Zig-zag brick kiln operation

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Types of brick kilns
Type of brick kilns

- Brick kilns
  - Continuous kilns
  - Batch type kilns
    - Moving ware kiln
      - VSBK
      - Tunnel kiln
    - Moving fire kiln
      - FCBTK
      - Zig-zag kiln

Our focus area: Moving fire kiln
Batch type kilns

Clamps

Downdraft Kiln
Continuous kilns – moving fire
Continuous kilns – moving fire

Hybrid Hoffman

Habla ZZ
Continuous kilns – moving ware
FCBTK vs zig-zag kilns
Comparison

FCBTK

FCBTK zig-zag
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

Natural draught

Induced draught
Clay fired brick production process

Raw mix preparation
- **Traditional method**: Manual
- **Modern practice**: Machines

Moulding
- **Traditional method**: Manual
- **Modern practice**: Extruders

Drying
- **Traditional method**: Open air
- **Modern practice**: Driers & shade drying
Clay fired brick production process

Traditional method

Traditional technologies -
Fixed Chimney Bulls trench kiln & Clamps

Modern practice

Intermediate & modern technologies – Hoffman, VSBK & Tunnel Kiln

Firing

Material handling

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**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Elements</th>
<th>Size</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sand</td>
<td>2 mm - 0.063 mm</td>
<td>20-45%</td>
</tr>
<tr>
<td>2.</td>
<td>Silt</td>
<td>0.063 mm - 0.002 mm</td>
<td>25-45%</td>
</tr>
<tr>
<td>3.</td>
<td>Clay</td>
<td>&lt; 0.002 mm</td>
<td>20-35%</td>
</tr>
</tbody>
</table>
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 METHODOLOGIES

FIELD TEST

LAB TEST

PHYSICAL ANALYSIS

CHEMICAL ANALYSIS

PHYSICAL ANALYSIS
Soil Testing

SMEARING TEST
Soil Testing

BALL TEST
Dry Ball test
Wet Ball test
Soil Testing

LIME TEST
Soil Testing

SEDIMENTATION TEST
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
Soil Preparation

✓ Structure opening material
  • Rice husk
  • Saw dust
  • Mustard husk
FCBTK Firing System
Brick Firing Process

- **Soaking**: 900-1100 °C
- **Heating**: 30°C
- **Cooling**: 30°C
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°C and completes at 700°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°C and completes at 800°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

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

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Parameter</th>
<th>Assam Coal</th>
<th>Ranigunj Coal</th>
<th>Indonesian Coal</th>
<th>Saw Dust</th>
<th>Wooden chips</th>
<th>Pet-coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Calorific value (kcal/kg)</td>
<td>4800-5600</td>
<td>4500-5500</td>
<td>6000 - 6500</td>
<td>3000-4000</td>
<td>3000-4000</td>
<td>8000 - 8500</td>
</tr>
<tr>
<td>3.</td>
<td>Ash content %</td>
<td>10-30</td>
<td>20-30</td>
<td>15</td>
<td>5 – 7</td>
<td>2 – 5</td>
<td>&lt; -1</td>
</tr>
</tbody>
</table>
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

\[
\text{Fuel} + \text{Oxygen} = \text{Heat} + \text{Carbon dioxide} + \text{Water}
\]
## Fuels - Ignition Temperature

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Ignition Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>450 – 750</td>
</tr>
<tr>
<td>Wood</td>
<td>300+</td>
</tr>
<tr>
<td>Sawdust</td>
<td>300+</td>
</tr>
<tr>
<td>Rubber tyre</td>
<td>350+</td>
</tr>
</tbody>
</table>

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

- Heat for chemical reaction ~ 30-35%
- Heat loss for moisture removal ~ 10%
- Black Soot, CO and unburnt coal - 10%
- Dry flue gas loss ~ 10-15%
- Surface Heat Loss: 15 – 20%
- Heat Loss in Hot Brick: 3-5%
- Heat Loss to Ground: 10-15%
Minimization of Surface Heat Loss

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>980</td>
</tr>
<tr>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>1.5</td>
<td>160</td>
</tr>
<tr>
<td>2</td>
<td>130</td>
</tr>
</tbody>
</table>

![Diagram of surface layers with labeled materials: Flat Brick Soling, Brick on Edge Soling, 6" THK Sand Bed, Aluminum Foil/Sheet, 6" THK SASND Bed, Rammed Earth.](image-url)
# Minimization of Surface Heat Loss

<table>
<thead>
<tr>
<th>Wall Thickness</th>
<th>Heat loss (kg coal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5ft</td>
<td>328kg</td>
</tr>
<tr>
<td>5ft</td>
<td>109kg</td>
</tr>
</tbody>
</table>

At least 9 inch thick insulation
Leakages and Effects on Brick Cooling
Minimization of Air Leakages

<table>
<thead>
<tr>
<th></th>
<th>5 ft wall thickness</th>
<th>18 inch wall thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of air leakage (m³/day)</td>
<td>59,000</td>
<td>196,000</td>
</tr>
<tr>
<td>Amount of air leakage % of total gas flow inside kiln</td>
<td>17%</td>
<td>57%</td>
</tr>
</tbody>
</table>
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
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 Manual
Improved Fixed Chimney Brick Kiln

Drawing and Construction Guidelines
Induced Draught Zig-Zag Kiln
2015

Drawing and Construction Guidelines
Natural Draught Zig-Zag Kiln
September, 2015
Design Elements

- Chimney
- Outer Wall
- Miyan
- Floor
- Wicket Gate
- Flue Duct and Inlets
ID Chimney Frame Structure
Outer Wall
Miyan Wall
Duct System
ID Chimney Composite Structure
Kiln Dimension

115 ft height
Base: 9x9ft (10'2" dia)
Top: 3x3 ft (3'4" dia)

Miyan Length – 156 ft
Miyan Width – 18 ft

Kiln Length – 178 ft

Width: 11 ft

Dug Wall – 5 ft

Flue Duct and Inlets

Outer Wall

Chimney

Gali width – 11 ft

Wicket Gate

Width – 11 ft

Floor
Kiln Dimension

Side Nali @ 18ft c/c
Kiln Dimension

Duct Diameter – 40 inch
Kiln Dimension
Kiln Dimension
References:


Thank you

Let’s protect the pulse.