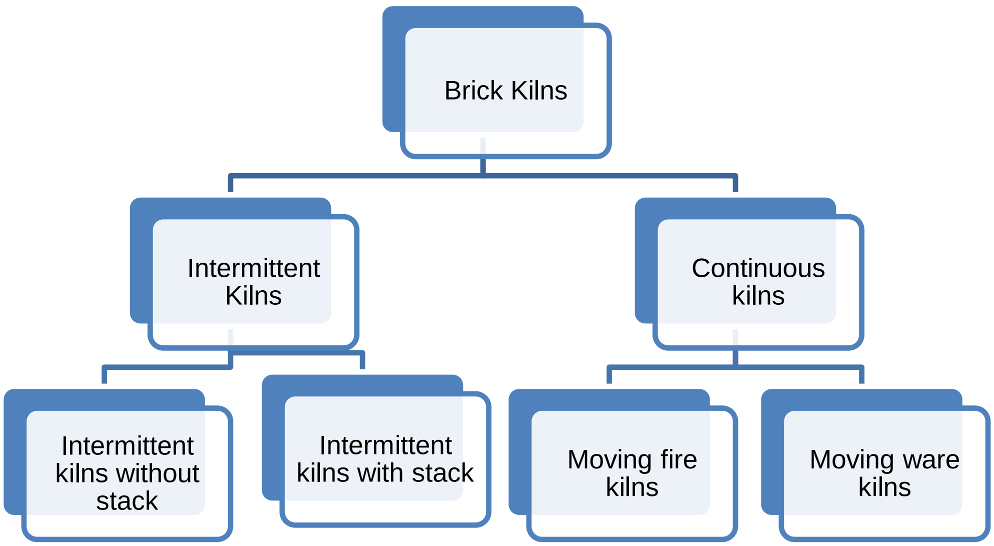


Figure 66: Classification of brick kilns based on production process

11.1.1 Intermittent kilns

In intermittent kilns, bricks are fired in batches; fire is allowed to die out and the bricks are allowed to cool after they have been fired. The kiln must be emptied, refilled and a new fire has to be started for each load/batch of bricks. In intermittent kilns, most of the heat contained in the hot flue gases, fired bricks and the kiln structure is thus lost. Intermittent kilns are still widely used in several countries of Asia, Africa and South and Latin America. Most of the traditional brick makers in the Greatlakes region uses intermittent kilns for brick firing. Intermittent kilns can be further sub-divided into two categories: –

Intermittent kilns without stack: The kilns which do not have any stack/chimney to guide the flue gases. In these kilns the flue gases can be seen coming out of the kiln from the sides or from all over the top surface of the kiln. Clamps, scove and scotch are the examples of intermittent kilns without stack.

Figure 67: (a) Clamp and, (b) Scotch kiln

Intermittent kilns with stack: As the name suggest, these kilns have a stack/chimney to create draught for releasing the flue gases at a higher point in the atmosphere. Down-draught kiln is the example of intermittent kilns with stack.

Figure 68: Down draught kiln

11.1.2 Continuous kilns

In a continuous kiln fire is always burning and bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Fired bricks are continuously removed and replaced by green bricks in another part of the kiln which is then heated. Consequently, the rate of output is approximately constant. Heat in the flue gas is utilised for heating and drying of green bricks and the heat in the fired bricks is used for preheating air for combustion. Due to incorporation of heat recovery features, continuous kilns are more energy efficient. Continuous kilns can be further sub-divided into two categories: moving fire kilns and moving ware kilns.

Moving fire kilns: In a moving-fire kiln, the fire progressively moves round a closed kiln circuit while the bricks remain stationary. The kiln circuit can have oval, rectangular or circular shapes. Ambient air enters from the left, whereas green bricks enter from the right. Brick firing takes place over a narrow zone shown in the figure. The cold air entering the kiln is preheated (and bricks are cooled) before entering the combustion zone. The combustion products (flue gases) from the combustion zone pass over the green bricks resulting in preheating of bricks (and cooling of flue gases). The fire travel takes place in the direction of airflow. A chimney stack and/or a fan provide the necessary draught for airflow. Hoffman kilns, Fixed Chimney Bull's Trench kilns and zigzag kilns are the examples of moving fire kiln.

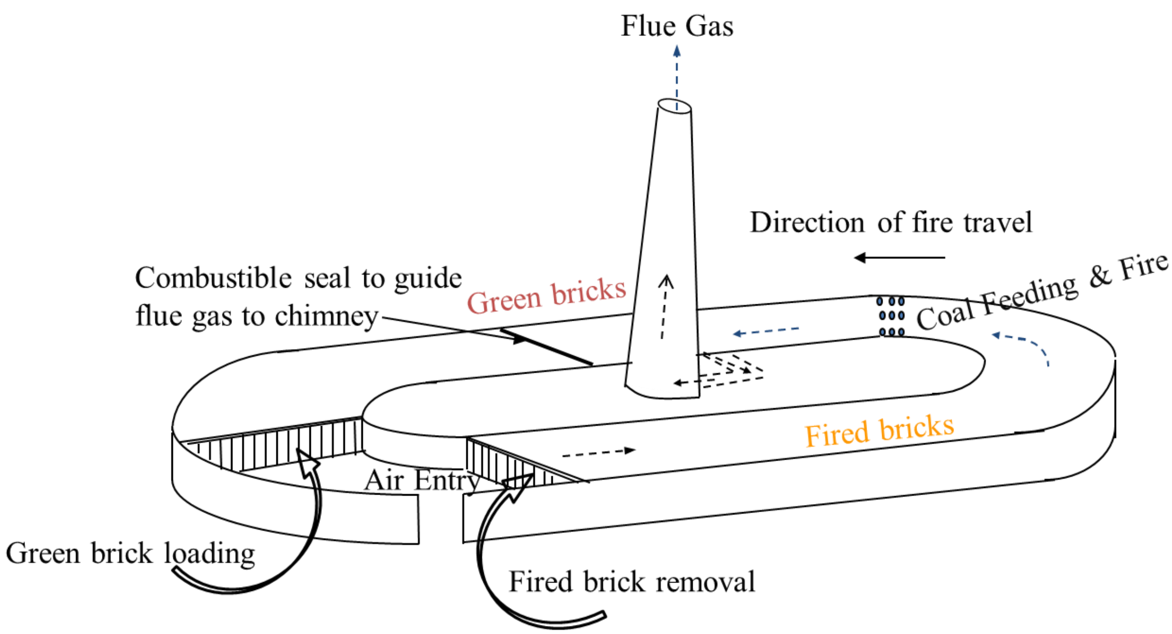


Figure 69: Moving fire kiln circuit

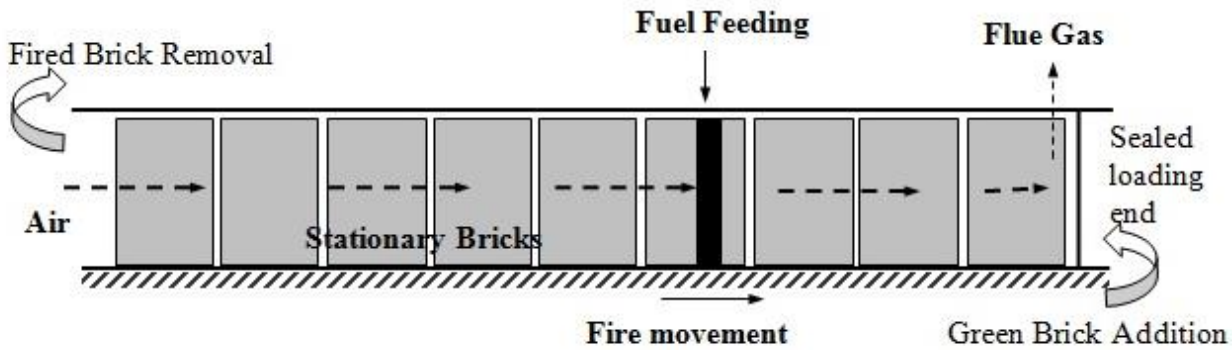


Figure 70: A part of moving fire kiln circuit showing fire travel

Moving ware kilns: In a moving ware kiln, fire remains stationary, while the bricks and air move in counter-current paths. In tunnel kiln, which is a horizontal moving ware kiln, goods to be fired are passed on cars through a long horizontal tunnel. The firing zone is located at the central part of its length. Cold air is drawn from the car exit end of the kiln and it cools the fired bricks. The combustion gases travel towards the car entrance losing a part of their heat to the entering green bricks. The cars can be pushed either continuously or intermittently at fixed time intervals.

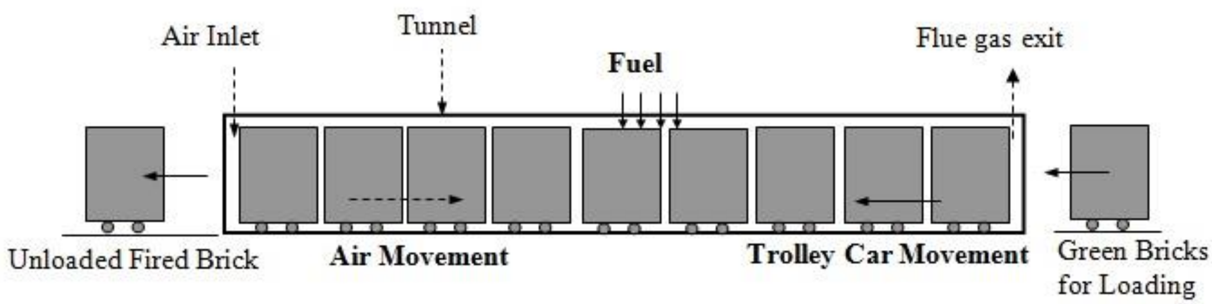


Figure 71: Tunnel kiln (moving ware kiln)

Vertical shaft brick kiln is another example of moving ware kiln. In this kiln the movement of bricks is in vertical downward direction and upward air movement is brought about by natural convection.

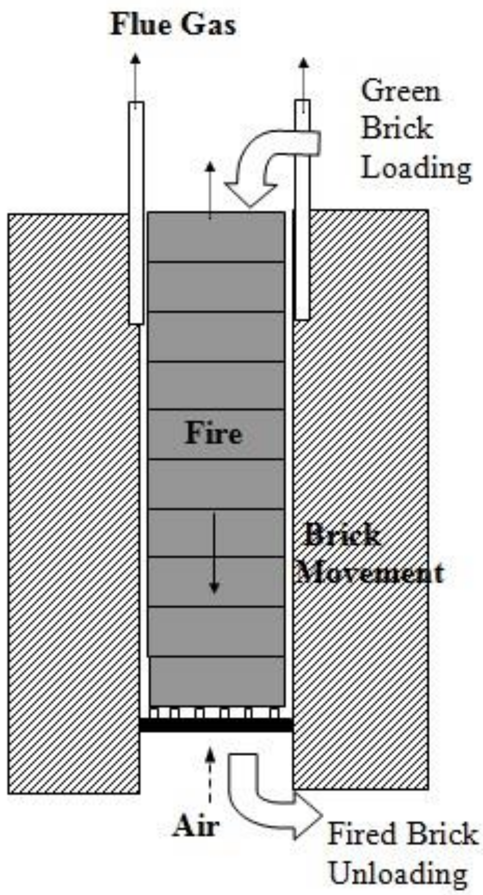


Figure 72: Vertical shaft brick kiln (moving ware kiln)

11.2 Points to remember

1. Depending upon the nature of production process, brick kilns can be classified as intermittent kilns and continuous kilns. These kilns can be further classified according to stack presence/absence and ware/fire travel.
2. In intermittent kilns, bricks are fired in batches; fire is allowed to die out and the bricks are allowed to cool after they have been fired. The kiln must be emptied, refilled and a new fire has to be started for each load/batch of bricks.
3. In a continuous kiln fire is always burning and bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Fired bricks are continuously removed and replaced by green bricks in another part of the kiln which is then heated.

Module 12: Fixed Chimney Bull's Trench Kiln (FCBTK)

12.1 Fixed Chimney Bull's Trench Kiln (FCBTK)

Figure 73: Fixed chimney Bull's trench kiln

Fixed Chimney Bull's Trench Kiln (FCBTK) technology is the most popular technology for the production of bricks in India, Bangladesh, Nepal, and Pakistan.

FCBTK is a continuous moving-fire kiln in which the fire moves in a closed circular or oval circuit through the bricks to fire them. It has an oval or circular shape in which the chimney is located at the centre. The bricks are fired in the annular space around the chimney, between the central part of the kiln (called 'miyana') and the outer wall. This annular space is called trench of the kiln.

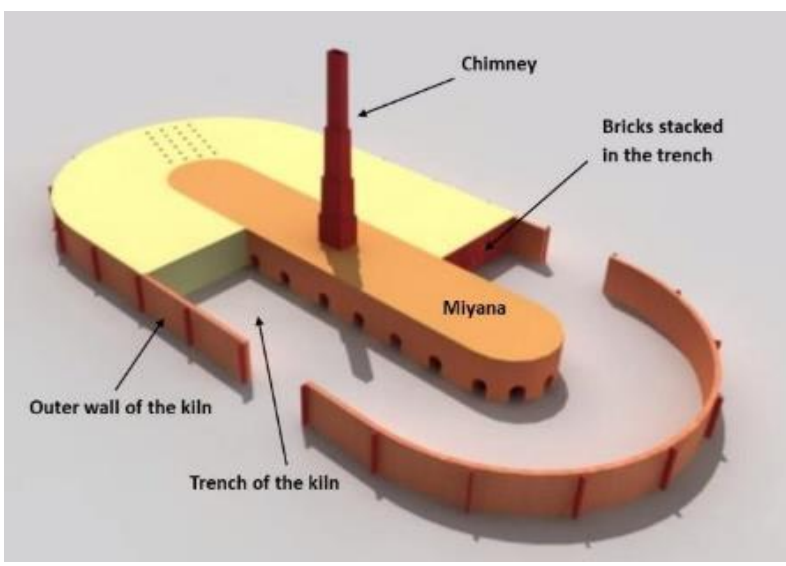


Figure 74: Different components of FCBTK

12.2 Working of FCBTK

In an FCBTK, the bricks are stacked and fired/burnt in the space (called 'trench' or 'dug') between the central part of the kiln (called 'miyana') and the outer wall.

Air is required in the kiln for combustion of the fuel and for the movement of fire in the forward direction. The flow of air into the kiln is caused by the draught created by the chimney. As the fire moves forward, the fired bricks behind the fire are taken out of the kiln after they cool down, while fresh green bricks are stacked ahead of the fire.

In an operational FCBTK, the bricks can be segregated into three distinct zones.

1. Brick firing zone where the fuel is being fed and combustion is taking place.
2. Brick preheating zone (ahead of the firing zone in the direction of air flow) where green bricks are stacked and are preheated by the hot flue gases coming from the firing zone.
3. Brick cooling zone (behind the firing zone) where the burnt bricks are cooled by the cold air flowing into the kiln.

In traditional operation of an FCBTK, fuel is fed intermittently. Usually two firemen feed fuel together for 5–10 minutes and there is a time gap of about 30–45 minutes before the next round of fuel feeding takes place. Usually the fuel is fed in two to three rows of the brick setting simultaneously.

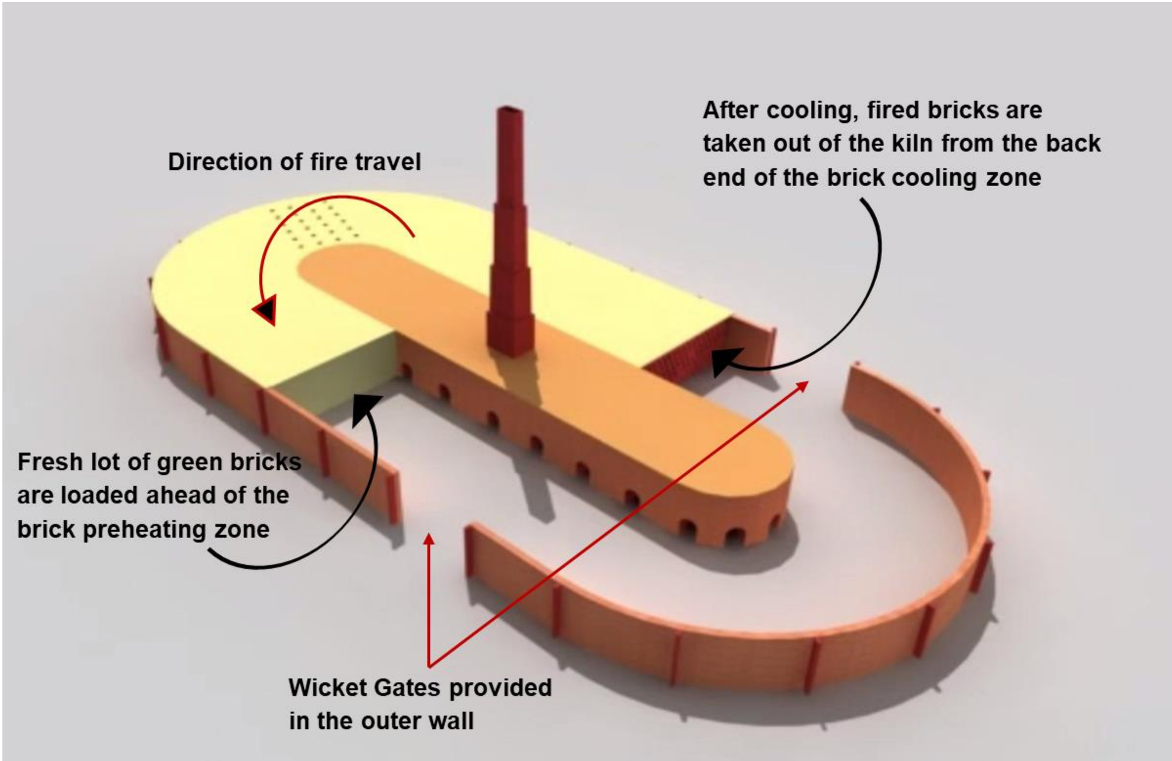


Figure 75: Flow of air/gases in FCBTK

Fired bricks, after having cooled down, are taken out of the kiln daily from the back end of the brick cooling zone. An equivalent batch of green bricks is loaded ahead of the brick preheating zone. Wicket gates are provided at regular spacing in the outer wall of the kiln to allow the movement of bricks and workers in and out of the kiln.

12.3 Short Comings of FCBTK

There are three main shortcomings of FCBTK:

12.3.1 Loss Due to Wastage of Fuel

A large amount of the fuel used in a BTK is not utilised fully, and hence wasted, mainly due to incomplete combustion of the fuel and heat losses from the kiln. About 25% of the fuel used in FCBTK can be saved through simple measures. For a typical FCBTK in North India, having annual production of 40–50 lakh bricks, 25% fuel wastage means wastage of about 100–150 tonnes of coal in a year. This means the entrepreneur is incurring an additional expenditure of Rs 5 lakh to Rs 15 lakh every year due to fuel wastage.

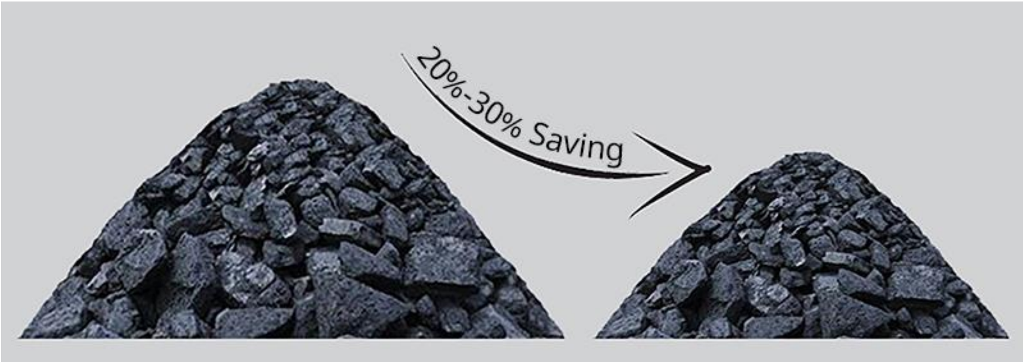


Figure 76: High fuel consumption in FCBTK and saving potential

12.3.2 Loss of Revenue Due to Production of Low-Quality Bricks

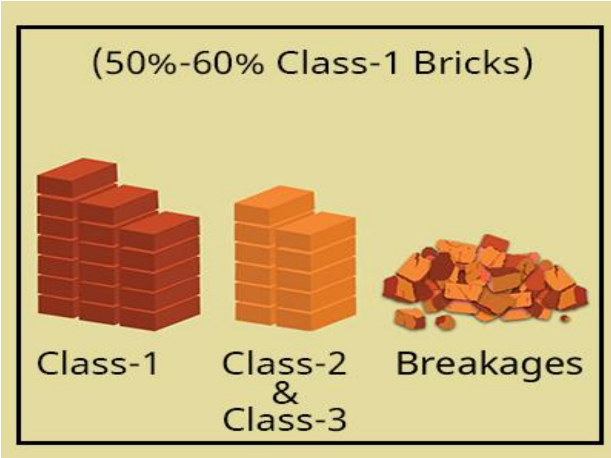


Figure 77: large production of low-quality bricks in FCBTK

Typically, only 60% of the bricks fired in a FCBTK are Class-I bricks. The remaining 40% are under-fired, over-fired or broken bricks. For a typical FCBTK in North India, this means losing a revenue of Rs 10 lakh to Rs 30 lakh in a year due to the high percentage of low-quality bricks.

12.3.3 Harmful Consequences of High Air Pollution

Figure 78: Air pollutants emanating from traditional brick kilns

Incomplete combustion of a large amount of fuel in a FCBTK, results in very high emission of harmful pollutants such as particulate matter (PM), carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), etc. The quantity of black smoke coming out from the chimney of a BTK gives an indication of air pollution.

High air pollution adversely affects the health of workers working in the kiln and also the health of the local population. It also adversely affects the health, growth and yield of crops, plants, and trees. Emissions of CO_2 and black carbon also contribute to global warming and climate change.

12.4 Points to remember

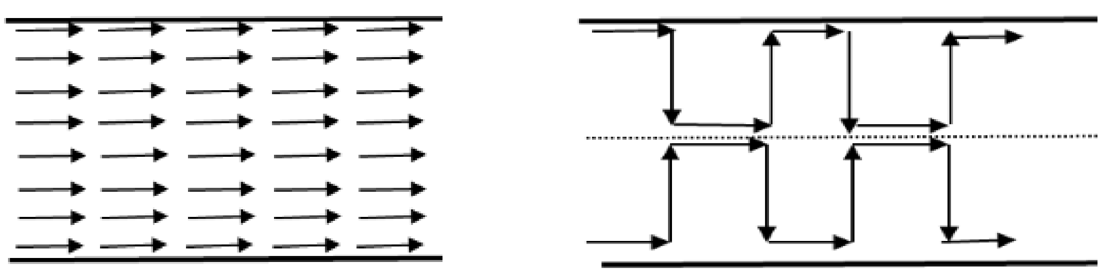
1. FCBTK is a continuous moving-fire kiln in which the fire moves in a closed circular or oval circuit through the bricks to fire them. It has an oval or circular shape in which the chimney is located at the centre.
2. In an operational FCBTK, the bricks can be segregated into three distinct zones i.e. cooling zone, firing zone and preheating zone.
3. In traditional operation of an FCBTK, fuel is fed intermittently. Usually two firemen feed fuel together for 5–10 minutes and there is a time gap of about 30–45 minutes before the next round of fuel feeding takes place.
4. A large amount of the fuel used in a BTK is not utilised fully, and hence wasted, mainly due to incomplete combustion of the fuel and heat losses from the kiln.
5. Typically, only 60% of the bricks fired in a FCBTK are Class-I bricks. The remaining 40% are under fired, over fired or broken bricks.
6. Incomplete combustion of a large amount of fuel in a FCBTK, results in very high emission of harmful pollutants.

Module 13: Natural Draught Zigzag Kiln

13.1 Introduction to Natural Draft Zigzag Kiln

Figure 79: A natural-draught Zig-zag kiln

In a Zigzag kiln, air flows in a zigzag path. Zigzag kilns are an improvement over Fixed Chimney Bull's Trench Kilns (FCBTKs), in which air flows in a straight-line path. The zigzag air flow considerably improves the combustion of fuel and heat transfer in a zigzag kiln, because of which its performance is better than an FCBTK.



Straight line air flow (FCBTK) **Zigzag air flow (Zigzag kilns)**

Figure 80: Comparison of air flow path in FCBTK and zigzag kilns

NDZK is a continuous moving-fire kiln in which the fire moves in a closed rectangular circuit through the bricks to fire them. Zigzag kilns are of rectangular shape in which the chimney is located at the centre. The bricks are fired in the space (called 'trench' or 'dug') between the rectangular central part of the kiln (called 'miyana') and the rectangular outer wall of the kiln.

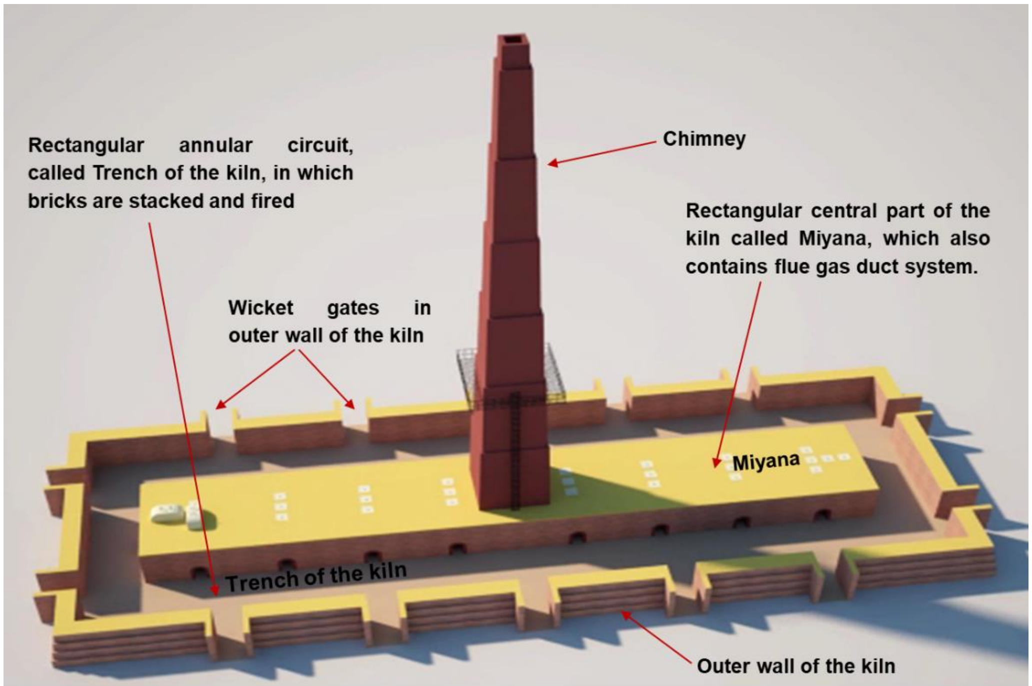


Figure 81: Components of a Zig-zag kiln

13.2 Working of natural draught zigzag kiln

Show the Animation on NDZK

In NDZK, the bricks are stacked and burnt in the space (called 'trench' or 'dug') between the rectangular central part of the kiln (called 'miyana') and the rectangular outer wall of the kiln. Air is required in the kiln for combustion of the fuel and for the movement of fire in the forward direction. The flow of air into the kiln is caused by the draught created by the chimney. As the fire moves forward, the fired bricks behind the fire are taken out of the kiln after they cool down, while fresh green bricks are stacked ahead of the fire.

In an operational NDZK, the bricks can be segregated into three distinct zones.

1. Brick firing zone where the fuel is being fed and combustion is taking place.
2. Brick preheating zone (ahead of the firing zone in the direction of air flow) where green bricks are stacked and are preheated by the hot flue gases coming from the firing zone.
3. Brick cooling zone (behind the firing zone) where the burnt bricks are cooled by the cold air flowing into the kiln.

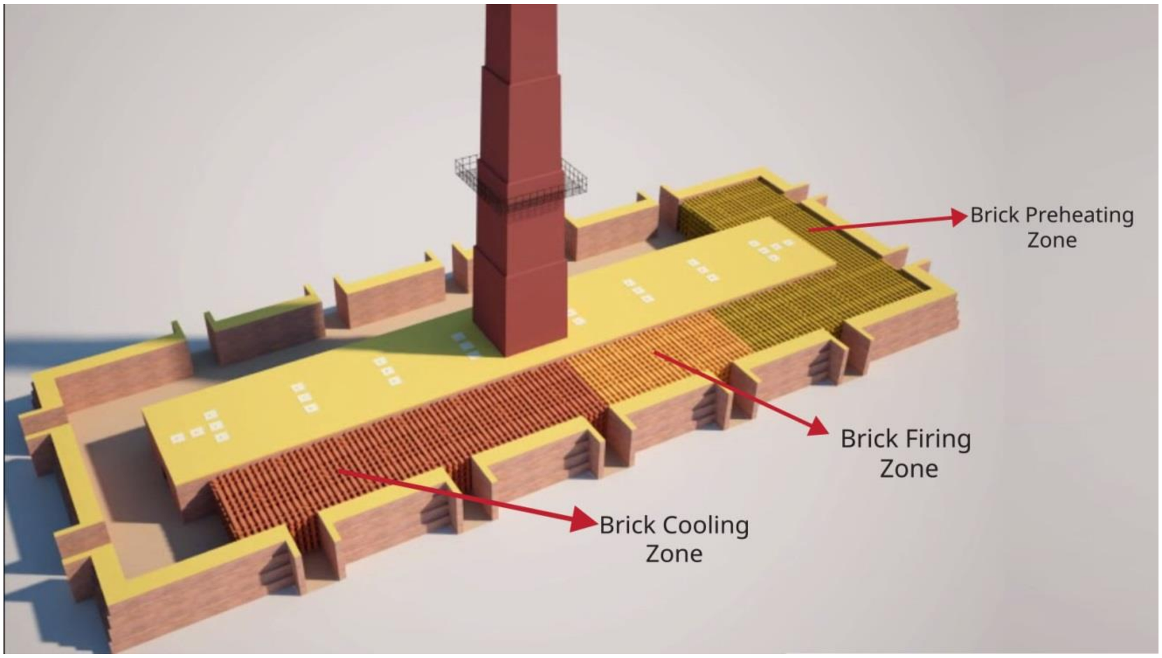


Figure 82: Distinct zones of a Zig-zag kiln

Fired bricks, after having cooled down, are taken out of the kiln daily from the back end of the brick cooling zone. An equivalent batch of green bricks is loaded ahead of the brick preheating zone. Wicket gates are provided at regular spacing in the outer wall of the kiln to allow the movement of bricks and workers in and out of the kiln.

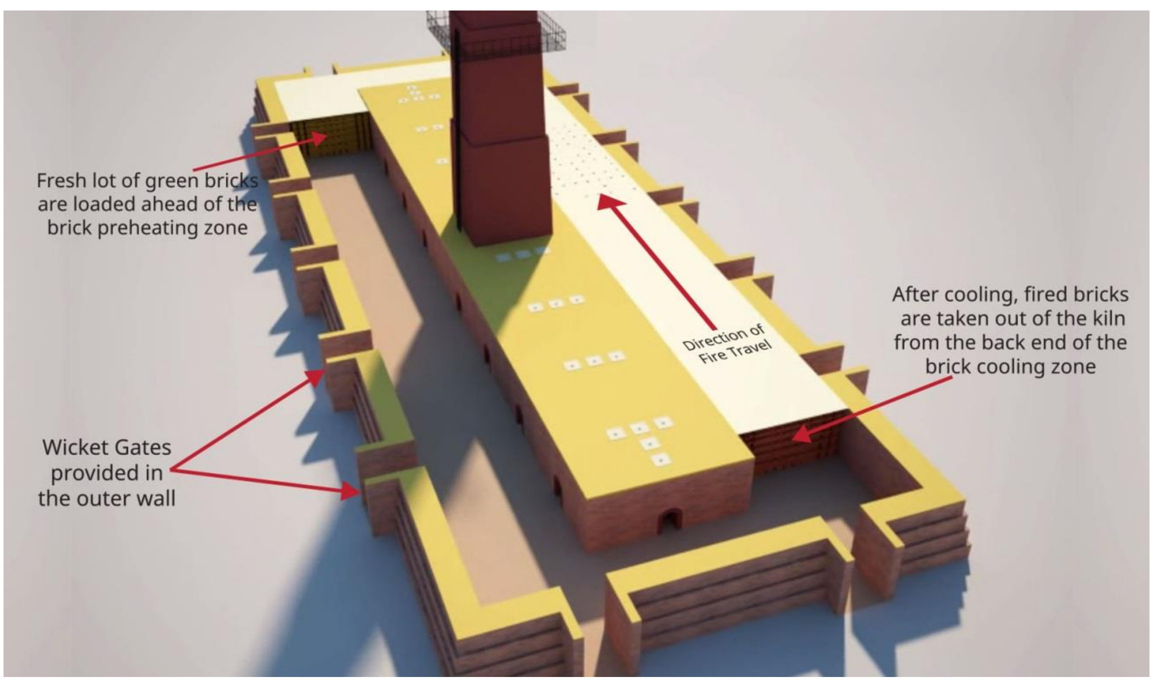


Figure 83: Flow of gases in a Zig-zag kiln

13.3 Main Advantages of Zigzag Kiln Technology

Zigzag kilns have several advantages over the traditional FCBTKs:

1. About 20%–25% savings in fuel consumption.
2. Better product quality –over 80% bricks are of Class-I quality.
3. Substantial reduction in carbon dioxide (CO_2) and PM emissions.

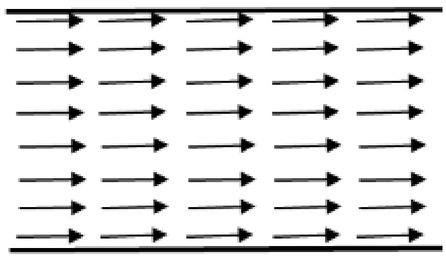
13.4 Points to remember

1. Zigzag kilns are an improvement over Fixed Chimney Bull's Trench Kilns (FCBTKs), in which air flows in a straight-line path.
2. The zigzag air flow considerably improves the combustion of fuel and heat transfer in a zigzag kiln, because of which its performance is better than an FCBTK.
3. In an operational Zigzag kiln, the bricks can be segregated into three distinct zones i.e. cooling zone, firing zone and preheating zone.
4. Zigzag kilns have several advantages over the traditional FCBTKs such as 25% less fuel consumption, over 80% class-I brick production and substantial reduction in pollutants' emission.

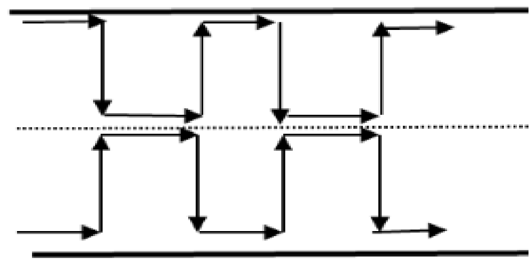
Module 14: Brick Setting Arrangement in a Natural Draft Zigzag Kiln

14.1 Basics of Brick Setting Arrangement

In natural draught zigzag kiln, the bricks are stacked in such a manner that the air follows a zigzag path.



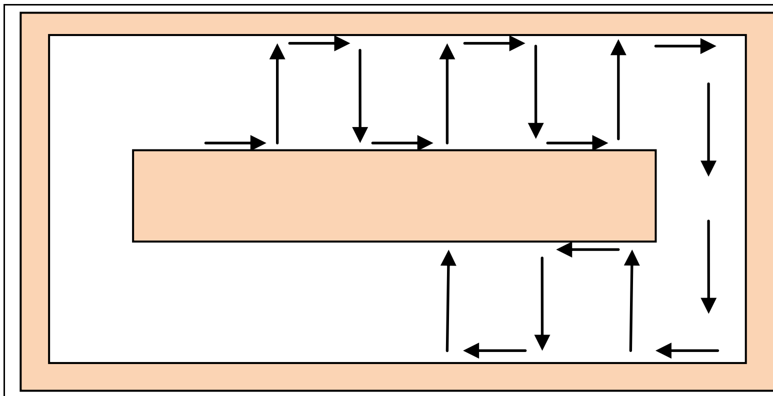
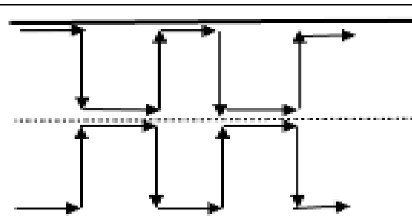
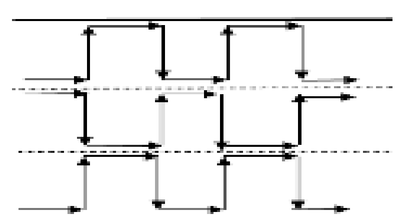
Straight line air flow (FCBTK)



Zigzag air flow (Zigzag kiln)

There can be one, two, or three parallel zigzag air flow streams in a kiln. Accordingly, the air flow and the brick setting are called single, double, or triple zigzag air flow and single, double, or triple zigzag brick setting, respectively.

Depending upon the trench width and the draught available in the kiln, single, double, or triple zigzag brick setting is practised in the kiln. For the same trench width, the draught required for air flow in a double zigzag brick setting is lower than that required in single zigzag brick setting and is further lower in triple zigzag brick setting.

	**Single zigzag brick setting or single zigzag air flow**
 **Double zigzag brick setting or double zigzag air flow**	 **Triple zigzag brick setting or triple zigzag air flow**

In natural draught zigzag kiln, mostly double or triple zigzag brick setting is practiced. A general thumb rule is given in table below:

Trench width (feet)	Brick setting
18 – 26	Double zigzag brick setting
27 – 35	Triple zigzag brick setting

14.2 Double Zigzag Brick Setting in NDZK

In an NDZK, bricks are stacked in such a manner that distinct chambers of brick setting are formed in the kiln. Just like in the case of FCBTK, in NDZK also, the bricks are stacked in vertical columns in a row across the width of the trench. However, unlike in FCBTK, all the brick columns are not of the same width. The rows of brick columns are stacked one ahead of the other in the forward direction of fire travel. In an NDZK, one chamber of brick setting consists of five such rows.

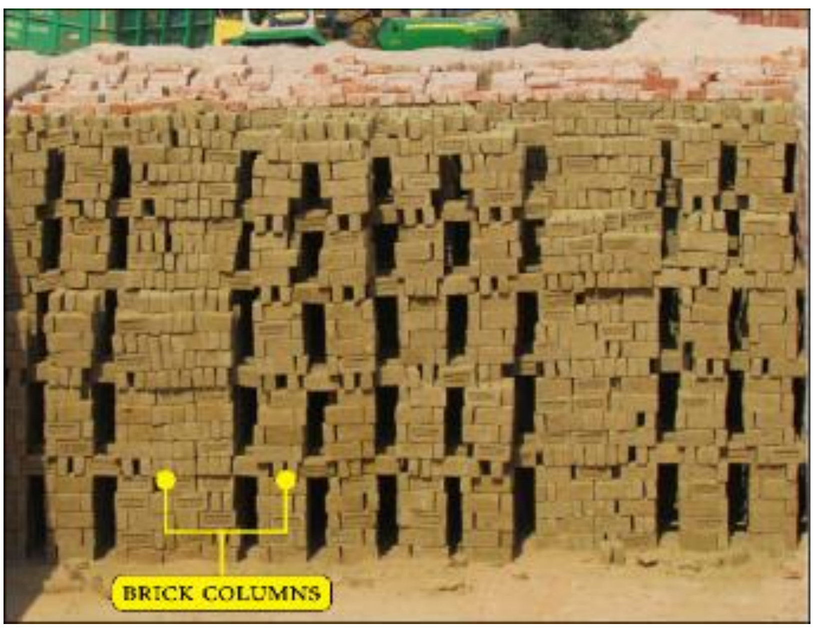
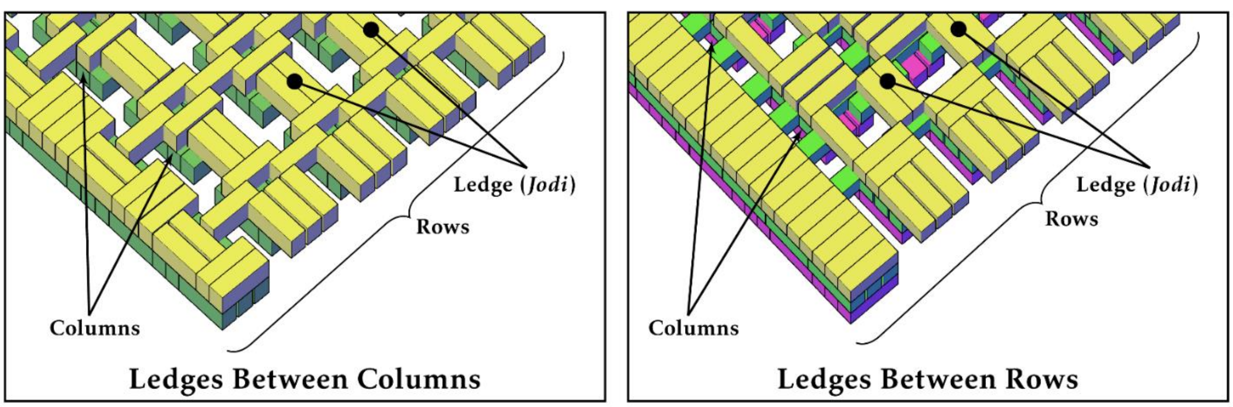


Figure 84: Different size columns in a Zig-zag kiln

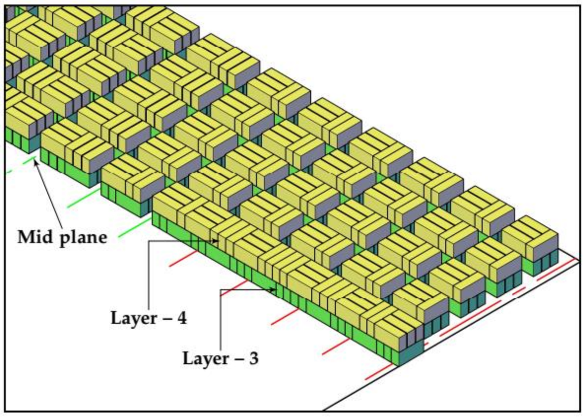
Consecutive rows (along the chamber length) are joined together by bricks, called as '*bandhan*', at multiple levels to keep the columns in vertical position. Consecutive columns in a chamber (along the chamber width) are joined together by a pair of bricks, called as '*jodi*' (ledge), at multiple levels to keep the columns in vertical position.

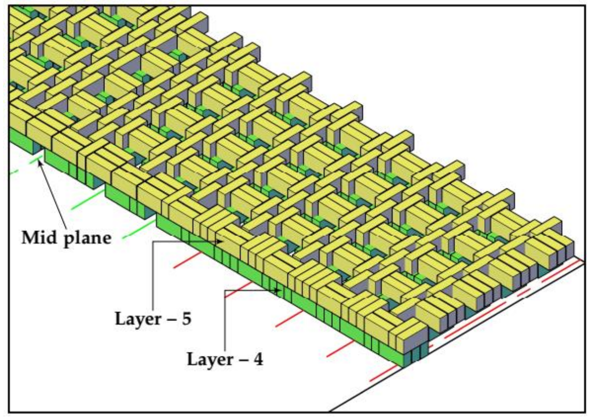
Figure 85: Brick-setting showing *Jodi* and *Bandhan* in a Zig-zag kiln

Irrespective of number of brick courses, ledges are provided at only 'five' layers in a chamber. All the ledges (Jodi) in a given layer are placed either between columns or between rows.



Courses containing ledges must be separated by at least three regular courses (except courses containing fourth and fifth level of ledges, which are separated by two regular layers).





The table below provides position of ledges for different brick-settings. It must be noted that ledges in a given layer are not in-line with the ledges in layers above or below. For example, for 21-layers chamber, first set of ledges are located between columns, second set between rows, third set again between columns and so on.

	Brick Setting			
	21-Layers	**22-Layers**	**23-Layers**	**24-Layers**
Ledge – 1 (Between columns)	5th layer	6th layer	7th layer	8th layer
Ledge – 2 (Between rows)	9th layer	10th layer	11th layer	12th layer
Ledge – 3 (Between columns)	13th layer	14th layer	15th layer	16th layer
Ledge – 4 (Between rows)	17th layer	18th layer	19th layer	20th layer
Ledge – 5 (Between columns)	20th layer	21st layer	22nd layer	23rd layer
Jaali (Top layer)	21st layer	22nd layer	23rd layer	24th layer

The air flow through the brick setting takes place through the gaps provided in between the brick columns. The openings for air flow in every fifth row (i.e., at the end of each chamber) are provided in such a way that it causes zigzag flow of air in the kiln.

In double zigzag brick setting, all the openings/gaps between the brick columns in the fifth row of one chamber (i.e. at the end of that chamber) are closed, except for three openings at each side. In the next chamber, in the fifth row, five openings at the center of the trench width are kept open and all other openings are kept closed. Similarly, in alternate chambers, such openings are left either at the centre or at the two ends of the trench width. This arrangement of openings in chambers results in the zigzag flow of gases, and is repeated throughout the length of the rectangular trench.

Figure 86: Openings at the ends of a chamber

Figure 87: Openings at the middle of a chamber

When seen from the top of the kiln, the flow of gases through a double zigzag brick setting will look like that in the image below:

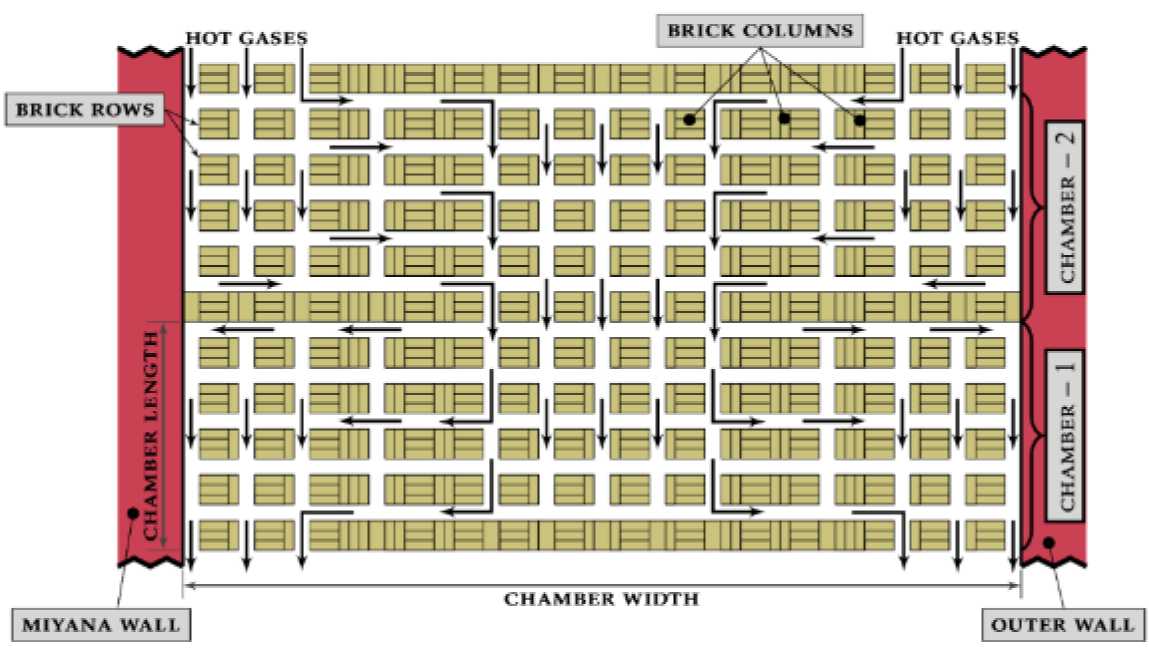


Figure 88: Zig-zag path of gases in a chamber

The zigzag brick setting is done only in the longer lengths of the rectangular trench. In the shorter lengths of the rectangular trench, which is often called as *Gully,* brick setting is done in straight line arrangement just like in FCBTK.

14.3 Points to remember

1. In natural draught zigzag kiln, the bricks can be stacked in single, double or triple Zigzag type.
2. Generally, the zigzag brick setting is done only in the longer lengths of the rectangular trench. In the Gully region bricks are stacked in traditional manner i.e. column type setting.

Module 15: Fuel Preparation and Feeding

15.1 Fuel Feeding Operation

In a Natural draught zigzag kiln (NDZK), fuel is fed continuously through the fuel-feed holes provided at the top of the kiln by a single fireman standing on the top of the kiln. Usually two firemen are deployed in a shift who feed fuel alternately. The fuel is fed in six chambers of the brick setting simultaneously. There are two rows of fuel-feed holes in each chamber and usually there are 7-11 fuel-feed holes in each row. The fuel is fed sequentially in six chambers (12 rows, about 84–132 feed holes), starting from fuel-feed holes of chamber-1 and going up to chamber-6. This cycle is repeated continuously in the firing zone.

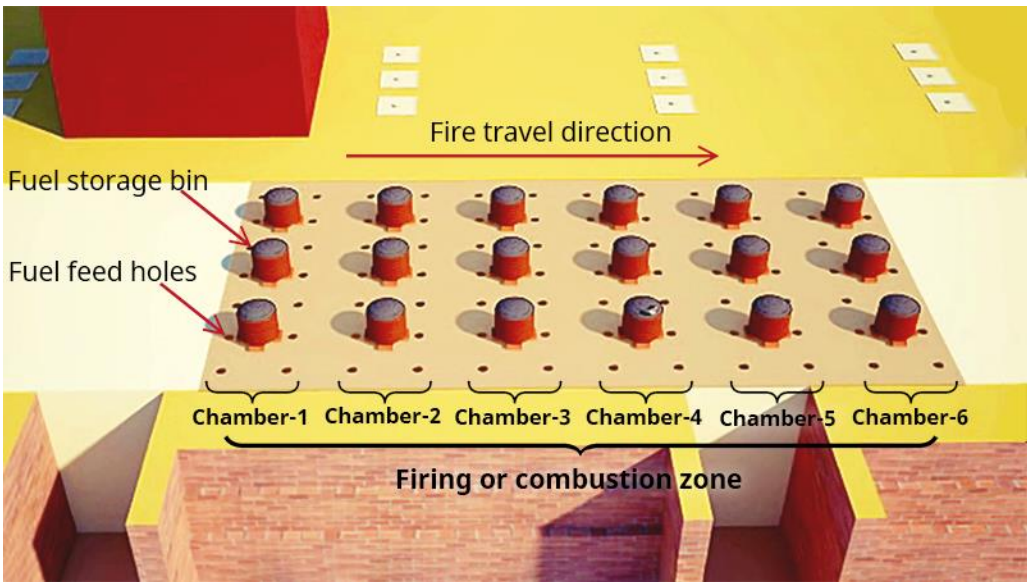


Figure 89: Firing zone of a Zig-zag kiln

In an NDZK, the fireman starts feeding fuel in chamber-1 from one end of the trench, and goes across the trench width to feed all the holes till he reaches the opposite end of chamber-1. The fireman then comes back to the starting end and starts feeding fuel in chamber-2 in the same manner. This sequence is repeated for other chambers till feeding is complete in chamber-6 to complete one feeding cycle. The new feeding cycle is again started from chamber-1.

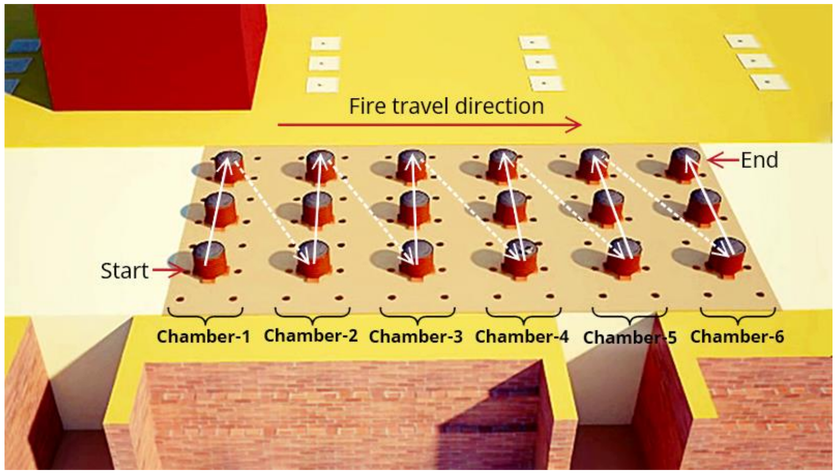


Figure 90: Fuel feeding path in a Zig-zag kiln

Figure 91: Single fireman feeding fuel in a Zig-zag kiln

Typically, in an NDZK (for all production capacities), three chambers are fired per day (fire travels about 18 feet (~5.5m) in 24 hours). In every 8 hours, a new chamber along the direction of fire travel is opened for fuel feeding.

15.2 Fuel preparation

15.2.1 Fuels used in NDZK

Usually solid fuels like coal, firewood, sawdust, and agriculture residues are used in NDZKs. fuel is fed in powdered form (less than 5 mm particle size). Fuel is fed continuously through the fuel-feed holes by a single fireman. Different sizes of spoons are used for feeding different fuels depending on fuel density. Sawdust requires larger spoon because of its low density. Medium sized spoon is used for feeding the mixture of sawdust and coal. Smallest sized spoon is used for feeding the coal. Generally, 200-400 g fuel is fed per spoon.

Figure 92: Different sized spoons are used in a Zig-zag kiln

Different sized spoons for fuel feeding

15.2.2 Fuel mix used in NDZK

The fuel is fed simultaneously in six chambers, however, the temperatures in different chambers are different. Ideally, the type of fuel or fuel mixture used in a particular chamber depends on the temperature to be maintained inside that chambers. A best practice example of fuel mixtures being used in different chambers of a NDZK is given below.

1. In the front chamber (chamber-6), which is just opened for fuel feeding, and where the brick temperature is relatively low, fuel that can burn easily (i.e., having low ignition temperature) and having high volatile content, such as sawdust, is fed. The temperature of bricks in this chamber is about 600-650 °C.
2. In Chamber-5, where the temperature has reached about 800-900 ^{0}C, a mixture of sawdust and coal is fed.
3. In chambers 4, 3 and 2, where the temperatures to be maintained are high (about 980-1050°C) so that vitrification is complete, high calorific value fuel such as coal, is fed.
4. In chamber-1, where the temperature of bricks is at about 800-900 ^{0}C, a mixture of sawdust and coal is fed.

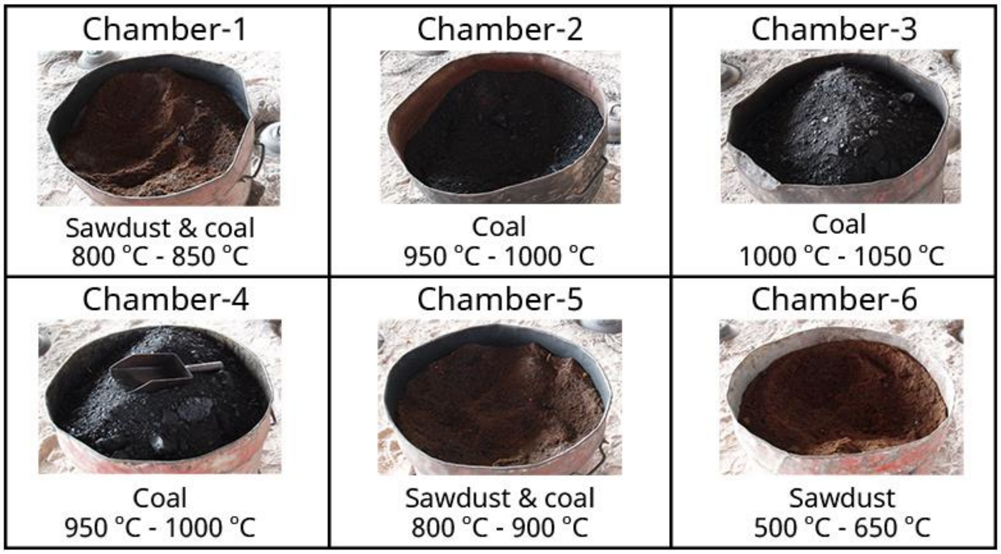


Figure 93: Temperatures maintained in different chambers of firing zone

15.3 Fire Temperature Colour Chart

The firemen estimate the temperatures in the brick firing zone by observing the colour of flames. The colour of flame at different temperatures is given in the chart below:

Colour		Temperature (°C)
Yellow		<475
Lowest Visible Red		475
Lowest Visible Red to Dark Red		475 to 650
Dark Cherry to Cherry Red		650 to 750
Cherry Red to Bright Cherry Red		750 to 815
Bright Cherry Red to Orange		815 to 900

15.4 Points to remember

1. Fuel must be fed continuously through the fuel-feed holes provided at the top of the kiln by a single fireman standing on the top of the kiln.
2. The sequence of starting the fuel feeding at chamber-1 and ending at chamber-6 must be followed in every feeding cycle.
3. Different sizes of spoons are used for feeding different fuels. Sawdust requires larger spoon, medium sized spoon is used for feeding the mixture of sawdust and coal and smallest sized spoon is used for feeding the coal.

Module 16: Air Flow and Control

16.1 Air Flow and Fire Travel in Natural Draught Zigzag Kiln

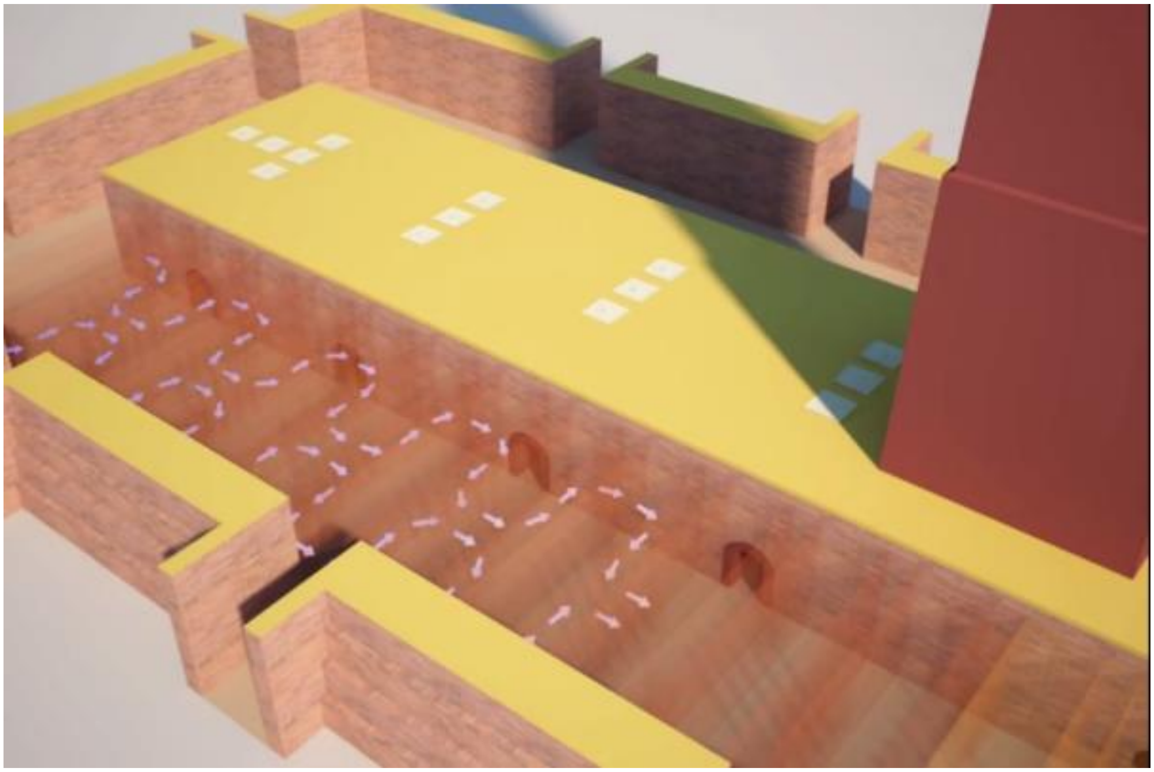


Figure 94: Double Zig-zag flow of hot gases in a Zig-zag kiln

In an NDZK, the fire moves along the forward direction of air flow. The air flow in the kiln is caused by the draught created by the chimney. The air flows in a zigzag path through the brick setting inside the kiln.

The back end of the brick cooling zone, where unloading of fired bricks from the kiln happens, is kept open to allow entry of air from the surroundings into the kiln. The front end of the brick preheating zone is sealed with the help of polythene sheets or tarpaulin to guide the flue gases to the chimney through the flue gas duct system.

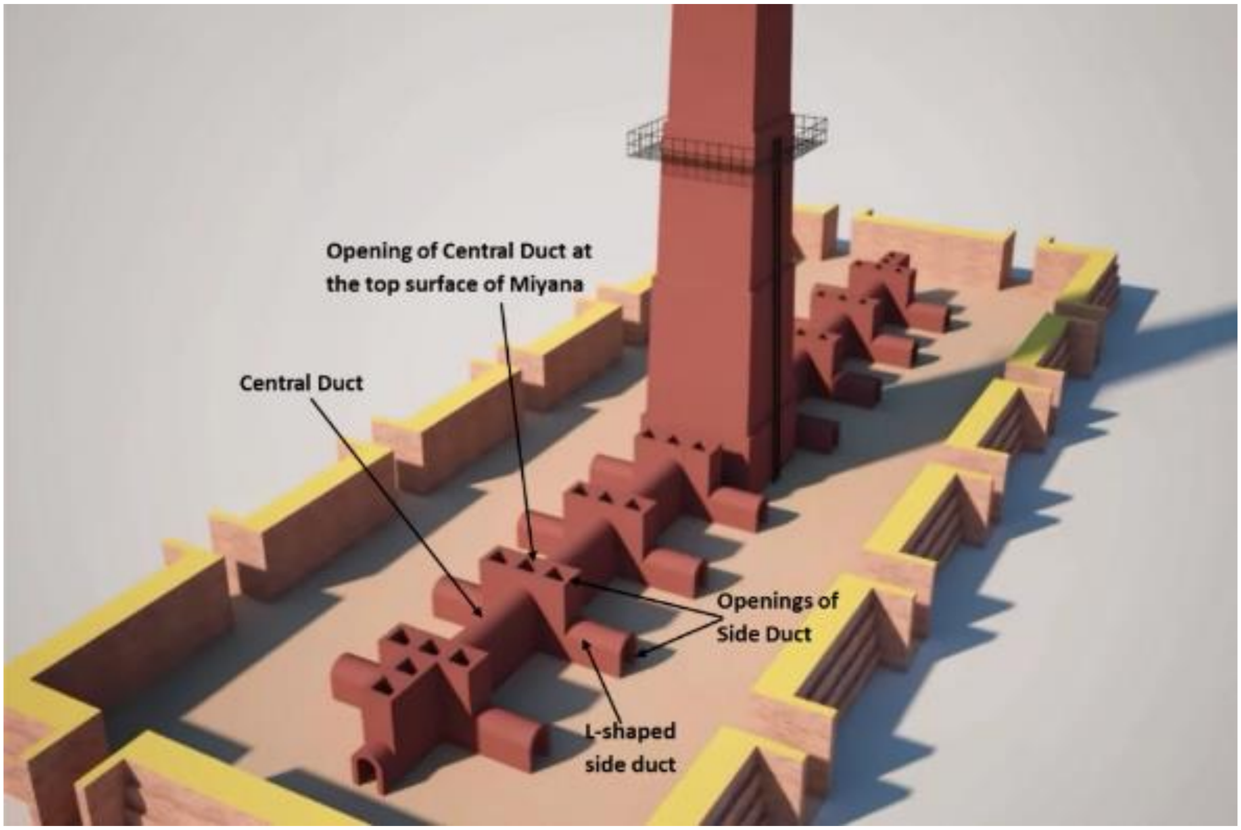


Figure 95: Arrangement of ducts in a Zig-zag kiln

The flue gas duct system consists of a central duct and several side ducts. The central duct originates from the bottom of the chimney and extends along the length of the miyana in both directions till the end. The side ducts are L-shaped ducts, which are provided at regular spacings along the perimeter of the miyana. One end of each side duct opens in the kiln while the other end opens at the top surface of the miyana. Adjacent to the top openings of the side ducts, the central duct also has openings at the top surface of the miyana.

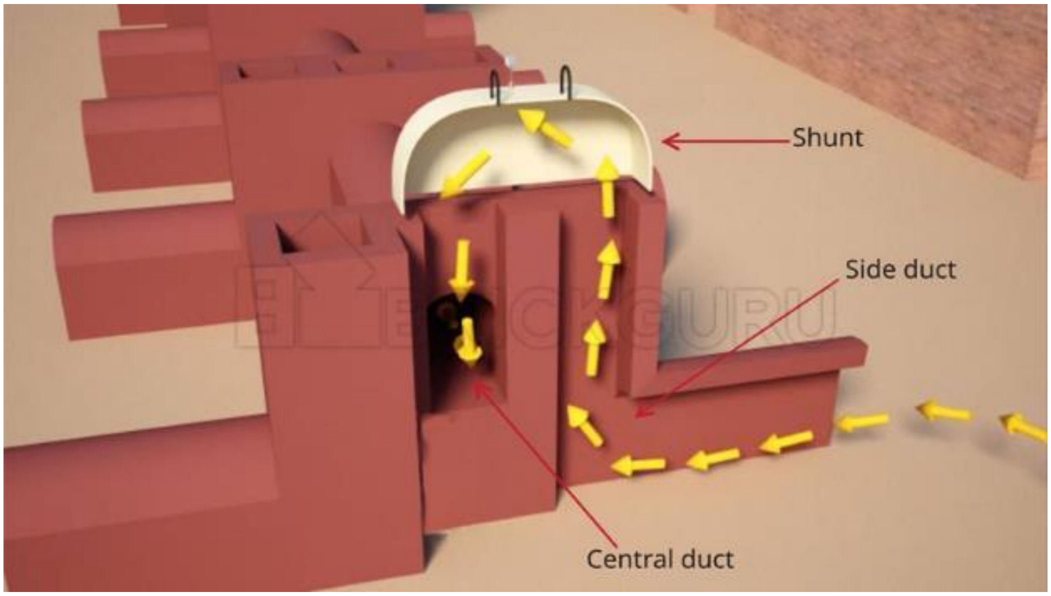


Figure 96: Design of central-duct in a Zig-zag kiln

The side ducts are connected to the central duct with the help of a shunt. The shunt is an inverted U-shaped metallic duct that is used to connect the top opening of a side duct to the adjacent opening of the central duct located at the top surface of the miyana. At a time, only one or two side ducts are in use to connect the kiln to the central duct for the passage of flue gases. The top openings of the side ducts and the central duct that are not in use are closed with the help of concrete slabs.

Air from the surroundings enters the kiln at the brick unloading end and flows through the brick cooling zone into the brick firing zone where it is used for burning the fuel. The hot flue gases flow into the brick preheating zone, and then through the open side ducts and central duct before coming out through the chimney. In the process, the cold air gets heated by the burnt bricks and transfers heat from the cooling zone to the firing zone, and the hot flue gases get cooled by the green bricks and transfer heat from the firing zone to the preheating zone.

As burning of bricks gets completed in a chamber, fuel feeding is stopped and fuel-feed holes in a new chamber in front of the firing zone are opened for fuel feeding. Usually in every 24 hours, a new side flue duct in the direction of fire travel is opened to sustain the fire movement.

16.2 Air leakage and its impact on kiln performance

Air is required in the kiln for the combustion of fuel to produce heat and for heat recovery. Heat recovery means the transfer of heat from the brick-cooling zone to the firing zone and from the firing zone to brick preheating zone. Ideally, all the air should enter the kiln from the brick unloading end and should flow through the cooling zone, the firing zone, the preheating zone, and the flue gas ducts before coming out through the chimney.

The inside of the kiln is at a lower pressure compared to the atmospheric pressure. Therefore, there is a possibility of cold air from the surroundings leaking into the kiln through wicket gates, kiln roof, flue gas ducts, kiln walls, and tarpaulin.

Any leakage of air into the kiln will reduce the amount of air entering the kiln from the brick unloading end, and hence will reduce the extent of heat recovery. Air leaking into the kiln at a point ahead of the firing zone will result in lesser amount of air being available for the combustion of fuel. This will reduce the combustion efficiency and the daily production. Leakage of cold air near to the firing zone will also create difficulty in maintaining high temperatures and will eventually increase the fuel intake.

Preventing air leakages will reduce fuel consumption and improve the product quality.

16.2.1 Leakage control

Following measures should be taken for prevention or control of air leakage

- Proper care should be taken while construction of the kiln. Kiln walls and flue gas ducts, if not properly constructed, can cause significant air leakage during operation of kiln
- The wicket gates should be closed with double layer wall, with cavity in between the layers filled with ash, to prevent air leakage.

Figure 97: Proper closing of wicket during firing

- The openings of flue gas ducts, which are not in use, should be properly closed with concrete slab, and ash layer should be laid along the edges to prevent air leakage.
- The shunt should be properly placed.
- A thicker layer of ash (6-9 inch thick) should be uniformly laid on the kiln top. It should be regularly checked for any hole/opening that can appear in the ash layer during kiln operation, and should be immediately closed.

16.3 Points to remember

1. The front end of the brick preheating zone is sealed with the help of polythene sheets or tarpaulin to guide the flue gases to the chimney through the flue gas duct system.

2. Ideally, all the air should enter the kiln from the brick unloading end and should flow through the cooling zone, the firing zone, the preheating zone, and the flue gas ducts before coming out through the chimney.
3. Any leakage of air into the kiln will reduce the amount of air entering the kiln from the brick unloading end, and hence will reduce the extent of heat recovery.
4. Leakage of cold air near to the firing zone will also create difficulty in maintaining high temperatures and will eventually increase the fuel intake.
5. Wickets should be closed with double layer wall, with cavity in between the layers filled with ash, to prevent air leakage.

Module 17: Labour Laws and Rights

17.1 Labour Laws and Rights

Indian labour law refers to laws regulating labour in India. Labour rights or workers' rights are a group of legal rights and claimed human rights having to do with labour relations between workers and their employers, usually obtained under labour and employment law.

- Everyone has the right to work, to free choice of employment, to just and favourable conditions of work and to protection against unemployment.
- Everyone, without any discrimination, has the right to equal pay for equal work.
- Everyone who works has the right to just and favourable remuneration ensuring for himself and his family an existence worthy of human dignity, and supplemented, if necessary, by other means of social protection.
- Everyone has the right to form and to join trade unions for the protection of his interests.

- Everyone has the right to rest and leisure, including reasonable limitation of working hours and periodic holidays with pay.
- Article 14 of the Indian Constitution states everyone should be equal before the law;
- Article 15 specifically says the state should not discriminate against citizens, and
- Article 16 extends a right of "equality of opportunity" for employment or appointment under the state.
- Article 19(1)(c) gives everyone a specific right "to form associations or unions". Article 23 prohibits all trafficking and forced labour, while article 24 prohibits child labour under 14 years old in a factory, mine or "any other hazardous employment".

The Payment of Wages Act 1936 requires that employees receive wages, on time, and without any unauthorised deductions. Section 6 requires that people are paid in money rather than in kind. The law also provides the tax withholdings the employer must deduct and pay to the central or state government before distributing the wages.

- Article 14 states everyone should be equal before the law;
- Article 15 specifically says the state should not discriminate against citizens, and
- Article 16 extends a right of "equality of opportunity" for employment or appointment under the state.
- Article 23 prohibits all trafficking and forced labour, while article 24 prohibits child labour under 14 years old in a factory, mine or "any other hazardous employment".

Child labour in India is prohibited by the Constitution, article 24, in factories, mines and hazardous employment, and that under article 21 the state should provide free and compulsory education up to a child aged 14 years.

17.2 Labour laws and rights pertaining to brick kilns

17.2.1 Bonded labour and rights against it

In India, a system of bonded labour was existing where whole families of peasant farmers were socially and economically dependent on their landlords down the generations. Presently, in brick kilns, agriculture and some other sectors, workers work to repay the advance being taken by them particularly in the off season and then getting trapped in a cycle of debt with the owner or contractor. This is known as debt bondage.

Basic characteristics of this debt bondage are:

1. Advance money paid to the workers.
2. Below minimum wages (a state that arises due to the existing debt on the workers as a result of the advance money being paid to them)
3. Long hours of work on an average 12-16 hours a day and lack of mobility.

Taking of advance payment is a common practice among brick kiln workers.

Remedy for Bonded Labour System: Bonded Labour is prohibited in India by law vide Article 21 and Article 23 of the Constitution of India. Specific law which has abolished the Bonded Labour System is the Bonded Labour System Abolition Act of 1976.Under this law bonded labourers stand freed and discharged from any obligation to render to bonded labour. The Act is a Central Act whereas the responsibility to implement the provisions of the Act lies with the different state governments. The responsibility of identifying bonded labourers lies with the District Magistrate, who heads the Vigilance Committee constituted under the Act. The National Human Rights Commission (NHRC) is mandated to oversee the implementation of the Bonded Labour System (Abolition) Act. A written application consisting of grievances can be sent to them in cases of issues of forced labour at brick kilns.

Relief available to the victim: The bonded labour is to be immediately released from the bondage. His liability to repay bonded debt is deemed to have been extinguished. Freed bonded labour shall not be evicted from his homesteads or other residential premises which he was occupying as part of consideration for the bonded labour. A rehabilitation grant of Rs. 20,000/- to each of the bonded labour is to be granted and assistance for his rehabilitation provided.

17.2.2 Rights of migrant workers

Workers who move from place to place to get work, especially seasonal work are called migrant workers. Majority of workers at the brick kilns are migrants: interstate or intrastate.

For protection of rights of interstate migrant workers, the government has in place The Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Act, 1979. It applies to any workplace/establishment in which five or more than five inter-state migrant workers have been employed or were employed in the previous twelve months. The Act makes it mandatory for such establishments to register who have employed or is employing inter-state workmen. It calls for issuing of licenses for contractors who employ interstate workers. The contractor must furnish details to the specified authority in the State from which such inter-state workmen are recruited. It should also issue to all the inter-state workmen a pass–book affixed with a passport size photograph of the workman with the details like name, place of the establishment, period of employment, proposed rates and modes of payment of wages, the displacement allowance payable, return fare payable to the workman on the expiry of the period of his employment, deductions made. The contractor is responsible for making payment of wages to the inter-state workers within the prescribed periods and in case the contractor fails to pay the same to the workers then the principal employer is made liable for the same for whatever amount has not been paid to the workers.

The Act further provides punitive punishment for contravening provisions of employment or licensing provided under the Act. Such contravention is punishable with an imprisonment which may extend to one year or a fine of one thousand rupees, or both. A displacement allowance equal to 50% of monthly wages or Rs.75/- whichever is higher to be paid at the time of recruitment to the workers. The displacement allowance is to be given by the Contractor to the migrant workers.

Remedy available to the migrant workers: The Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Act, 1979 provides for the appointment of the Inspector for carrying out the provisions of the Act. Workers can approach and make a complaint to the Inspector who is appointed under the Act by the appropriate State Government.

The Inspector is vested with the powers to enter the premises of any establishment or place where the Inter-State migrant workmen have been employed for the purpose of satisfying himself whether the provisions of the Act in relation to payment of wages, conditions of service or other facilities to be provided to such workmen have been complied with or not.

For this purpose, he can examine any register or record of notice required to be kept or exhibited vide the provisions of the Act and can also ask for the production therefore for inspection. The inspector can also examine any person in such premises or place for the purpose of determining whether such a person is an Inter-State migrant workman.

17.2.3 Coverage of brick kilns under the Factories Act, 1948

Brick kilns are classified as factories within the meaning of the Act, as it has been established that the process of manufacturing bricks comes within the definition of the manufacturing process as defined under the Factories Act and that the premises where the process is carried on, is covered by the expression “Premises” used in the definition of factory in the Act.

Therefore, provisions with regards to health, safety and welfare of workers also apply to the brick kilns. The Act provides for effective arrangements to maintain sufficient supply of wholesome drinking water, sufficient latrine and urinal facility, including separate enclosed facility for male and female workers, and adequate and suitable facilities for washing. First-aid boxes equipped with the prescribed contents are also to be provided in the premises.

Every worker who has worked 240 days in a year is entitled for leave with wages at the rate: one day's wage for every 20 days he worked for adult and one day's wage for every 15 days work for a child. He/she may take leave during or after completion of the year. In the case of a female worker, maternity leave with wages are to be provided for any number of days not exceeding twelve weeks.

Remedy under the Factories Act: If provisions of the Factories Act are being violated then one can approach labour inspector or other labour officials and ask them to visit the brick kiln worksites for inspection. This inspection can be with regards to health, safety and/or welfare measures taken up at the brick kilns. Alternatively, a written application about such grievances can also be sent to the labour department.

17.2.4 Contract Labour and rights under the Contract (Regulation and Abolition) Act, 1970

The Contract (R & A) Act provides for licensing of both the contractor and the principal employer and lays down elaborate list of facilities like canteens, toilets, rest rooms, crèches, washing facilities, first aid, etc., to be provided to the workers while on job. The act also outlines duties of the contractor with respect to payment of wages to the workers. It bounds the contractor to pay wages timely and before representatives of principal employer. Significantly, the Act also states that workers cannot be paid by the contractor at rates which less than what has been given under the Minimum Wages Act, 1948.According to Act, the wages of the contract labour shall not be less than the rates prescribed under Minimum Wages Act, 1948.The Act applies to every establishment/contractor in which 20 or more workmen are employed or were employed on any day in the preceding 12 months as contract labour and to every contractor who employs or who employed on any day of the preceding 12 months, 20 or more workmen.

In cases where the contract worker performs the same or similar kind of work as the workmen directly employed by the principal employer of the establishment, the wage rates, holidays, hours of work and other conditions of service shall be the same as applicable to the workmen directly employed by the principal employer doing the same or similar kind of work.

Remedy under the Act: The workers doing same or similar work and not getting same wages can raise the issue before the appropriate "Government". The Central Government is the appropriate Government in respect of the establishments falling in Central sphere. The private companies in non-government sector and unorganized sector come in State sphere. Brick kilns fall under the state sphere. In the state concerned, the complaints can be made to the Deputy Labour Commissioners of that particular state.

17.2.5 Rights of Workers to receive Minimum Wages

Under the Minimum Wages Act, 1948 it is mandatory under the Act for the employer to maintain a register of wages of all the employees working in the enterprise. Under the Minimum Wages Rules 1950 it is stated that employers are required to issue wage slips to all workers mentioning the wage period, payment in each wage period, date of payment, amount of deduction, number days where overtime was worked.

OBLIGATIONS OF THE EMPLOYER UNDER THE MINIMUM WAGES ACT

REGISTERS	FORM NO.	WHEN TO COMPLY
Muster Roll cum Wage register	II	To be always maintained
Inspection Book		To be always maintained
Abstract	I	To be always displayed
Attendance cum wage slip or wage card		To be always maintained
All registers and records to be preserved for a period of THREE years		

Source: http://www.cec-india.org/

All the provisions of the Act equally apply to both male and female workers and it does not provide for any discrimination to an inter-State migrant workman in terms of wages.

Remedy available under Minimum Wages Act: The presiding officers of the Labour court and Deputy Labour Commissioners hear and decide claims arising out of payment of less than the minimum rates of wages. One can file a claim petition with them. The employee or any legal practitioner or any official of a registered Trade Union or any Inspector or any other authorized person may file a claim petition under this Act.

If the employer is not maintaining the prescribed registers, complain can be file with the Assistant Labour officer having jurisdiction over the area where he is notified as the Inspector under the Minimum Wages Act.

17.2.6 Working hours and rest time

Brick kilns fall under the ambit of factories under the Factories Act, 1948 which states that a worker cannot be employed for more than 48 hours in a week. Compulsory weekly holiday has to be provided to the workers and added to this a worker cannot be employed for more than 9 hours in a day. Minimum one holiday to be provided within 10 working days to the worker. Extra wages to be paid for overtime. In a day, a worker can be employed for maximum of ten and a half hours of work (including intervals).

WORKING HOURSE OF ADULTS

Weekly Hours: < 48 hours

Weekly Holidays: Minimum 1 holiday in a week, swap holidays

Compensatory Holidays

Daily Hours <9 hours

Intervals for rest: at least half an hour

Night Shifts

Source: http://www.cec-india.org/

17.2.7 Constitutional rights of workers

Article 14 of the Constitution talks about equality before law and the concept of "equal pay for equal work" is derived from this Article of the Constitution. Secondly, Article 19(1)(c) provides the right to form association and unions. Dignity of human labour is recognised under Article 21 of the Constitution which provides for Right to lead a life with dignity. Article 23 of the Constitution prohibits traffic in human being and beggar and other similar forms of forced labour.

There are certain directive principles which cater to the interest of workers as human beings. They provide for:

1. For securing the health and strength of employees, men and women.
2. That the tender age of children is not abused.
3. That citizens are not forced by economic necessity to enter avocations unsuited to their age or strength.
4. Just and humane conditions of work and maternity relief are provided and,
5. That the Government shall take steps, by suitable legislation or in any other way, to secure the participation of employee in the management of undertakings, establishments or other organisations engaged in any industry.

Remedy: In order to provide legal assistance and legal aid to the unorganized workers in respect of any claim or defence before any court or other authority and to ensure efficient implementation of beneficial schemes to the organised sector workers, the State has come up with a Scheme called "National Legal Services Authority (Legal Services to the Workers in the Unorganised Sector) Scheme 2015"

In order to provide effective legal services to the workers in this sector, each State Legal Services Authority (SLSA) forms a special cell focusing exclusively on these services. The cell is manned by one panel lawyer specialising in Labour Laws, one counsellor, wherever feasible, representative of an NGO and Para Legal Volunteers.

The special cell for Unorganized Workers provides counselling, legal assistance and legal aid by way of legal representation before any court or other authority, as required, to all Unorganized Workers.

17.2.8 Employer- Employee relationship

Entering into an agreement with the employer is in the best interest for both the employer as well as the employees (workers). The agreement acts as a proof of employment for the workers, thus providing them benefits under various labour laws and schemes formulated by the government. The employer cannot go against the terms of the agreement which he has signed with the employee. He has to abide by the terms mentioned in it. Under the law, it is mandatory for the employer of brick kiln workers to maintain a register with the name of all the workers. Records are important because they help in providing social security benefits to the workers. For instance, the Maternity Benefits Act, 1961 requires a muster roll to be maintained at each kiln and the nonappearance of any woman from the roll prohibits them from maternity benefits accessible under the Act.

Workers should also maintain their own record of the account of bricks that they work upon every day.

Remedy: A consequence of entering into an agreement with the employer or the contractor is that the terms of the employment are defined and noted. Non-abidance of the terms of the agreement is a breach of the contract which is a violation of the law. Secondly, the employers are forced to enter the names of such workers in official records, thereby creating a database for such workers. This database helps the workers in being identified as a worker for the purpose of government based social security schemes.

17.2.9 Right to unionise

A group or association formed by people with common interest or purpose is a union. A union caters to the needs and interest of people which forms part of it by presenting these interests to the employers. There is a clear recognition guaranteed by the Constitution of India for individuals "to form associations or unions". This right has been provided as a fundamental right under Article 19 of the Constitution.

In addition to the above there is a specific statute related to the labour unions, which is the Trade Unions Act of 1926.It legalizes the formation of trade unions and provides safeguards for trade union related activities. Labour Unions provide workers an opportunity to make their concerns be heard by the management through the use of collective bargaining.

17.2.10 Injury related compensation to workers

The Employee's Compensation Act, 1923 provides that in the case of an employment injury, compensation is to be provided to the injured worker and in case of his/her death to his/her dependants. An employer is liable to provide monetary compensation to a disabled worker, or to his/her dependents in case of his/her death, if the disablement or death occurs "out of and in the course of employment."

Employer to compensate in following cases:

1. Death.

2. Permanent Total Disablement.
3. Permanent Partial Disablement.
4. Temporary disablement whether partial or total.
5. Contracted Occupational Diseases.

The employer is only liable under the Act in cases of where disablement to the worker is for more than 3 days. The compensation is provided in accordance with the following:

1. In cases of death: an amount equal to 50% of the monthly wage multiplied by the relevant factor or Rs. 80,000/-, whichever is more.
2. In case of permanent total disablement, it is 60% or Rs. 90,000/- whichever is more and,
3. In case of permanent partial disablement occurs then the compensation is proportionate to the disability arrived as at (2) above.

Remedy under the Act: In order to receive compensation, the worker or his/her dependents have to give a notice to their employer. If the employer refuses or fails to provide compensation to the injured worker then the worker can file an application to the Commissioner for Employee's Compensation under the Employee's Compensation Act, 1923 of the area where the accident took place or, where the claimant ordinarily resides or, where the employer's registered office is located. After hearing both the parties, the Commissioner decides the claim. Any agreement whereby an injured worker or his/her dependant, relinquishes or reduce his right to receive compensation is null and void to that extent.

17.3 Points to remember

1. Labour rights or rights of workers are a group of legal rights available to the workers which cater to the labour relationship between the worker and the employers.
2. Fundamental labour rights include decent working conditions, minimum wages, decent working hours, right to unionise, safety at workplace, equal pay for equal work etc.
3. The debt bondage is with regards to advance being taken by workers particularly in the off season and then getting trapped in a cycle of debt with the owner or contractor. Bonded Labour is prohibited in India by law vide Article 21 and Article 23 of the Constitution of India and particularly under Bonded Labour System (Abolition) Act, 1976.
4. Discrimination at brick kilns is generally faced by:
    - Migrant Workers;
    - Workers belonging to minority groups;
    - Women workers not being recognised as workers at brick kilns;
    - Workers belonging to different religions;

5. The rights of interstate migrant workers are protected by the government through The Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Act, 1979.
6. Factories Act, 1948 ensures health, safety, welfare, proper wages and annual leaves for workers working in brick kilns.
7. Under the Minimum Wages Act, 1948 it is mandatory under the Act for the employer to maintain a register of wages of all the employees working in the enterprise.
8. For protection of interest and rights of women, The Equal Remuneration Act, 1976 has been provided which is a beneficial legislation which ensures adequate payment or remuneration to be made irrespective of the physical strength of employee and removing the scope of social and economic in justice merely on the ground of sex, thereby working to establish a just society in the country.
9. A group or association formed by people with common interest or purpose is a union. Workers are provided with a right to form a union which has been provided as a fundamental right under Article 19 of the Constitution.
10. In case of injury or death of worker during work compensation has to be provided under The Employee's Compensation Act, 1923 which provides that in the case of an employment injury, compensation is to be provided to the injured worker and in case of his/her death to his/her dependants.
11. Complaint with regards to benefits available to the workers can be filed with the labour commissioner or other labour officials. Cases of bonded labour and/or child labour can also be reported to the local police.