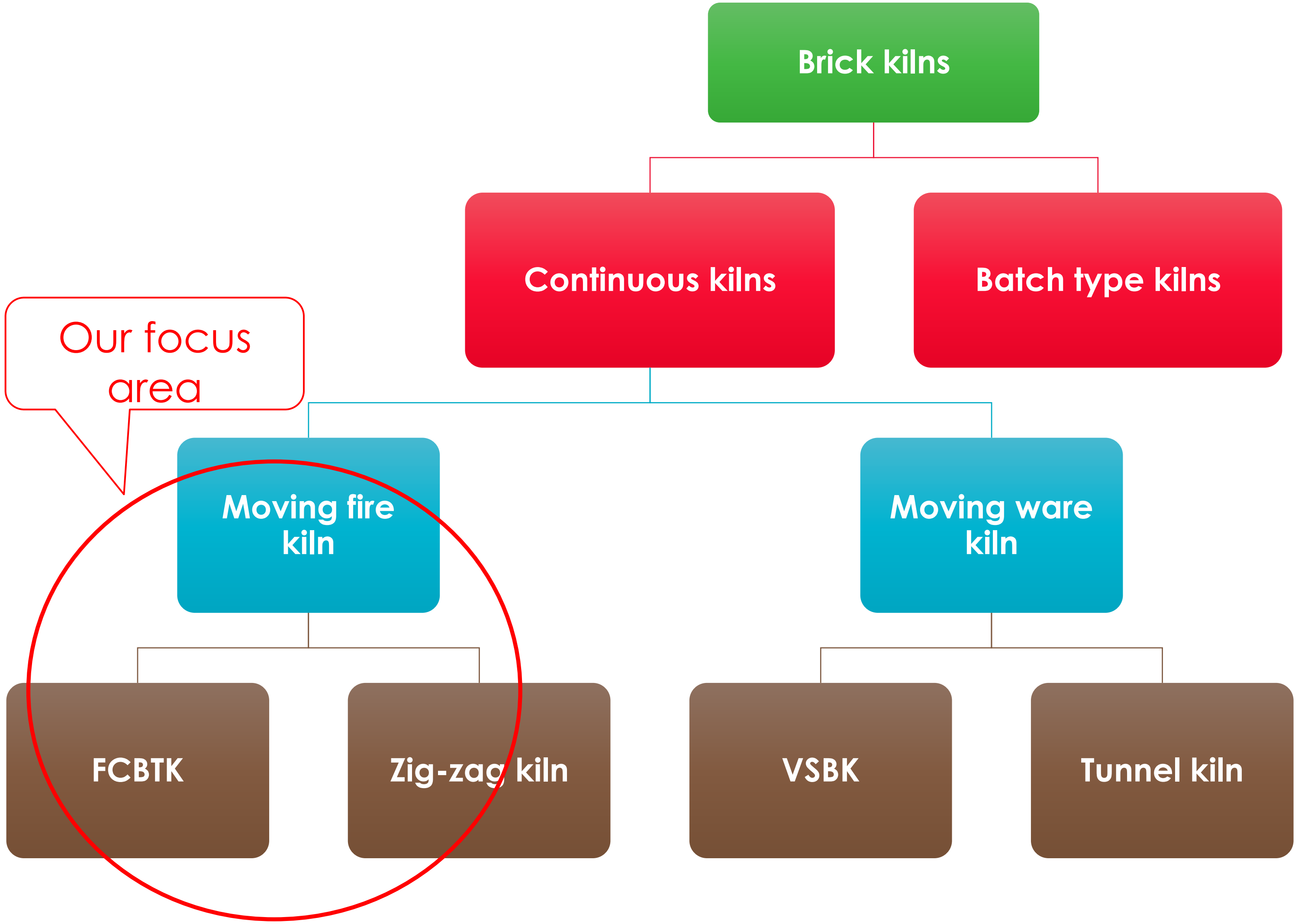
ICIMOD

Zig-zag brick kiln operation

Sagar Adhikari &
Bidya B Pradhan, ICIMOD
Date: 20 March 2023

Types of brick kilns

Type of brick kilns



Batch type kilns

Clamps

Downdraft Kiln

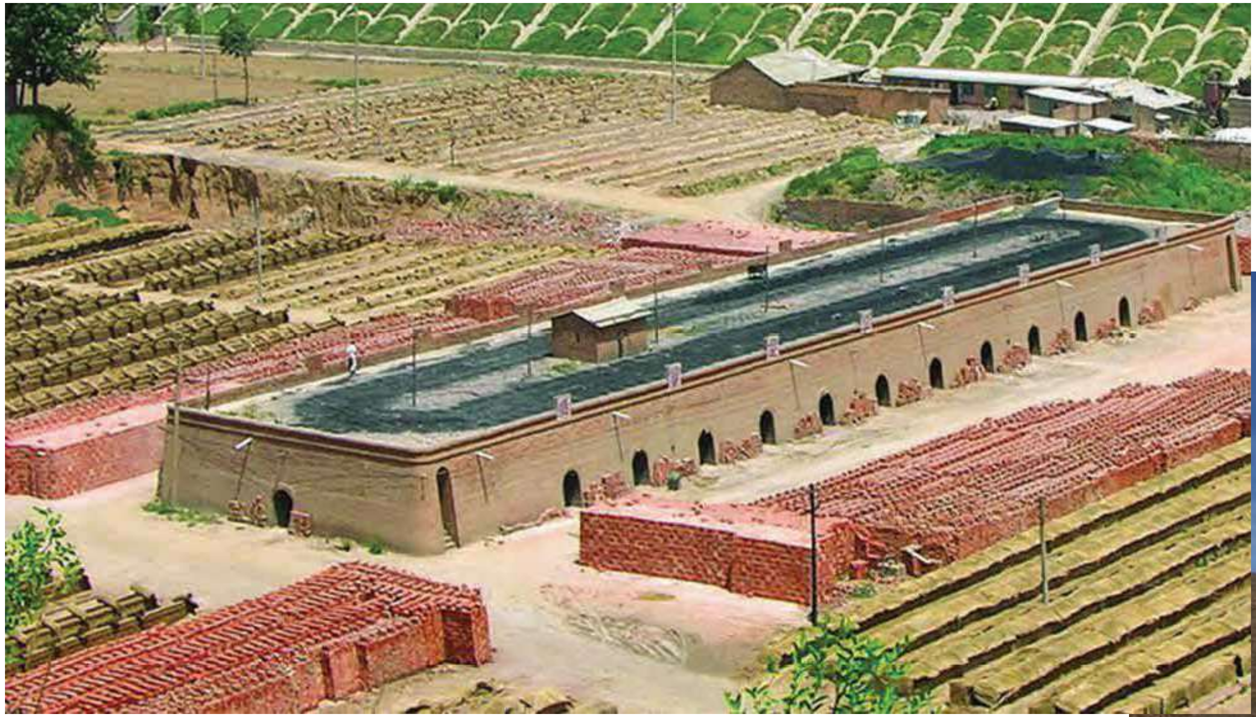
Continuous kilns – moving fire

Hoffman

FCBTK ZZ

FCBTK

Continuous kilns – moving fire

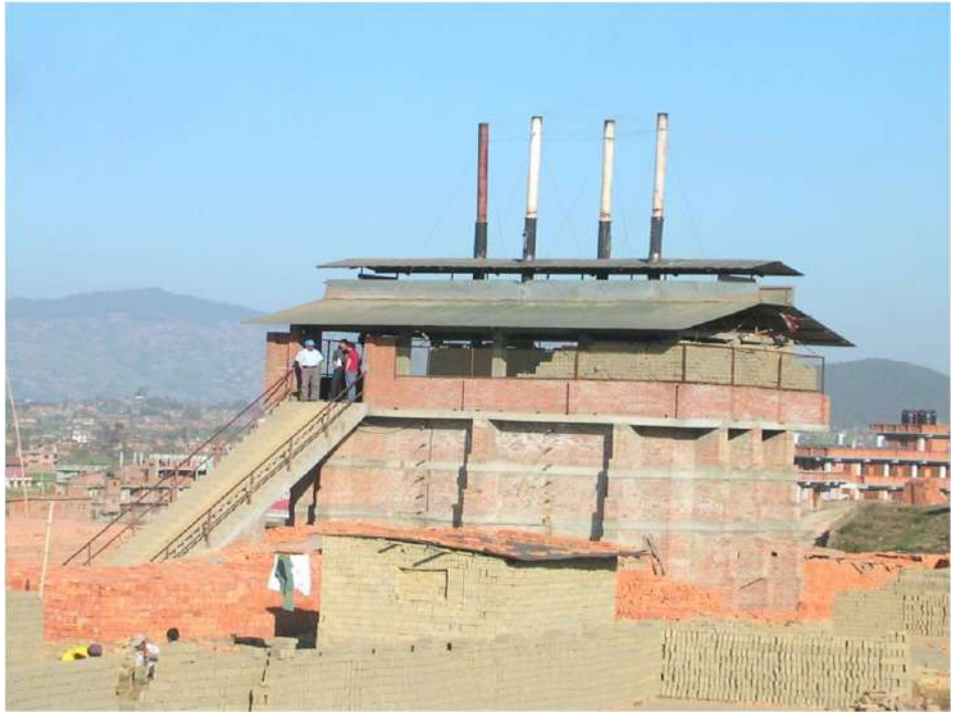


Hybrid Hoffman

Habla ZZ

Continuous kilns – moving ware

VSBK

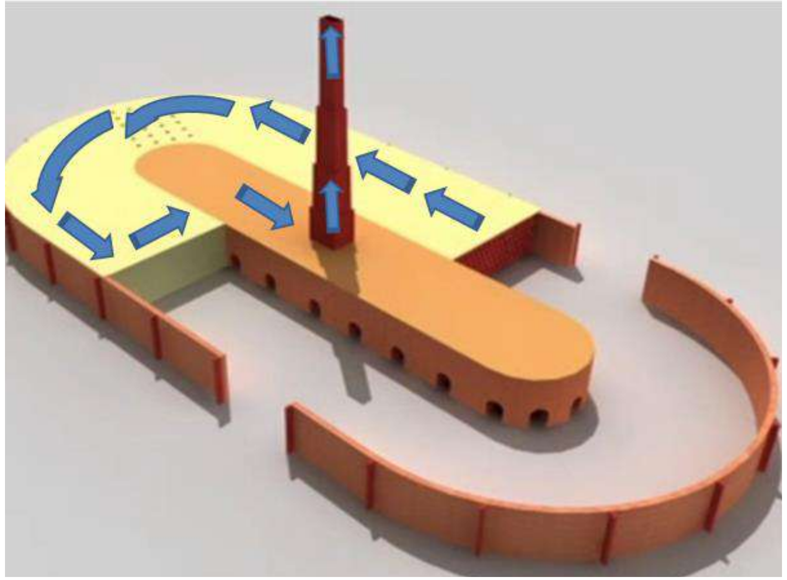


Tunnel

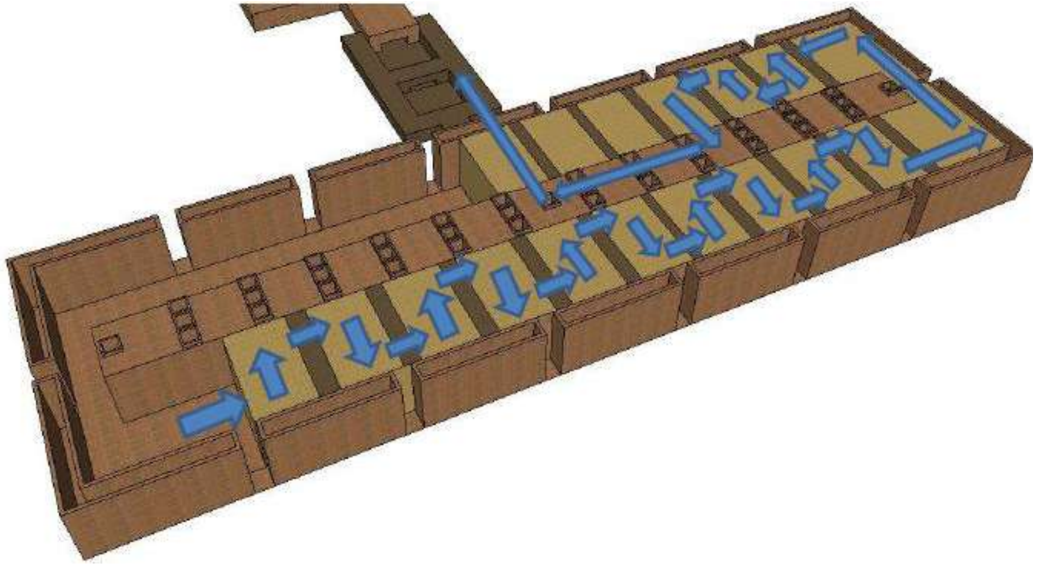
FCBTK vs zig-zag kilns

Comparison

Comparison

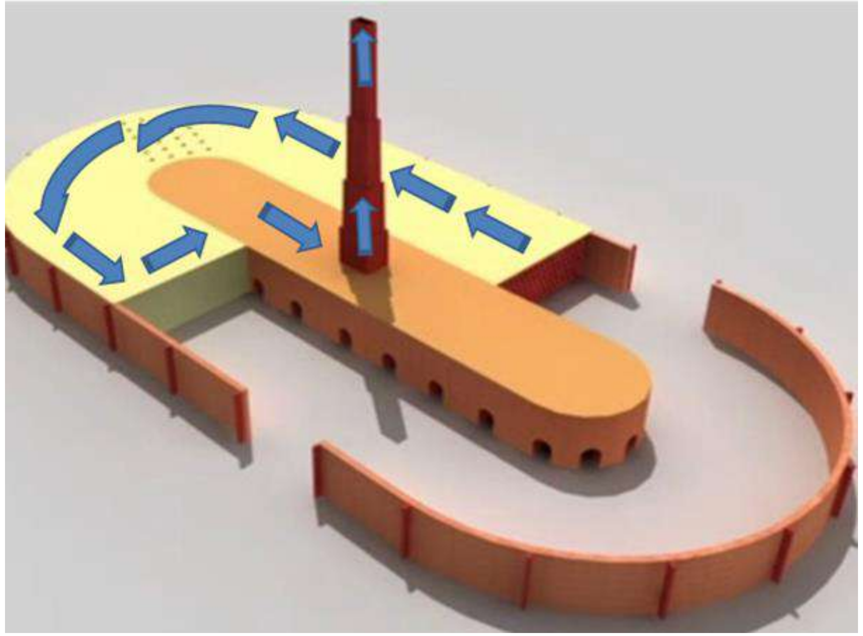


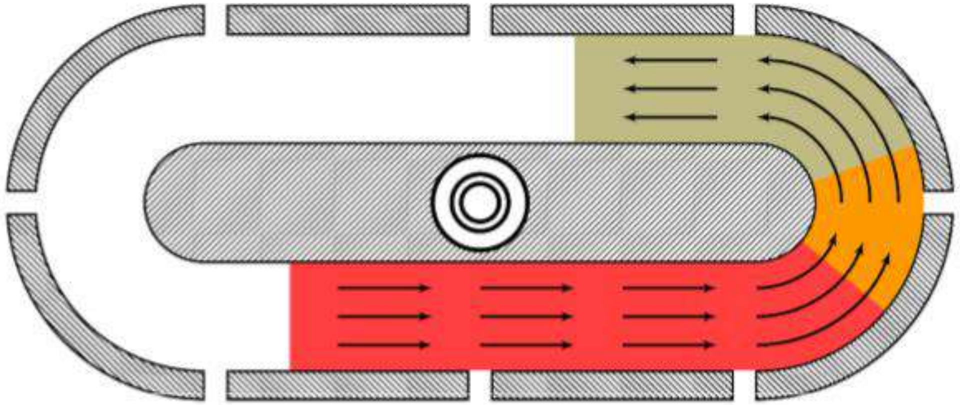
FCBTK



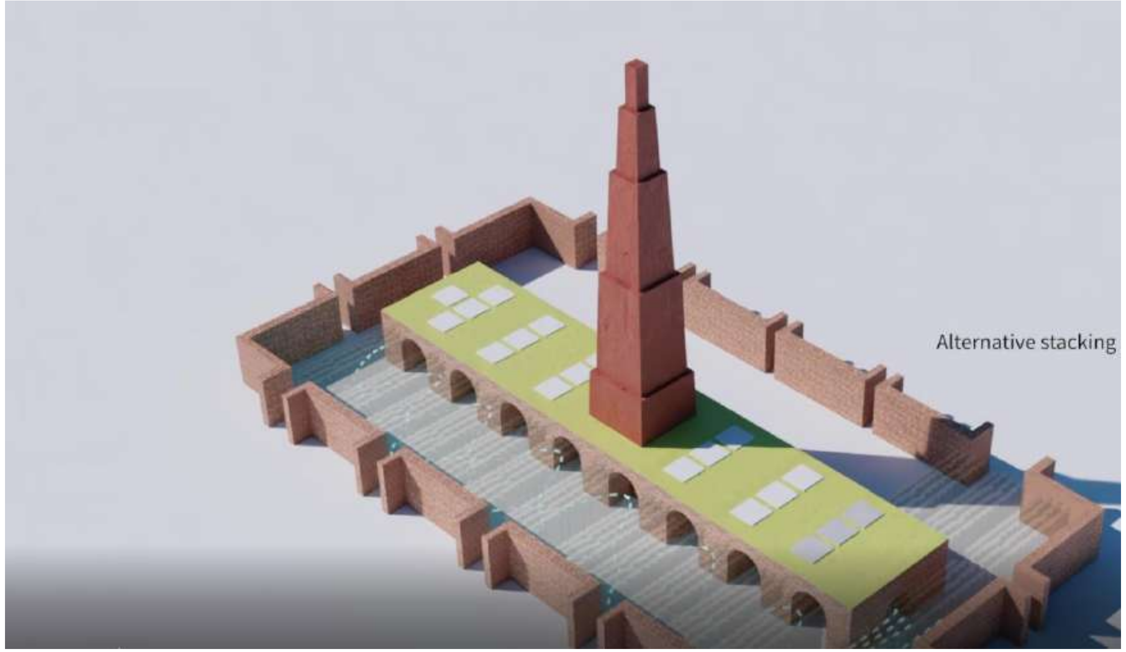
FCBTK zig-zag

Straight line stacking





Zig-zag stacking



Why zig-zag?

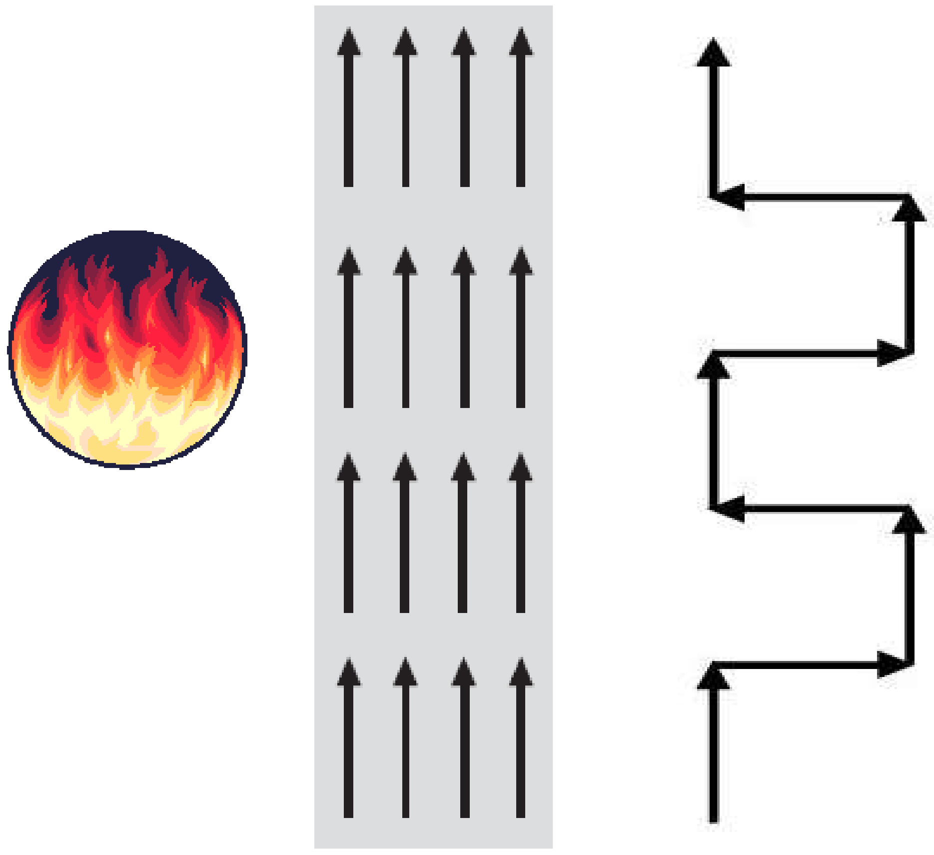
The zig-zag air path is about three times longer than the straight-line air path

TIME

Provides sufficient **time** for reaction

TURBULENCE

Turbulence created due to the zig-zag air movement results in improved heat transfer between air/flue gases and bricks



Types of zig-zag

Clay fired brick production process

	Traditional method		Modern practice	
Raw mix preparatio n	Manual		Machines	
Moulding	Manual		Extruders	
Drying	Open air		Driers & shade drying	

Clay fired brick production process

Firing

Material handling

Traditional method

Traditional technologies - Fixed Chimney Bulls trench kiln & Clamps

Modern practice

Intermediate & modern technologies – Hoffman, VSBK & Tunnel Kiln

Manual

Machines

Soil composition

Clay

(Grain sizes of clay are smaller than 2μm i.e; (0.002 mm)

- Imparts workability and green brick strength
- Helps in binding the coarser particles during vitrification
- Too much clay content in any soil reduces the workability and increases the shrinkage rate thus forming cracks during drying

Silt

(Grain sizes of silt ranges from 0.002 to 0.063 mm)

- Prevents high shrinkage cracks during drying process
- Fills up gaps between sand and clay thus providing a homogenous structure resulting in high fired strength

Soil Composition

According to Grain Size:

- **SAND** *(Grain sizes of sand are greater than 0.063mm-2mm)*
  - Helps in opening up the fine-clay structure and making it workable so that the brick making soil does not stick to the hand or to the mould.
  - During the firing of a brick it prevents high firing shrinkage thus avoiding firing cracks and abrupt achievement of vitrification.
  - Imparts the compressive strength to green bricks during stacking and avoids sagging during firing process.

Recommended composition of soil

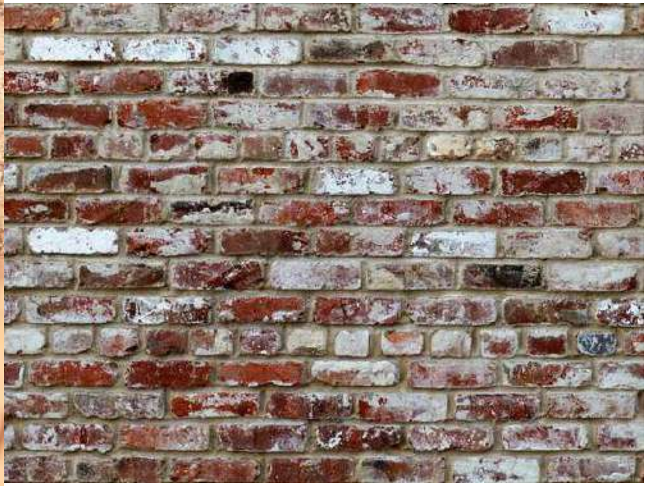
S.N.	Elements	Size	Recommended Value
1.	Sand	2 mm - 0.063 mm	20-45%
2.	Silt	0.063 mm - 0.002 mm	25-45%
3.	Clay	< 0.002 mm	20-35%

Chemical Properties of Soil

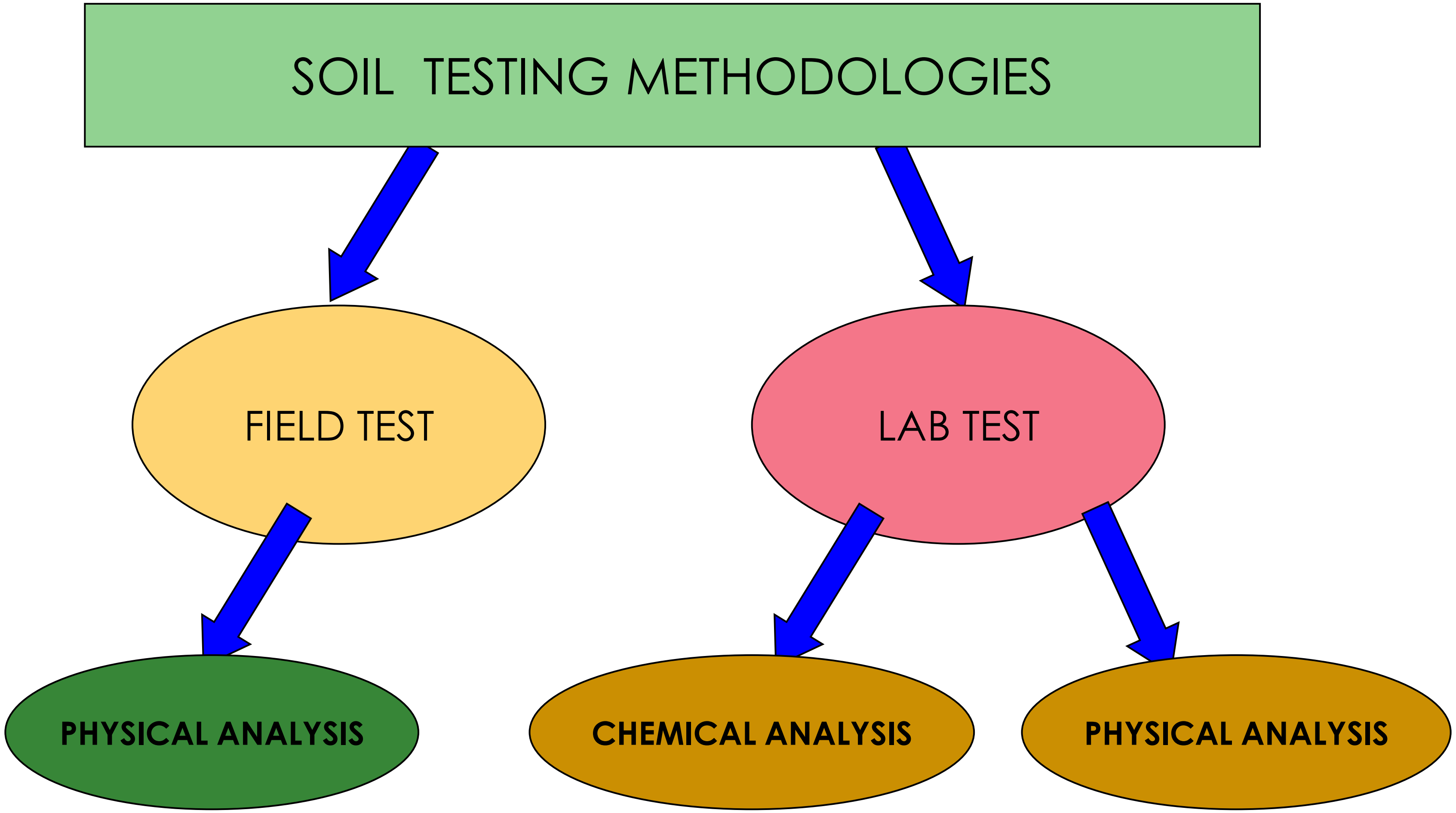
Calcium content >2% causes the brick white in colour

The size of calcium content mineral lime >2 mm causes lime bursting

Present of Sodium content 1% causes shade in the brick



Soil Testing



Soil Testing

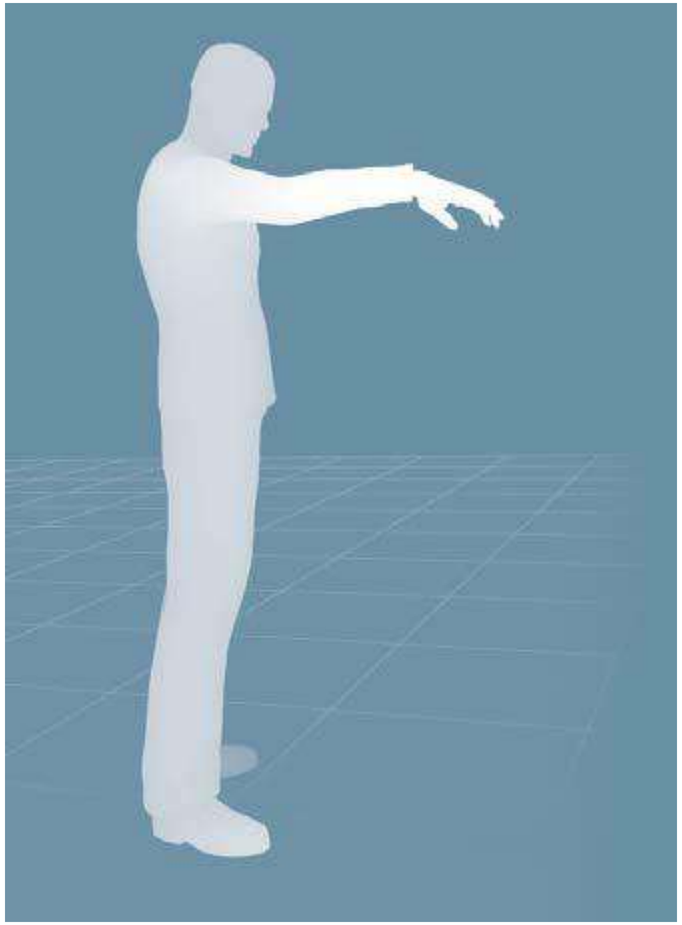
SMEARING TEST

Soil Testing

BALL TEST

Dry Ball test

Wet Ball test

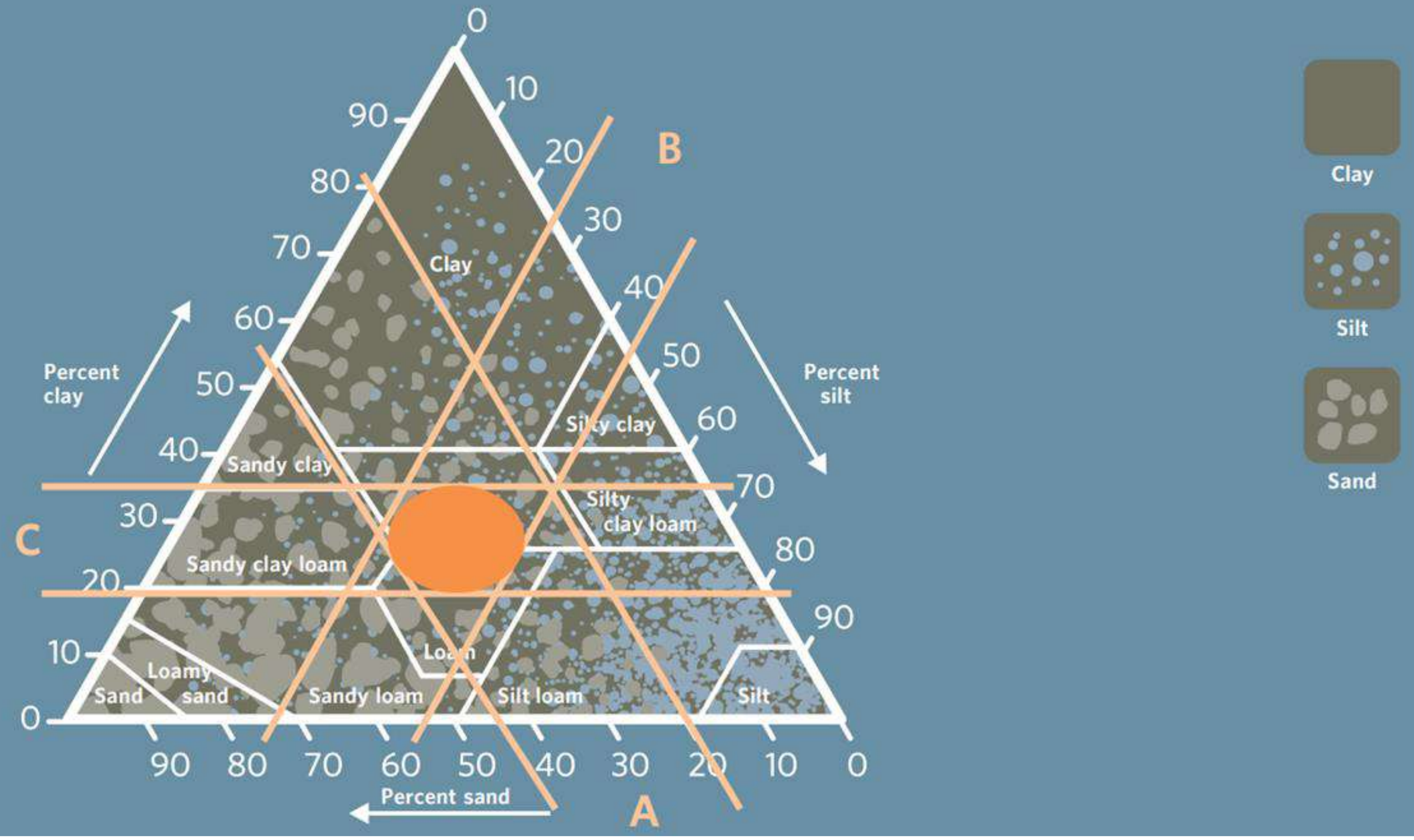


Soil Testing

LIME TEST

Soil Testing

SEDIMENTATION TEST



Clay
Silty clay
Sandy clay
Silty clay loam
Sandy clay loam
Loam
Loamy sand
Sand
Sandy loam
Silt loam
Silt
Percent clay
Percent silt
Percent sand
A
B
C
Clay
Silt
Sand

Soil Preparation

- **Soil Selection**
- **Soil Excavation**
  - ✓ ***Top soil conservation***
  - ✓ ***Vertical vs Horizontal Mining***
- **Soil Storage –** ***Balancing, Blending & Opening up/Ageing function***
  - ✓ ***Deposit /age or at least 3 months***
  - ✓ ***Add adequate amount of water***
  - ✓ ***Deposit layer by layer***
- **Pugging/Mixing**
- **Molding**

Soil Storage

Soil Preparation

Pugging

Molding

Soil Additives

- ✓Internal fuel
- ✓Anti shrinkage material
- ✓Structure opening material

Soil Preparation

✓ **Internal fuel**

- Benefits:
- Less pollution
- Improved fired brick quality
- Use of different fuels – coal dust, boiler ash, distillery waste, sponge iron waste, rice husk, saw dust, etc.

Soil Preparation

✓ **Anti shrinkage material**

- Fine river sand
- Medium sand
- Stone dust
- Sandy soil

Fine river sand   Medium sand   Stone dust   Sandy soil

Soil Preparation

✓**Structure opening material**

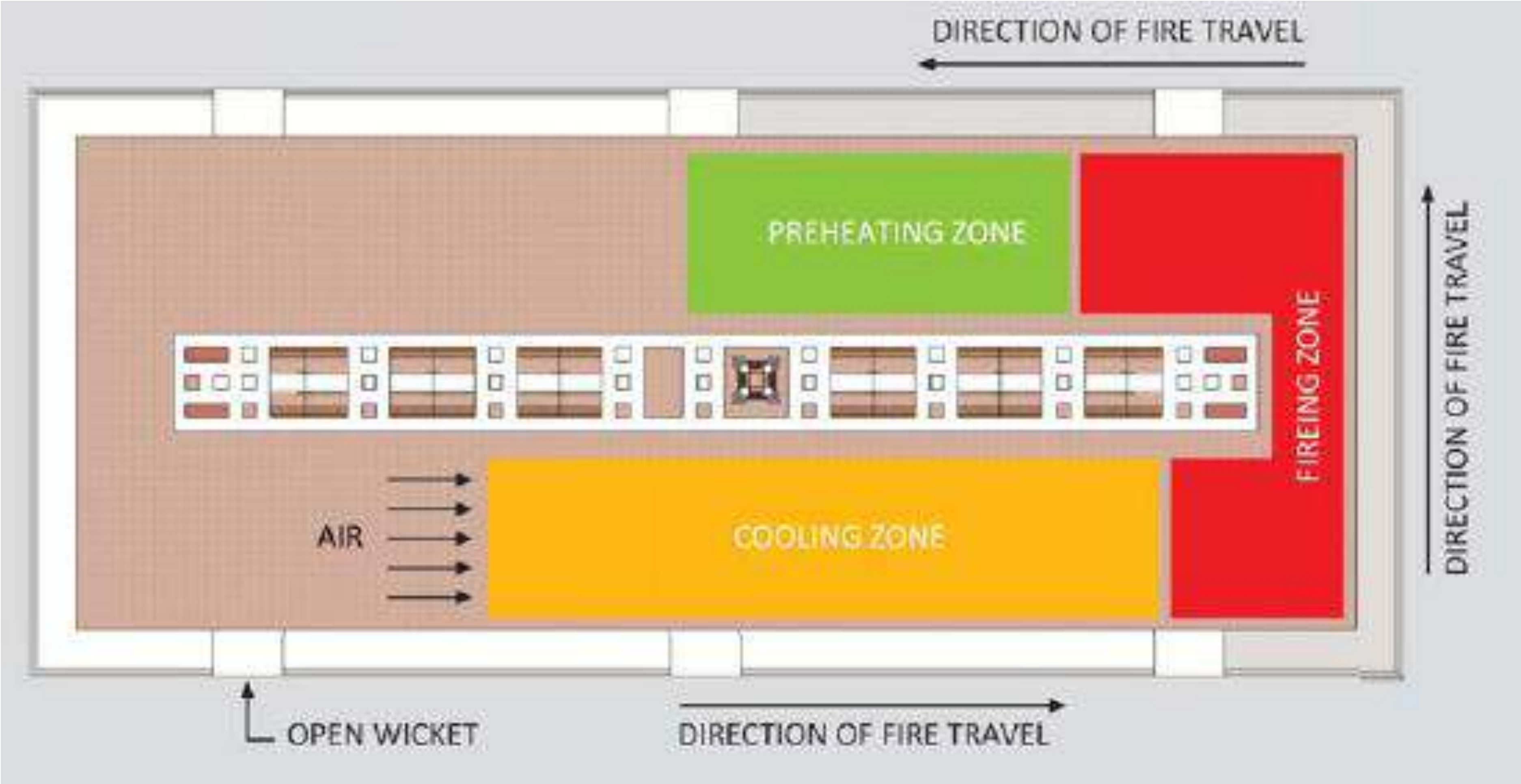
- Rice husk
- Saw dust
- Mustard husk


Rice husk

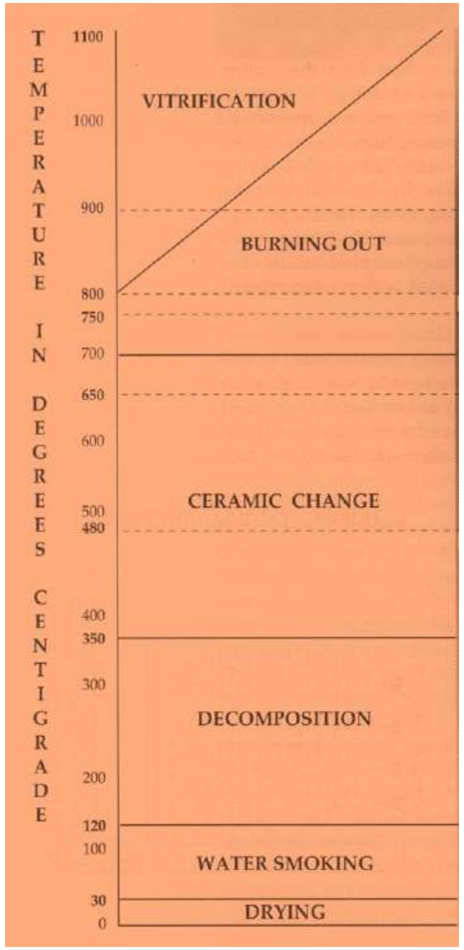

Saw dust

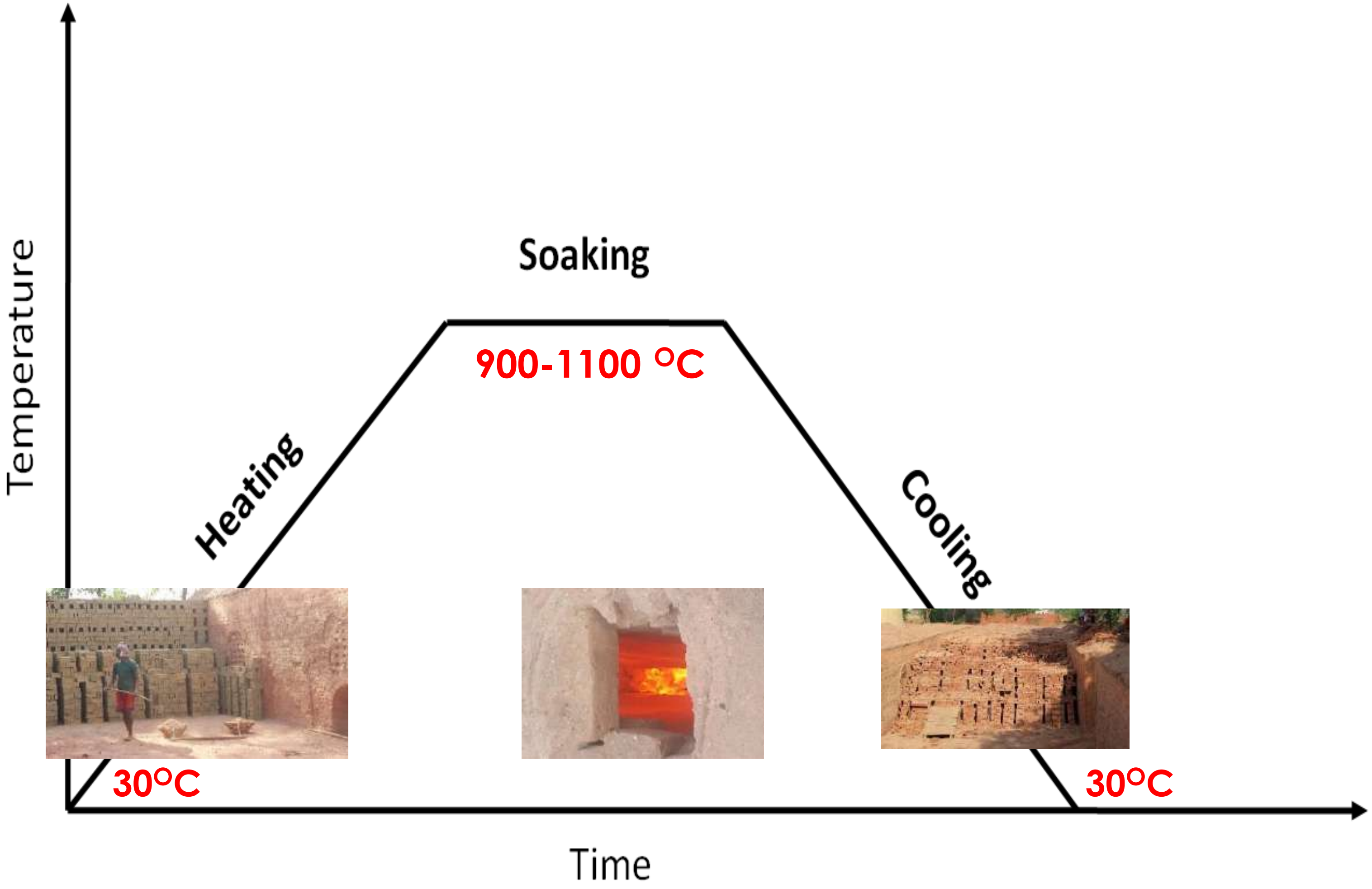

Mustard husk

FCBTK Firing System

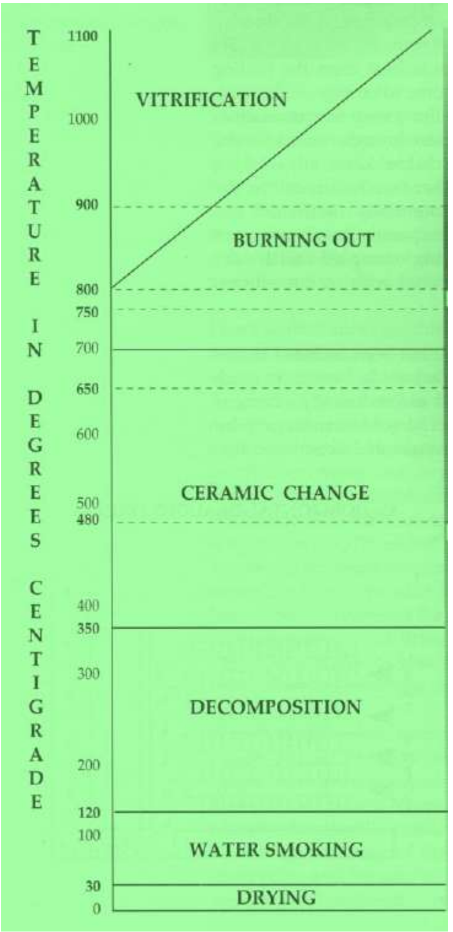


Brick Firing Process





Brick Firing Process



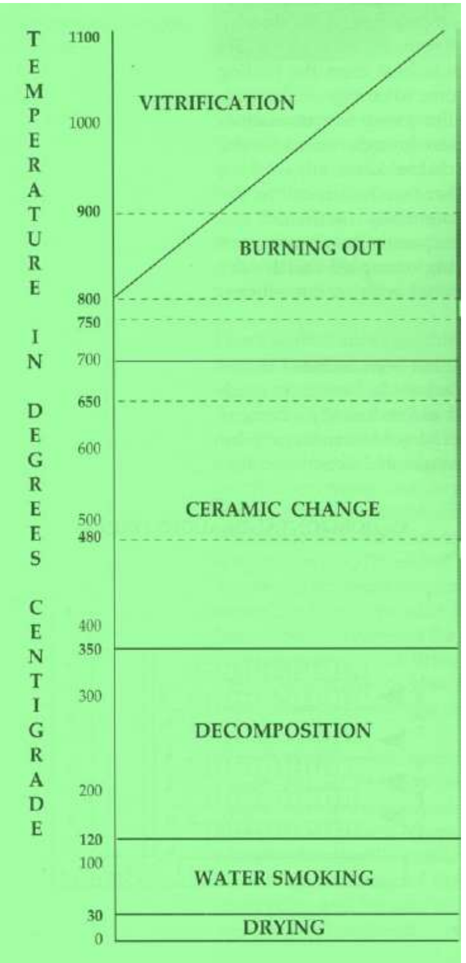
Water Smoking

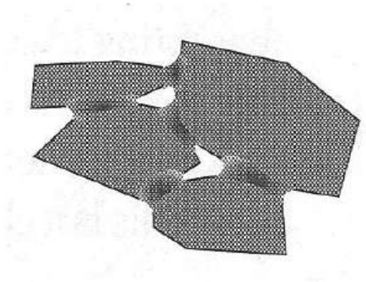
- 2 – 6% moisture in dried green bricks
- Drives away mechanically added water, usually completes by 120°C

Decomposition

- Organic matter breaks down at approximately 200°C.
- A slight expansion of the bricks, but this is too small to be noticed, being less than 1%

Brick Firing Process





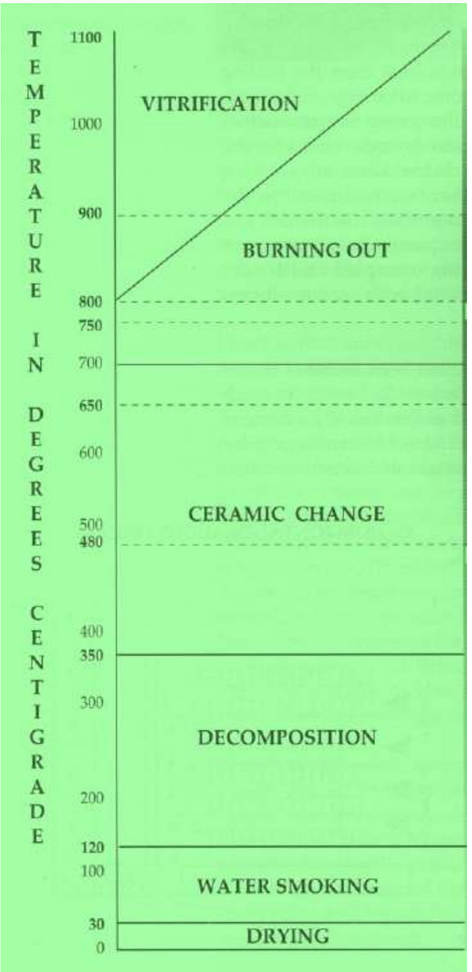
Ceramic change

- Action begins very gently at between 350^{O}C and completes at 700^{O}C.
- Irreversible change from clay to ceramic
- Dry clay particles in the bricks only just touch one another by a process called sintering

Burning out

- Carbon and sulphur are present in clays burnt out
- Starts at 700^{O}C and completes at 800^{O}C

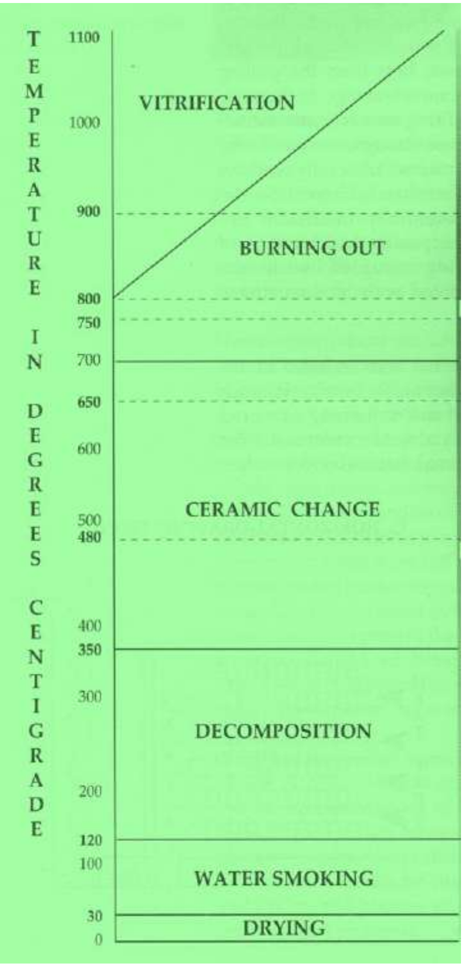
Brick Firing Process



Vitrification

- Partial melting of clay particles to form glassy bond
- Main reason behind the metallic sound produced by good quality bricks
- Takes places between 900 – 1100°C, temperature may vary depending on clay type

Brick Firing Process



Soaking Period

- Achieves a constant temperature (temperature at surface = temperature at the core of the brick), so that the vitrification process is uniform
- Brick body gets sufficient time for the completion of the vitrification process

Fuel & Combustion

Fuels used in Brick Kilns

Solid	**Coal, Fuel wood, Pet coke, Briquettes/Pellets, Charcoal** **Crop Residue:** Rice Husk, Mustard crop residue, Guar crop residue, Soya crop residue or husk, Groundnut shell, Cotton stalks, Coffee husk etc **Industrial wastes / by-products**: Sawdust, Wood chips, Bagasse, Boiler Ash
Liquid	Boiler oil; Rendering fat, Waste motor or hydraulic oil, Lampante Oil
Gas	Natural gas; Landfill gas, Biogas, Synthgas from waste stream

Fuels used in Brick Kilns

Common fuels used in South Asian Brick Kilns

- Coal
- Sawdust
- Mustard Crop Residue
- Fire-wood
- Petcoke

- **New fuel types**
  - Rice straw pellets
  - Briquettes
  - Biogas – A tunnel kiln in Delhi runs on biogas

Fuel Analysis

- Heating Value – Calorific Value
- Proximate analysis
  - Fixed Carbon
  - Volatile Matter
  - Ash Content
  - Sulfur Content
  - Moisture Content

Significance of Calorific Value

Calorific Value (kCal/kg or MJ/kg)

Calorific value is a measure of the heat content of the fuel

Higher the calorific value, higher is the heat content

Calorific value of coal used in brick kiln ranges from 4500 – 6500 kcal/kg

Why it is important?

Avg. wt of a brick: 2.5 kg

Energy required to fire a brick: 1 MJ/kg

Total energy to fire 40 lakhs bricks: ~10,000,000 MJ

Coal with 5,000kcal/kg (20.9MJ/kg): ~478 tons of coal

Coal with 6,000kcal/kg (25MJ/kg): ~ 398 tons of coal

Difference: 80 tons (Say if cost is Rs 25/kg; **20 lakhs difference**)

Significance of Various Parameters in Proximate Analysis

Fixed Carbon

Amount of carbon in coal

Gives a rough estimate of heating value of coal

Volatile Matter (VM)

Gasseous fuel such as methane, hydrocarbons, hydrogen and carbon monoxide, carbon dioxide and nitrogen in coal

Proportionately increases flame length, and helps in easier ignition of coal

Ash Content

- An impurity that will not burn
- Reduces burning capacity
- Increases handling costs

Significance of Various Parameters in Proximate Analysis (contd.)

Moisture Content

Decreases the heat content per kg of coal

Increases heat loss, due to evaporation and superheating of vapour

Sulphur Content

Corrodes chimney and other metallic equipment

Limits exit flue gas temperature

Significance of Various Parameters in Proximate Analysis

Ash Fusion

Fiber Coating

Fuel Characteristics

S. N.	Parameter	Assam Coal	Ranigunj Coal	Indonesian Coal	Saw Dust	Wooden chips	Pet-coke
1.	Calorific value (kcal/kg)	4800-5600	4500-5500	6000 - 6500	3000-4000	3000-4000	8000 - 8500
2.	Volatile matter %	20-40	25-30	35 - 40	65 – 70	55 – 60	10 – 12
3.	Ash content %	10-30	20-30	15	5 – 7	2 – 5	< -1
4.	**Fixed carbon %**	**35-50**	**30-45**	**~ 60**	**15 - 20**	**15 – 20**	**80 – 85**

What is Combustion?

Burning of a substance to produce heat is called "**Combustion**"

Three conditions are required for Combustion

1. Presence of a combustible substance i.e fuel
2. Presence of air (oxygen).
3. Presence of sufficient temperature i.e. Ignition temperature

Fuel + Oxygen = Heat + Carbon dioxide + Water

Fuels - Ignition Temperature

Fuel	Ignition Temperature °C
Coal	450 – 750
Wood	300+
Sawdust	300+
Rubber tyre	350+

Coal should be fed on forward row only when a temperature is about 650°C

Complete & Incomplete Combustion

Complete Combustion

When there is sufficient air required for the combustion, all the fuel burns completely.

Theoretically 5-10 kg of air is required per kg of coal for complete combustion

Incomplete Combustion

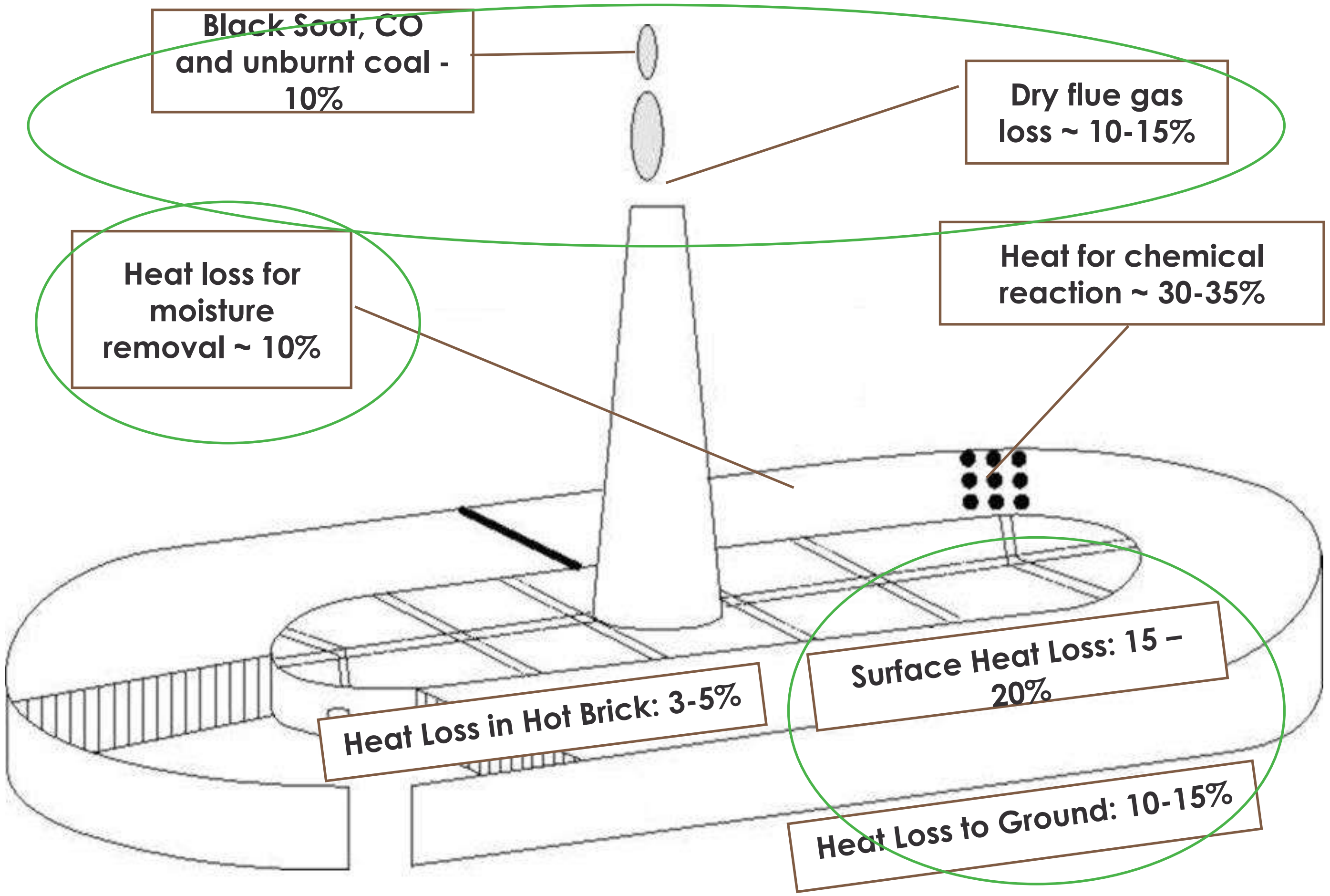
When there is insufficient supply of air, fuel doesn't burns completely resulting into carbon monoxide

Black Smoke = Incomplete Combustion

Invisible/light grey colour = Complete Combustion

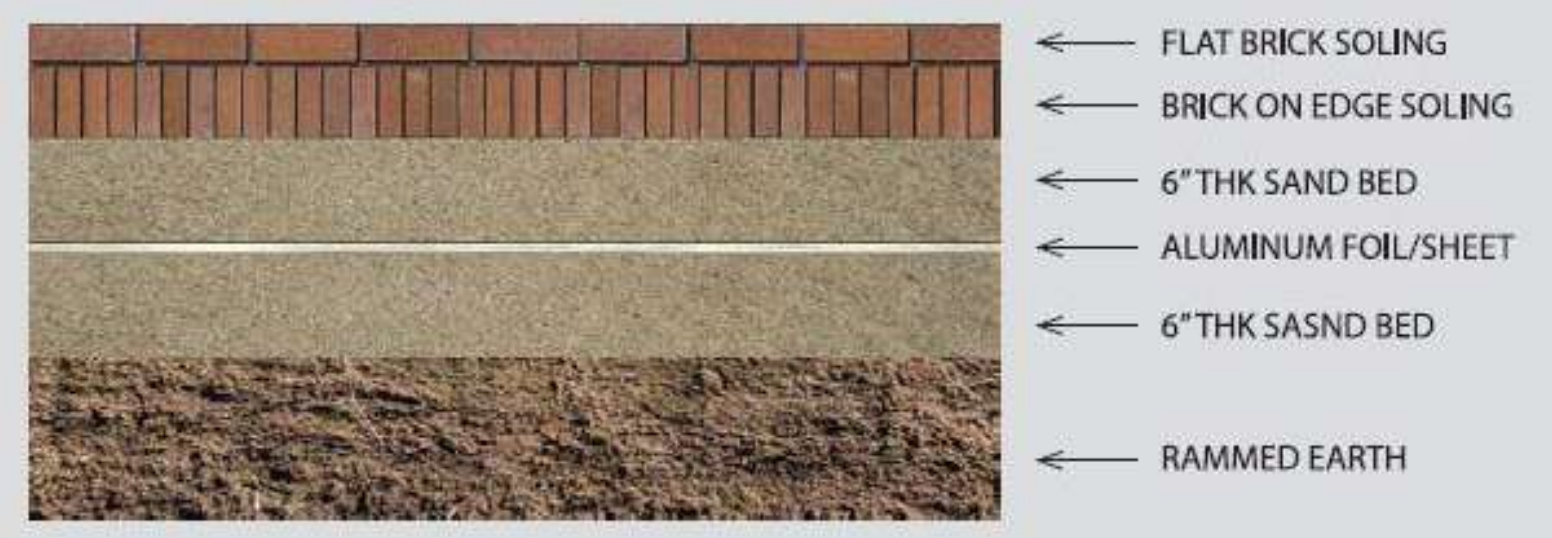
Minimizing Losses in Brick Kilns

Energy Balance of FCBTKs



Minimization of Surface Heat Loss

Depth (m)	Temperature (^oC)
0	980
0.5	300
1	200
1.5	160
2	130

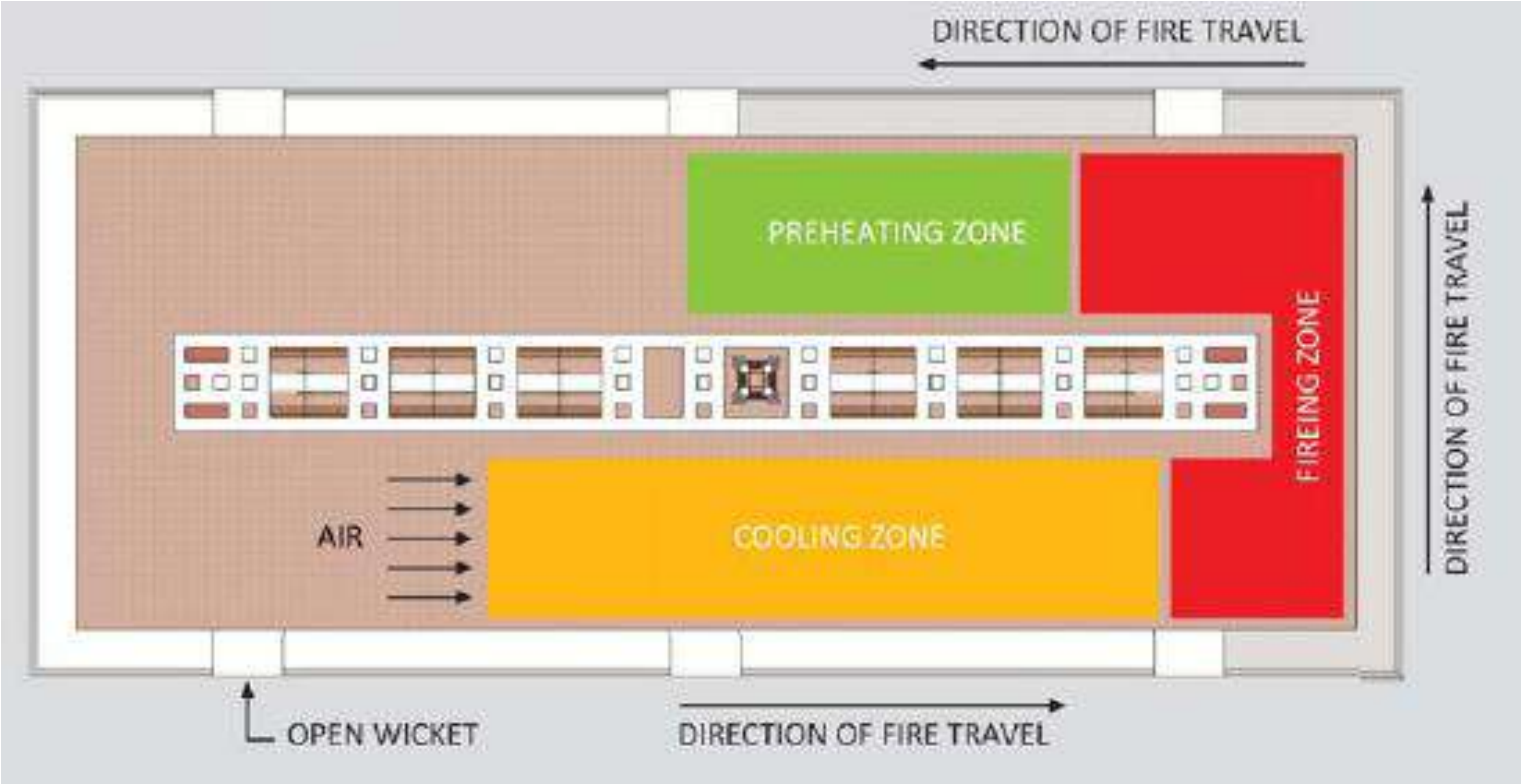


Minimization of Surface Heat Loss

Wall Thickness	Heat loss (kg coal/day)
1.5ft	328kg
5ft	109kg

Atleast 9 inch thick insulation

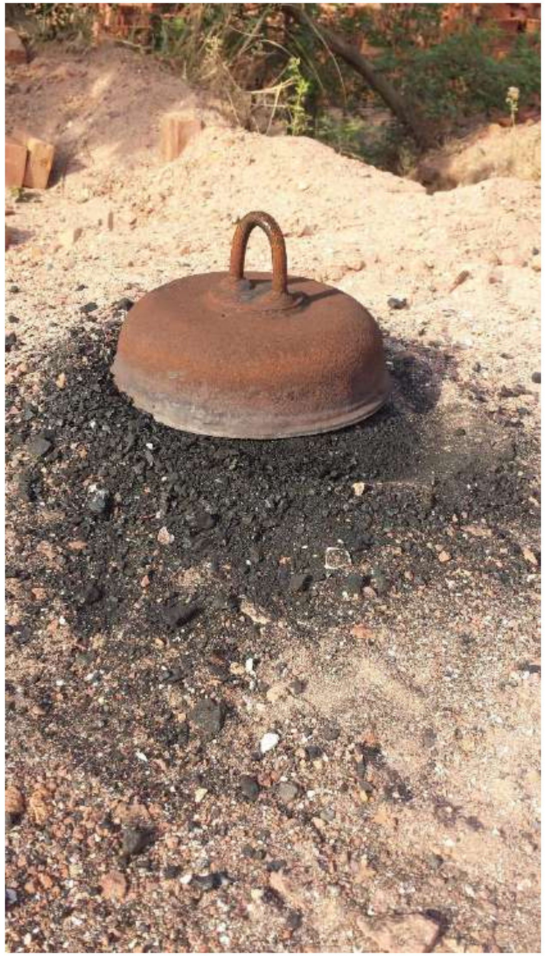
Leakages and Effects on Brick Cooling



Minimization of Air Leakages

	5 ft wall thickness	18 inch wall thickness
Amount of air leakage (m3/day)	59,000	196,000
Amount of air leakage % of total gas flowinside kiln	17%	57 %

Minimization of Surface Heat Loss



Insulation of feedhole cover and shunt

Minimization of Flue Gas Loss

Limit flue gas temperature between 80 - 120°C

Minimization of heat loss for moisture removal

Pre-Drying Green Bricks

Construction of Shed

Improving Chemical Reaction

Shed house for coal storage

Improved Fixed Chimney Design

Aftermath of Earthquake

Total damage: ~350 kilns

105 kilns within Valley damaged

Estimated loss: Rs1.12 billion

Production loss: 30-40%

Design Manual: Earthquake Response

Help rebuild Nepalese brick kilns in a “right way” to make it:

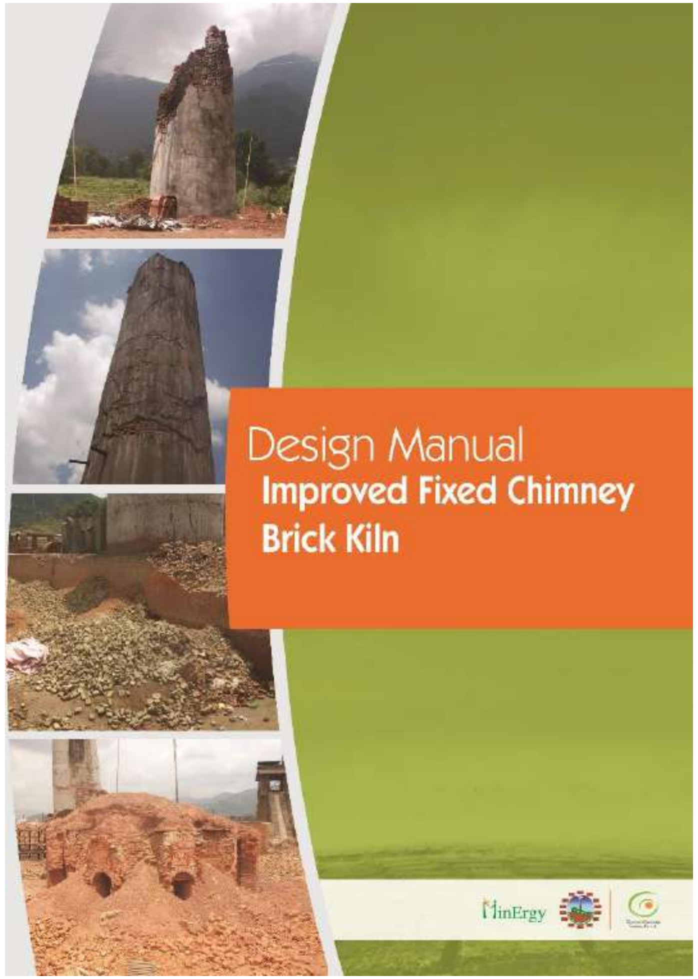
- Earthquake resistant
- Energy efficient
- Lower emitting

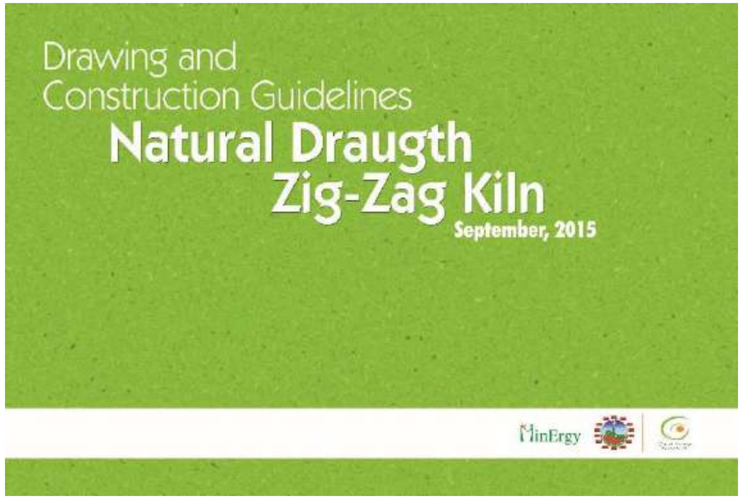
Photo – Kantipur Daily

Manual Preparation Phase

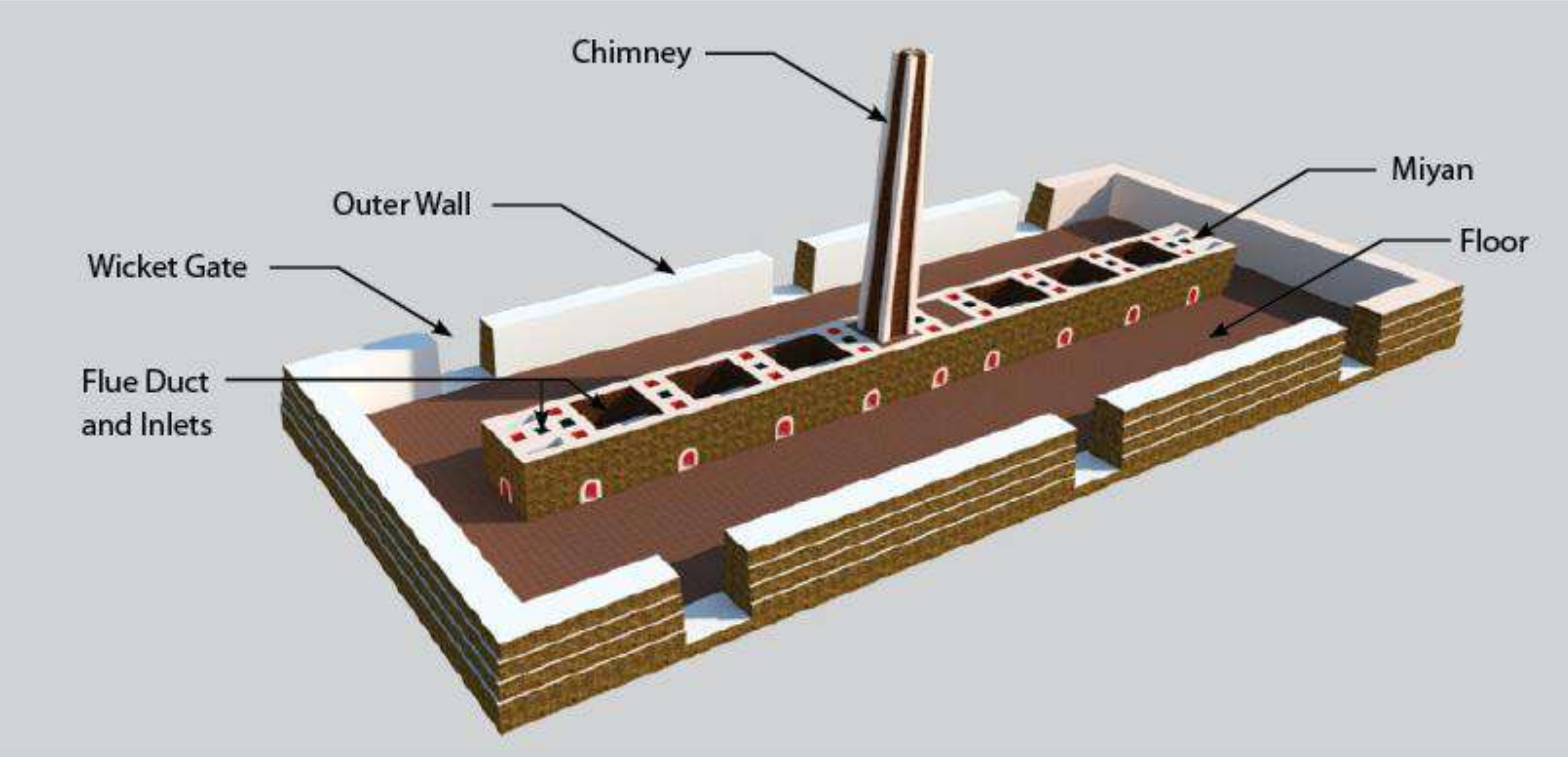
- Output of four months of intensive work
- A technical committee comprising of experts and entrepreneurs from Nepal and India
- Detail assessment of damaged kilns
- Design incorporates both practical experiences and scientific analysis
- Consultation and feedback from broad range of stakeholders including institutes like TERI, Punjab State Council

Output of Design Work





Design Elements



ID Chimney Frame Structure

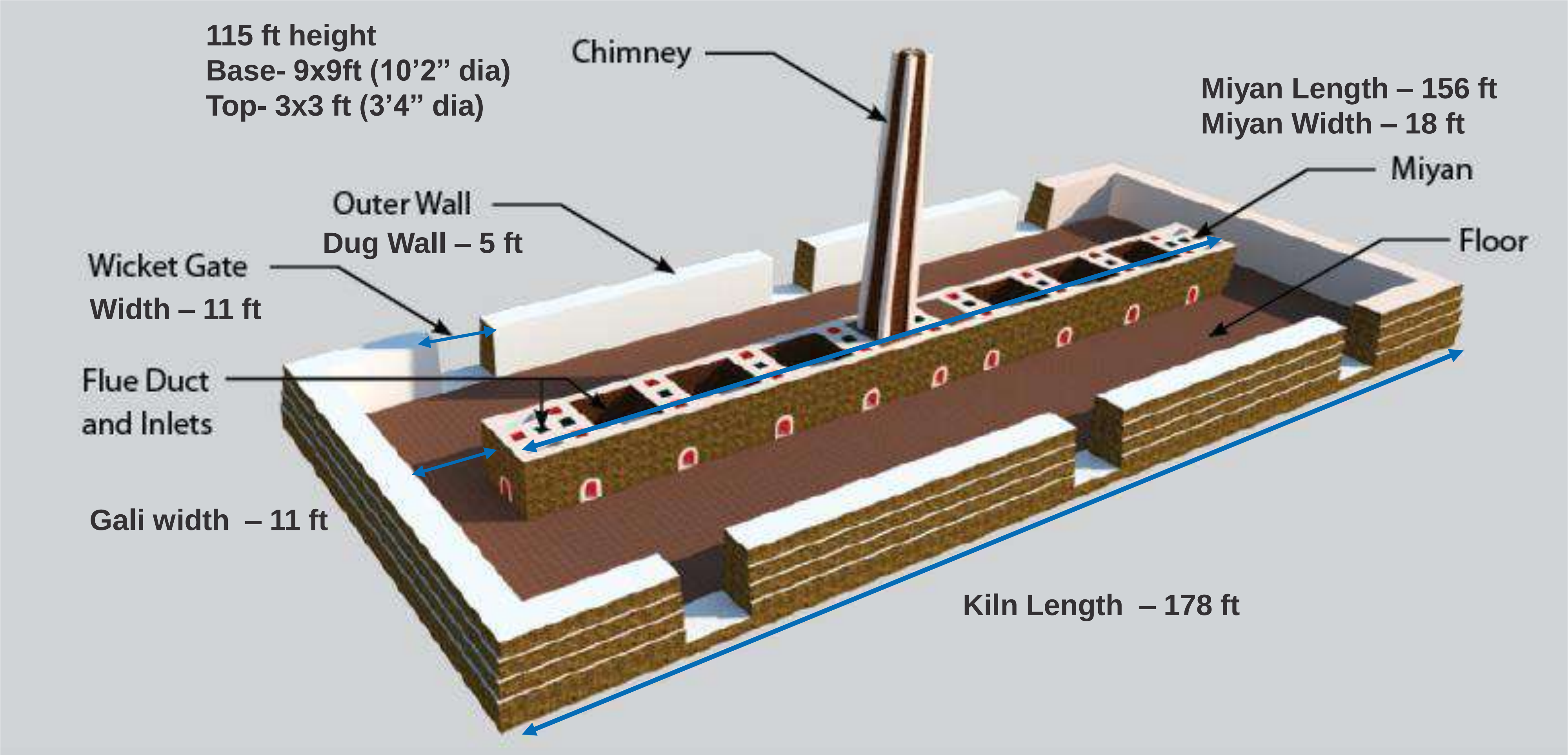
Outer Wall

Miyan Wall

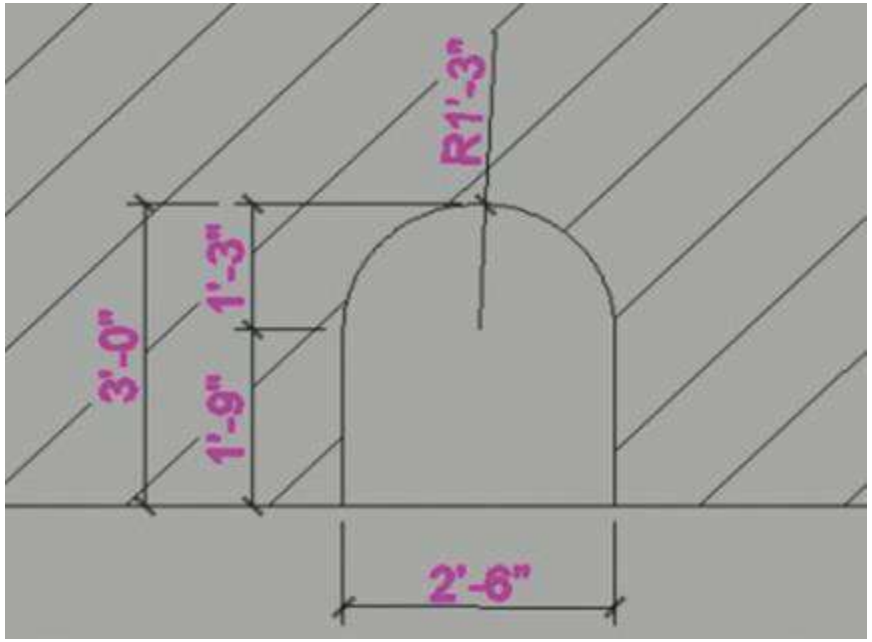
Duct System

ID Chimney Composite Structure

Kiln Dimension

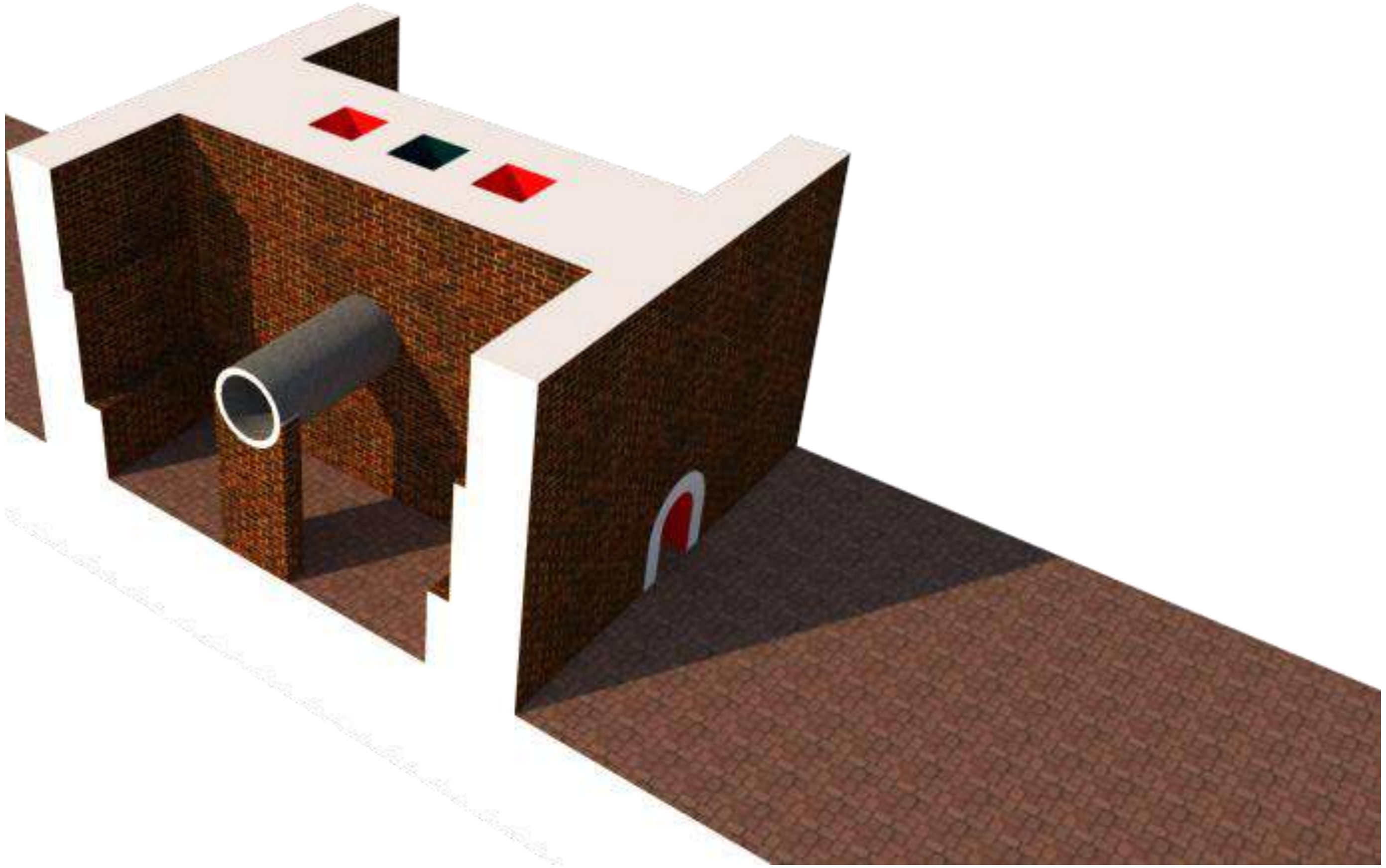


Kiln Dimension



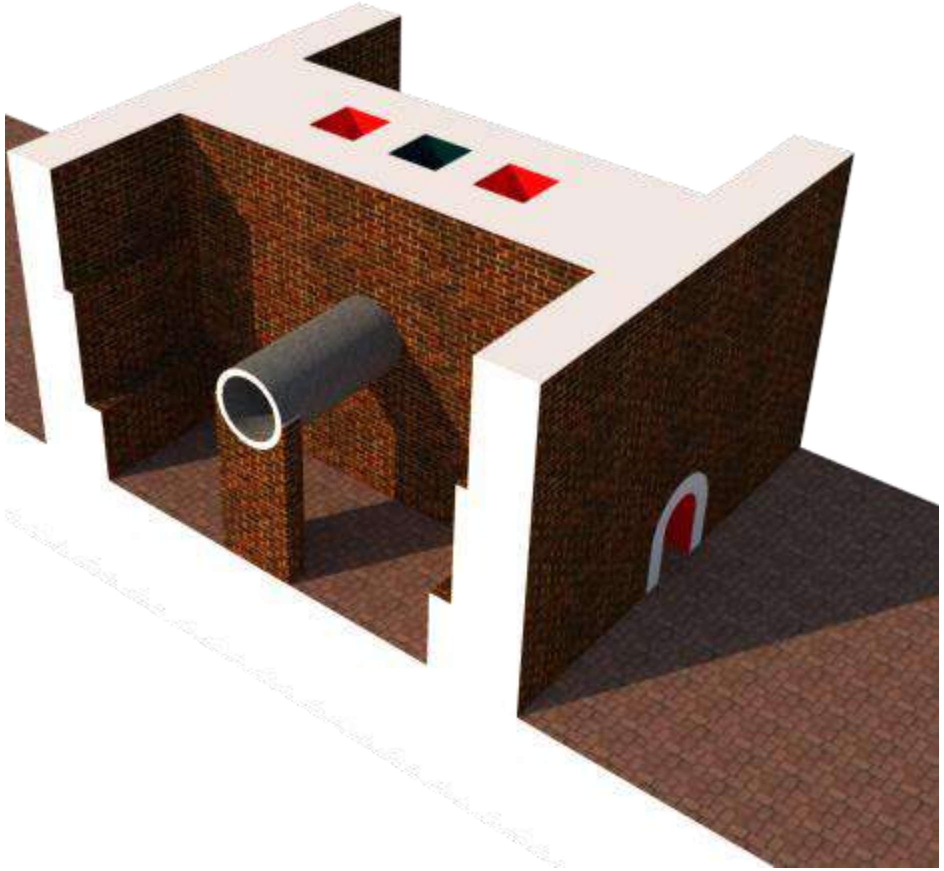
Side Nali @ 18ft c/c

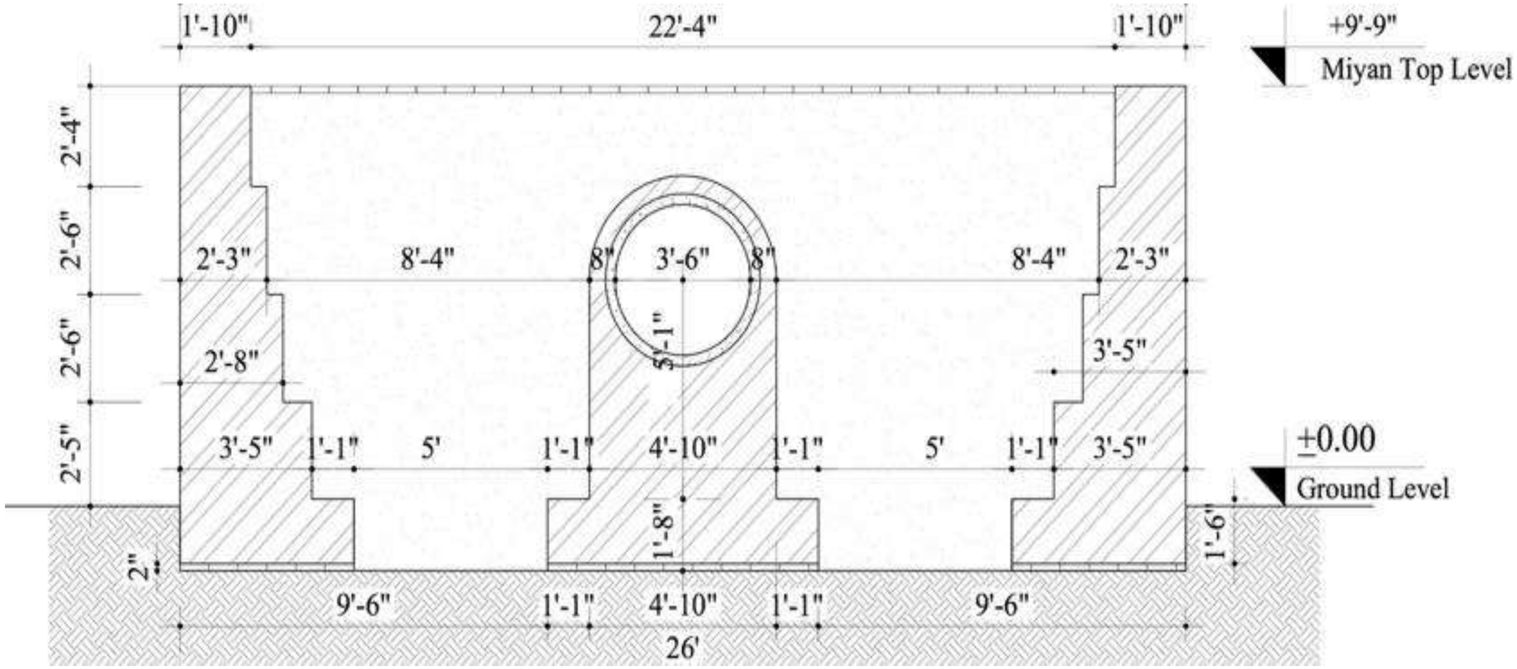
Kiln Dimension



Duct Diameter – 40 inch

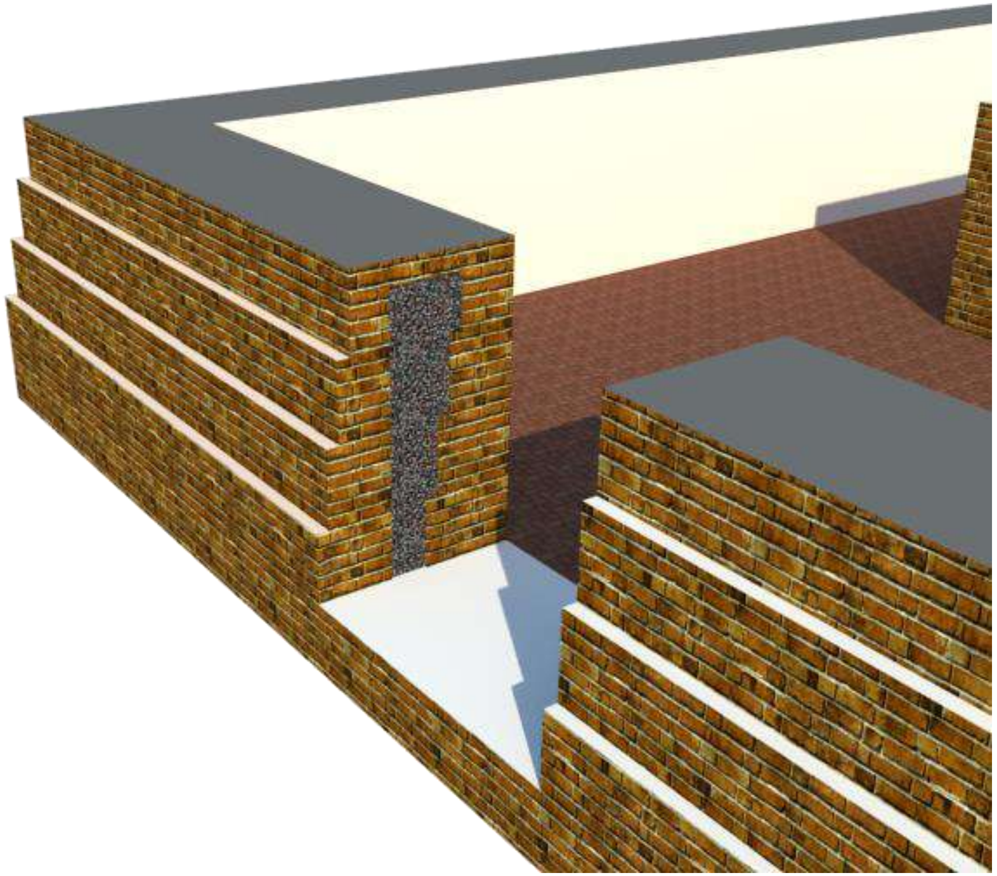
Kiln Dimension

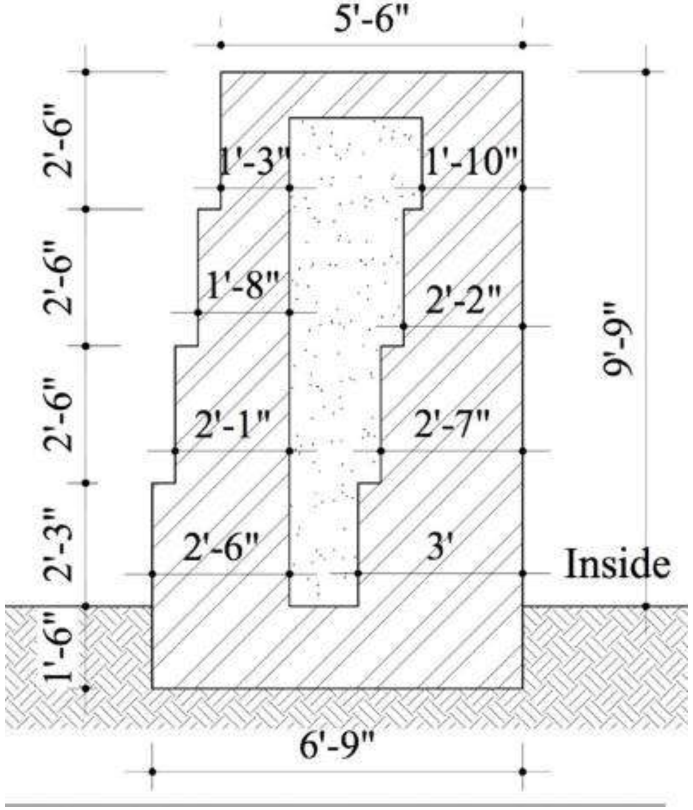




Miyan Design

Kiln Dimension





Outer Wall

References:

1. Mueller, H., Maithy, S., Prajapati, S., Bhatta, A., and Shrestha, B.L., 2008. Green Brick Making Manual, VSBK Programme Nepal. http://www.ecobrick.in/resource_data/KBAS100046.pdf

2. Prajapati, S. 2018. Training on Construction & Understanding Operations of Zig-Zag Brick Kilns, ICIMOD.

3. https://lib.icimod.org/record/31703/files/DesignMannualBL.pdf?type=primary

4. https://lib.icimod.org/record/31704/files/id-drawingManual.pdf


Thank you
Let’s protect the pulse.