



# ZigZag Kiln

## How to Build an Industrial Kiln



Schweizerische Eidgenossenschaft  
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Swiss Agency for Development  
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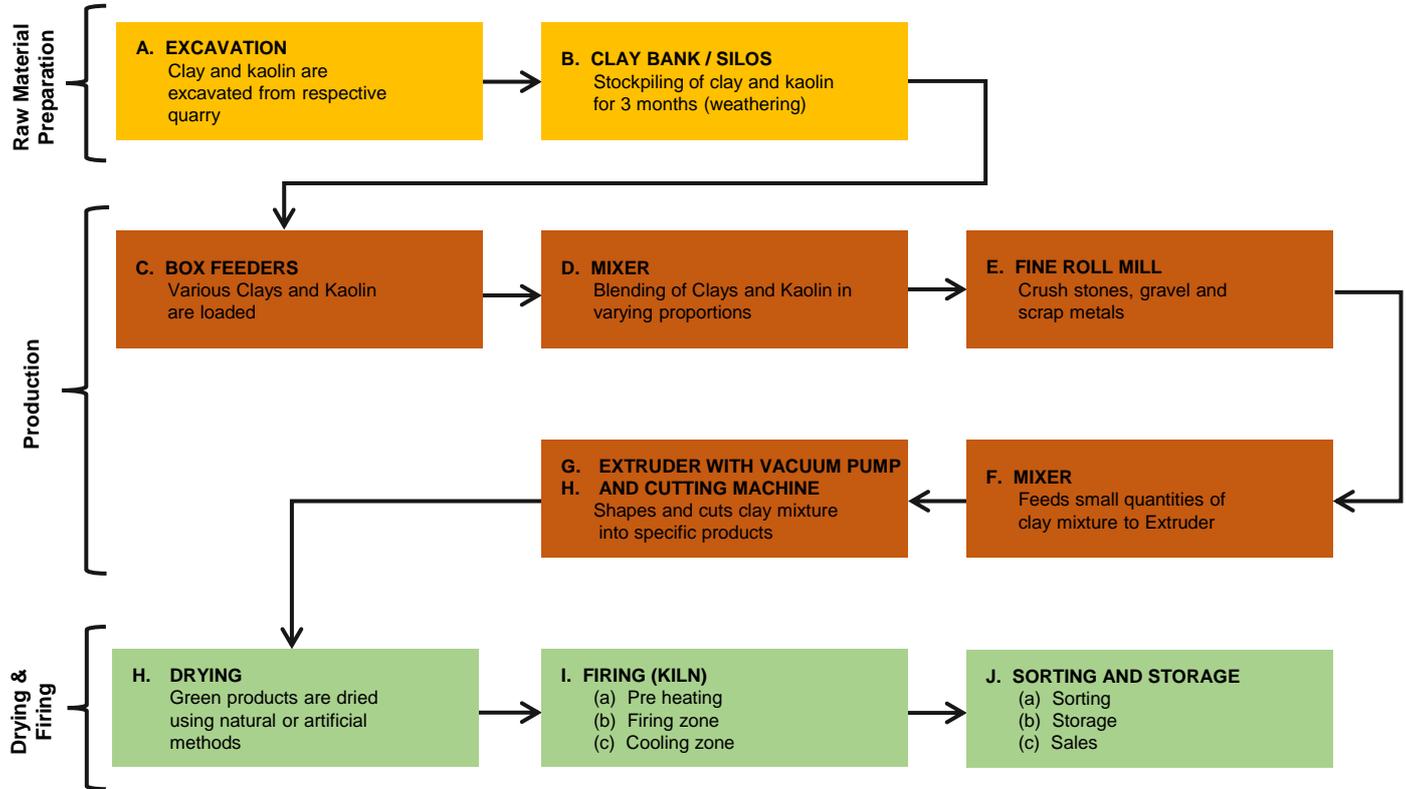
**skat** Swiss Resource Centre and  
Consultancies for Development

**PROECCO** **PR**o**MO**ting **E**m**PL**oyment through  
**CL**imate Responsive **CO**nstruction

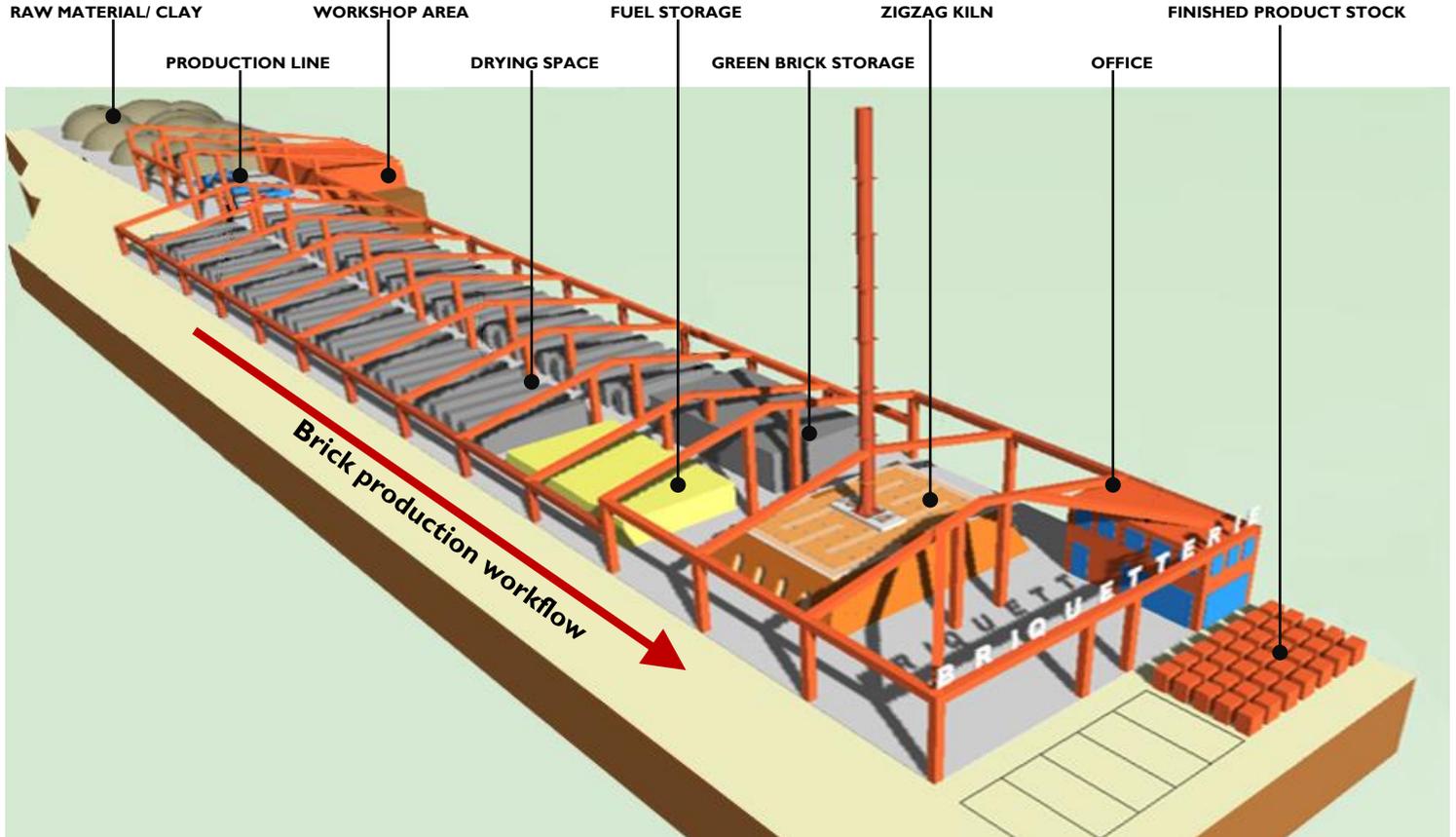
# PART ONE

Layout and work Flow in a Brick Factory

# Production process in a brick factory



# Model Layout plan for a brick factory



# Layout plan for a brick factory



Brick sales



The Kiln



Fuel storage



Clay bank



Brick extrusion

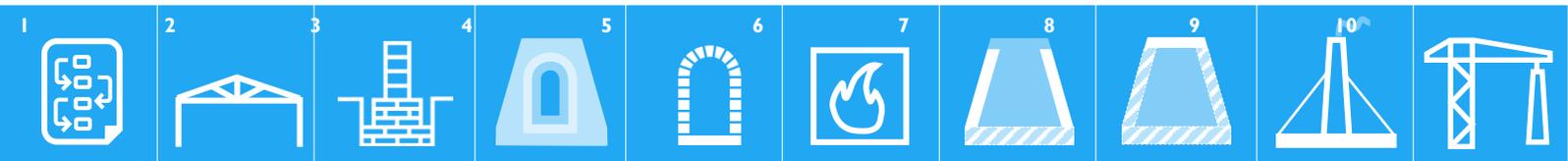


Drying area for bricks



# PART TWO

## Process of kiln construction



# Comparisons between Local & ZZ Kiln



Local kiln



ZZ kiln

# Comparisons between Local & ZZ Kiln



## Local Kiln

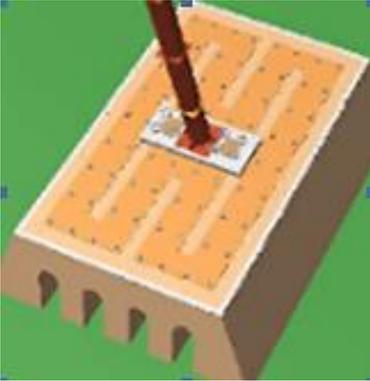
- Uses logs of trees, destroying the environment.
- Damaged by rain.
- Expensive as has to be built every time.
- Unhealthy working conditions.



## Zigzag-Kiln

- Fuel efficient, using sawdust, coffee and rice husks.
- Continuous firing.
- Permanent.
- Extra storage space.
- Smokeless, healthy working environment.

# Features of an 8-chamber ZZ Kiln



## Technical data

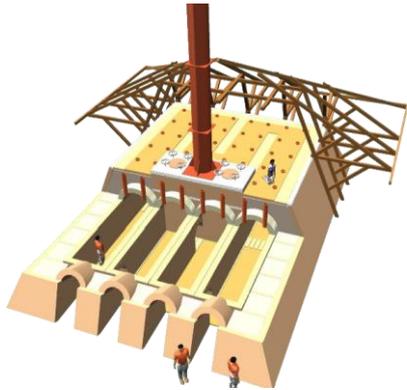
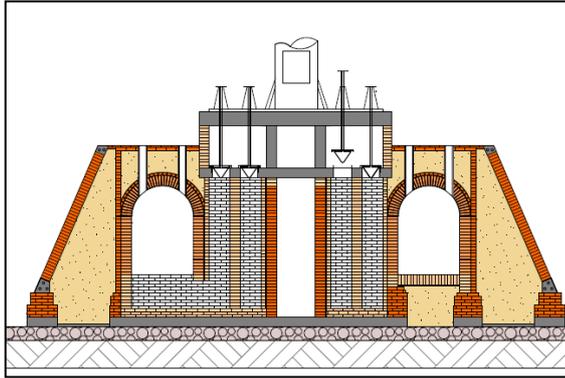
- Volume of 104M<sup>3</sup> = 3-4 million bricks in a year
- Has eight (8) firing chambers
- Daily production = 14,000
- Requires 360M<sup>3</sup> of clay annually, equivalent to 0.3 hectares of land a year
- Requires 600 tons of fuel a year
- Employs 100-150 workers
- Expected lifespan of 100 years dependent on maintenance

# Different sizes of the ZZ Kiln

The Different possible kiln sizes and their capacities are illustrated below.

<b>Kiln size</b>	Full size semi-industrial kiln L 17.8m x W 13.7m x H 2.89 m	½ size semi-industrial kiln L 17.8m x W 6.85m x H 2.89 m	¼ size semi-industrial kiln L 8.9m x W 6.85m x H 2.89 m
<b>Kiln annual capacity</b>	3 million bricks a year (210 x 100 x 65 mm)	1.5 million bricks a year (210 x 100 x 65 mm)	750,000 bricks a year (210 x 100 x 65 mm)
<b>Kiln picture</b>			

# The systematic stages in Kiln construction

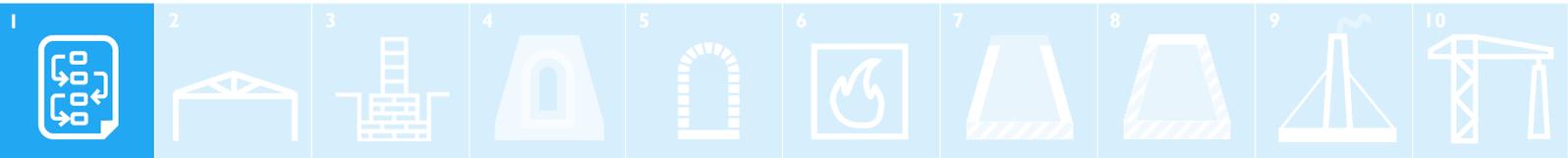


Kiln construction has several stages that can be summarized as follows:

1. Planning for the Kiln construction
2. Hangar construction.
3. Foundation works to floor level.
4. Walls construction to vaults level.
5. Vaults construction.
6. Construction of the Fire Control box.
7. Walls construction to kiln top level.
8. Kiln top construction.
9. Fabrication of steel chimney.
10. Installation of chimney.

# Stage I.

## Planning for the kiln construction





This is detailed planning and preparation of how the kiln will be constructed within a specific period and budget. It involves the following:

1. **Legal compliance:** Getting construction permit and environmental impact assessment approval.
2. **Logistics:** Procurement for the resources (*materials & labor*) required.
3. **Construction management:** Preparation of a construction schedule.

# A sample construction schedule for kiln construction



Kiln Construction Schedule - Estimated Construction Period in Weeks & Materials required for special construction																									
N°	Construction Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Planning	█																							
2	Hangar Construction	█	█	█	█																				
3	Foundation works to floor level					█	█	█	█																
4	Walls construction to vaults level								█	█	█														
5	Vaults construction											█	█	█											
6	Fire control box														█	█	█								
7	Construction to roof level																	█	█	█					
8	Kiln top construction																		█	█	█				
9	Chimney fabrication													█	█	█	█	█							
10	Chimney installation																					█	█	█	█

Construction schedule helps keep track on construction progress, logistics and coordination of activities.

# Procurement of materials must be guided by the construction schedule



Kiln Construction Schedule - Estimated Construction Period in Weeks & Materials required for special construction																									
N°	Construction Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Planning	█																							
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8	Kiln top construction																	█	█	█					
9	Chimney fabrication													█	█	█	█	█							
10	Chimney installation																					█	█	█	█

Starting procuring materials for the next stage of construction in advance. Gravel, Sand, reinforcement steel & ordinary bricks for foundation works should be ordered when hangar is under construction.

Construction schedule helps keep track on construction progress, logistics and coordination of activities.

# Procuring materials as per construction schedule



Kiln Construction Schedule - Estimated Construction Period in Weeks & Materials required for special construction																											
N°	Construction Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
1	Planning	█																									
2	Hangar Construction	█	█	█	█																						
												Gravel, Sand, reinforcement steel & ordinary bricks															
3	Foundation works to floor level					█	█	█	█																		
												42,000 semi-refractory bricks for tunnels															
4	Walls construction to vaults level									█	█	█															
5	Vaults construction												█	█	█												
												31,000 special refractory bricks for vaults															
6	Fire control box															█	█	█									
												Fire control valves															
7	Construction to roof level																		█	█	█						
8	Kiln top construction																				█	█	█				
9	Chimney fabrication																										
		65M2 Corten steel & 16 mm x 120 m steel cable																									
10	Chimney installation																										

Construction schedule helps keep track on construction progress, logistics and coordination of activities.

# Materials requiring advance preparation

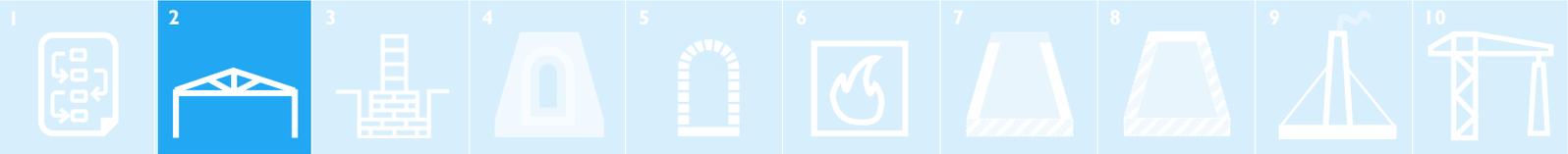


Summary of key materials required for special construction works			
Material	Description	Quantity	Construction activity
Ordinary bricks 210x100x50 mm	With 25% perforations	84,000	Exterior walls
Refractory bricks 230x110x70 mm	Made from 50% clay, 35% kaolin and 15% chamotte	31,000	Vaults & internal walls
Semi refractory bricks	Made from 75% clay and 25% kaolin	42,000	kiln floor, smoke tunnels and fire control box
L-shaped refractory bricks	Made from 50% clay, 35% kaolin and 15% chamotte	2,250	For expansion joints
Fuel feeding refractory bricks	Made from 50% clay, 35% kaolin and 15% chamotte	160	For fuel feeding holes
Tapered refractory bricks	Made from 50% clay, 35% kaolin and 15% chamotte	26,000	For buildings vaults
Kaolin	Alumina silicate	5M <sup>3</sup>	For special clay mortar
Chamotte	Crushed burnt brick dust	2M <sup>3</sup>	For special clay mortar

Special materials such as refractory bricks or special fuel feeding bricks should be ordered in advance.

# Stage 2.

# Hangar construction



# Hangar Construction



Hangar construction takes 20-25 days.

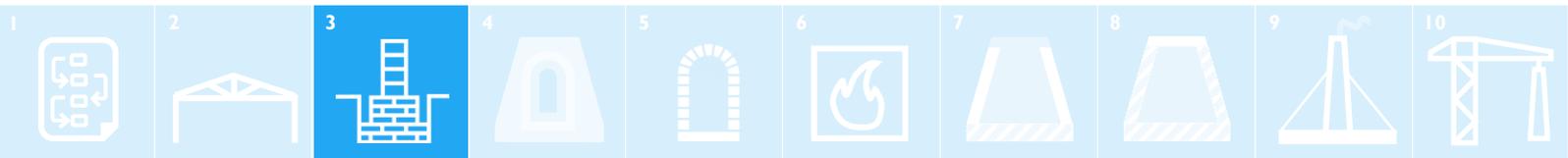
Frame work can be built from concrete, wooden or steel columns.

The roof can be built with iron sheets or tiles.

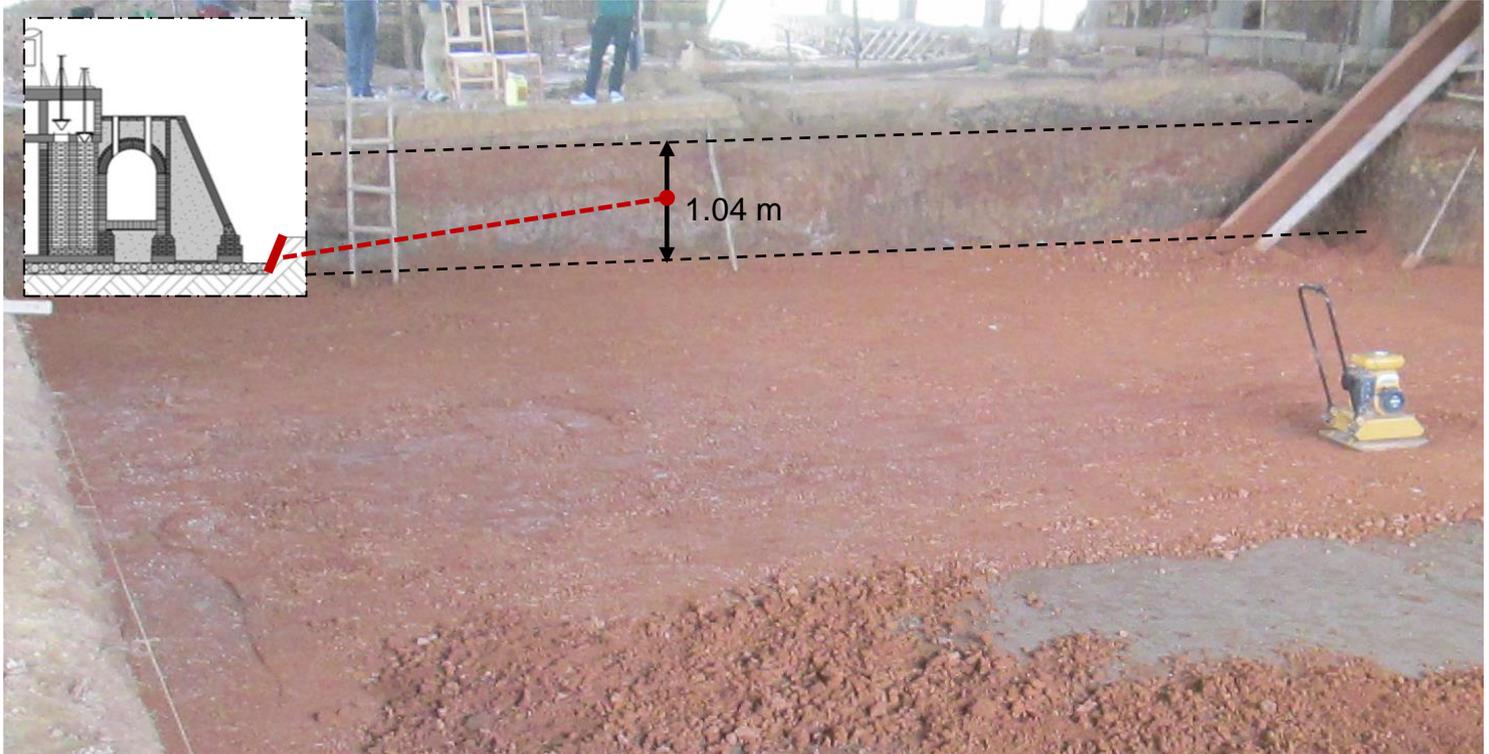
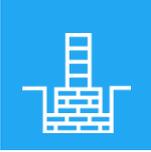
The hangar protects the kiln from rain damage during construction.

## Stage 3.

# Foundation works



# A. Excavation to 1.04m depth



Kiln foundation should be excavated to 1.04m depth (5 days)

## B. Compacting soil to required bearing capacity



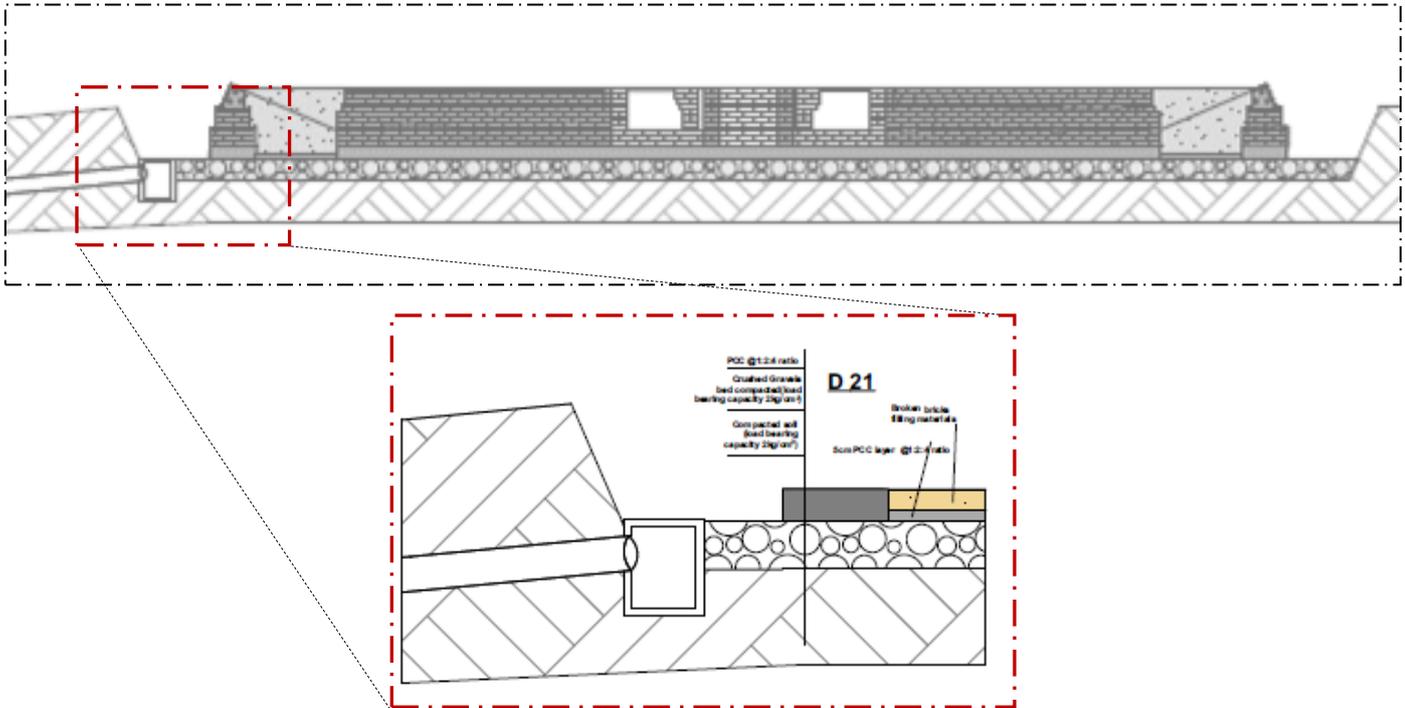
If the sub-soil at 1.04M depth is not stable enough, good soil (50M<sup>3</sup>) such as laterite must be brought and compacted to 2Kg/cm<sup>2</sup>, 200mm thick. (2days.)

## C. Compacting gravel



A 20-40cm thickness layer of gravel is compacted for drainage purpose. Approximately 112M<sup>3</sup> of Gravel 15-40mm thick is required. (2days).

## D. Installation of drain pipe



A drain pipe is installed at the kiln base where any water collected is disposed

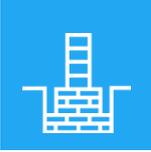


# E. Setting/Mapping out the Kiln Foundation



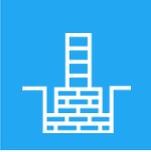
This process involves accurately setting the kiln foundations on the ground. (1 day)

## F. Making formwork for the foundation pads



Formwork to support concrete pads for kiln foundation is erected accurately, set as per specifications. (2days).

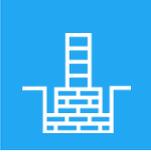
# G. Pouring concrete for foundation pads



18m<sup>3</sup> concrete (1:2:4) is poured inside the formwork (2days).



# H. Construction of brick wall to floor level

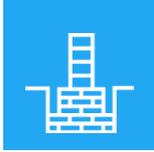


Building external walls to ring beam (10days). Joints should not exceed 5mm. 83,600 bricks are required for the entire external walls.

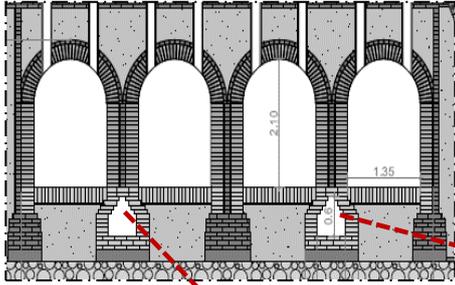


Brick laying at the foundation base  
Bricks staggered at  $\frac{1}{2}$  lap with maximum joints of 5mm.

# I. Building of smoke tunnels to floor level



Smoke tunnels are built simultaneously with external walls, using semi-refractory bricks. 42,000 semi refractory bricks are required for the entire kiln (10days)



Tunnel construction



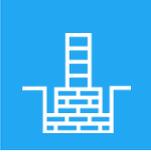
Kiln construction at floor level with the smoke tunnels in place



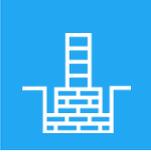


Casting the Ring Beam. The concrete ratio for ring beam is 1:2:4, The ring beam is reinforced with (3), 12mm steel bars tied with 6mm stirrups.

## K. Backfilling foundation walls to floor level



Approximately  $73\text{M}^3$  of broken bricks is required for backfilling the various sections of the kiln. (3days).



Backfilling with approved materials such as hard broken burnt bricks for insulation.

## L. Laying bricks to form the kiln floor



The kiln floor is built with semi-refractory bricks laid vertically (soldier course). (5days).

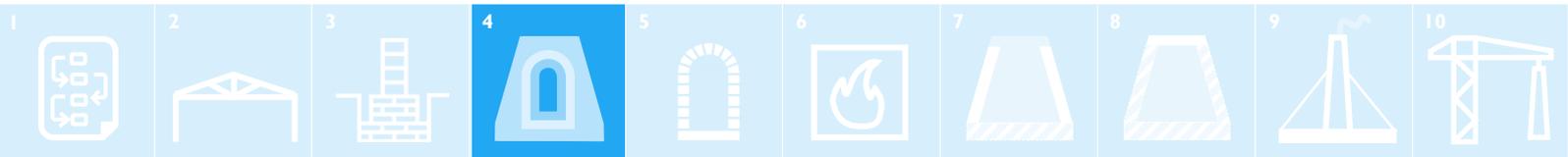


The finished kiln floor.

The kiln floor is built with semi-refractory bricks laid on the head

## Stage 4.

# Kiln construction to vaults level



# A. Building the vertical smoke tunnel



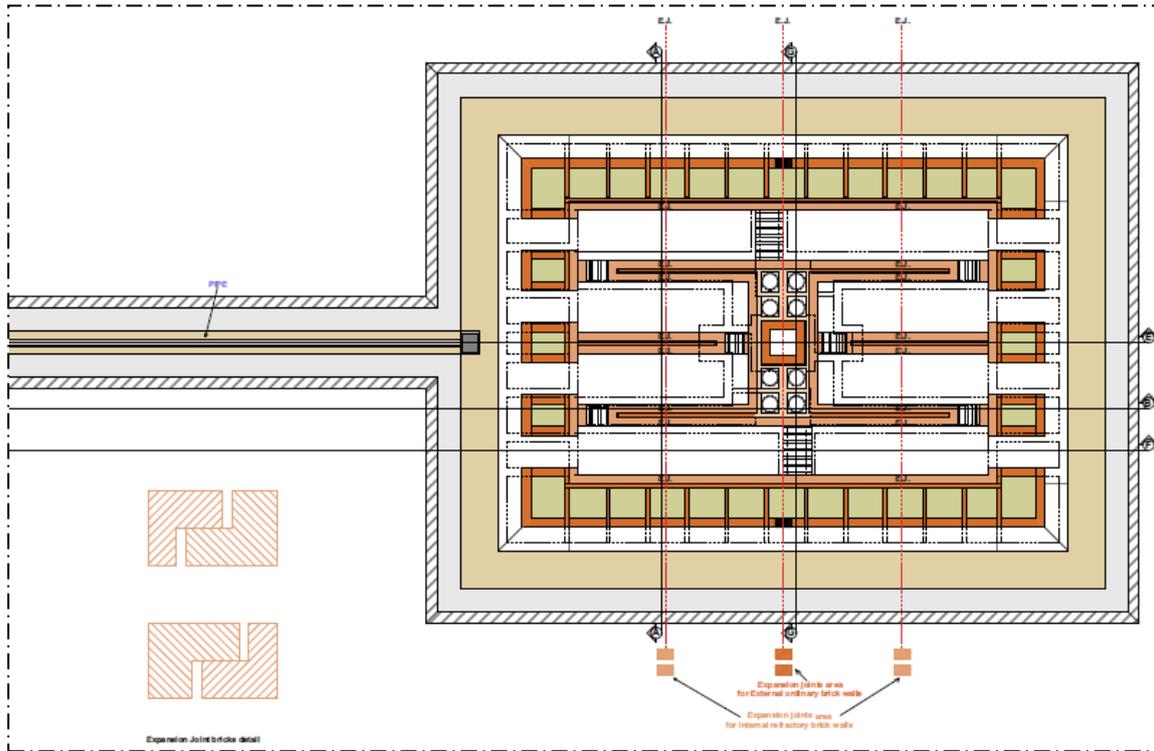
Joints between bricks should not exceed 5mm and are filled with clay/ kaolin/ chamotte mortar. (7days)

## B. Building the slanting walls to vaults level



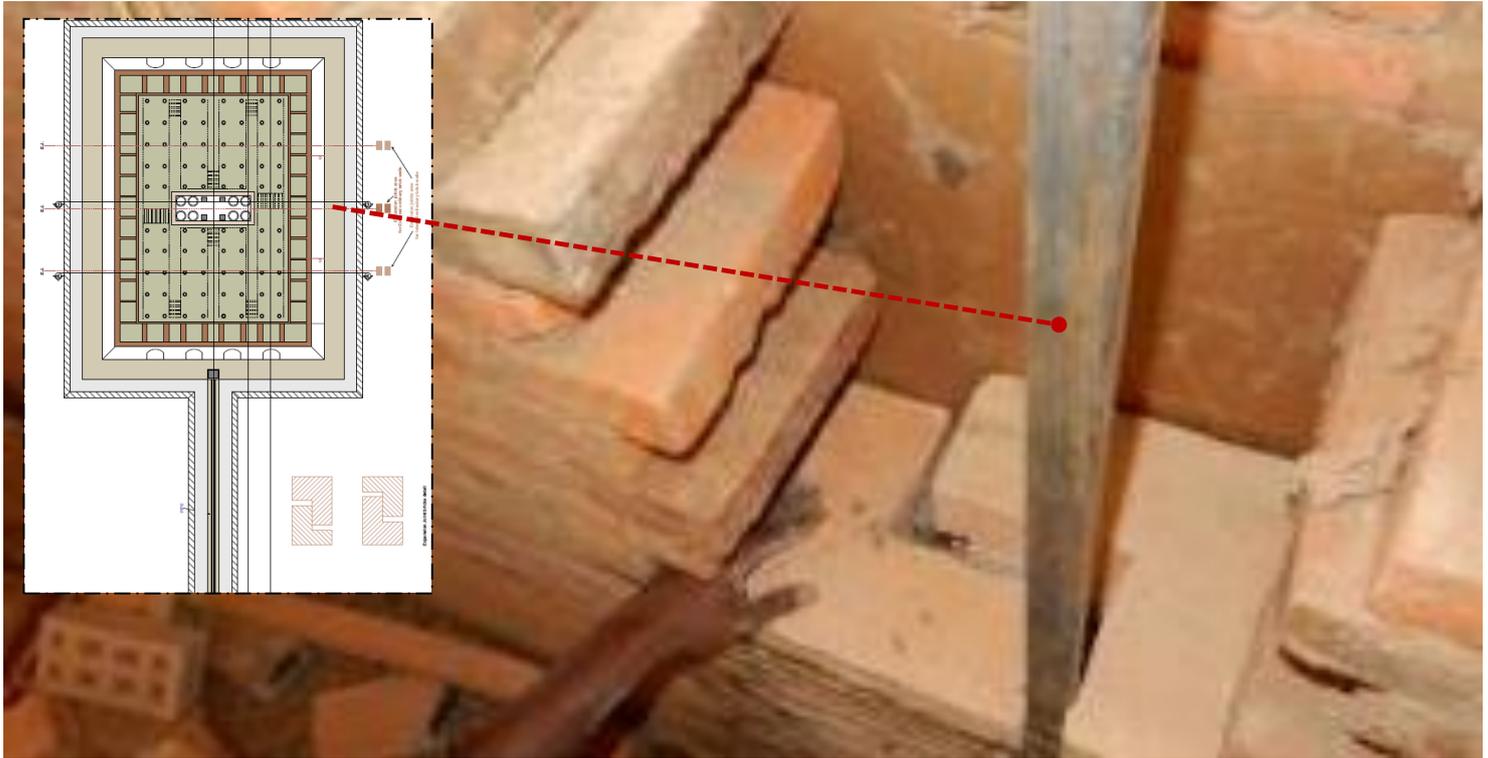
A metal or timber frame is made to guide in building the kiln slanting wall.

# C. Positioning the expansion joints



Special L-shaped bricks are used to make expansion joints in designated places. There are expansion joints at 8 positions of the kiln.

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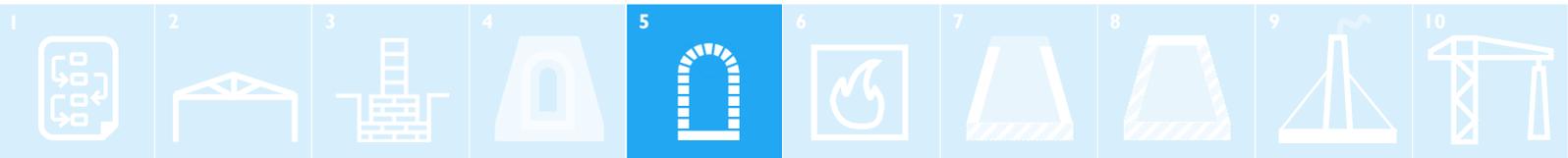
## D. Exterior walls construction & backfilling



All the gaps between walls are filled with well compacted broken bricks as wall construction progresses. (10days).

## Stage 5.

# Building the vaults



# A. Making vaults formwork



Kiln chambers are bridged with vaults. The vaults are supported with wooden formwork. (5days).

# A. Making vaults formwork



The vault wooden formwork is covered with polythene sheet to prevent leakage of the liquid mortar.

## B. Building the vaults



The vaults are built with special wedged refractory bricks with joints filled in clay/kaolin/chamotte mortar.(10days). 26,000 bricks are required.

## C. Sealing expansion joints



Expansion joints in the vaults are sealed with fire resistant material. There are 6 expansion joints, one in each vault.

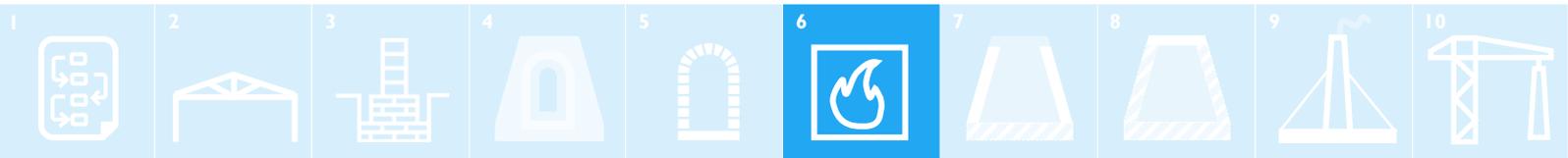
## D. Inserting fuel feeding holes



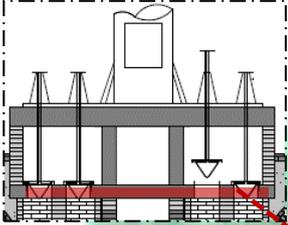
Fuel feeding bricks are inserted in place, creating the holes for feeding the firing fuel. 160 pieces of such bricks are required.

## Stage 6.

# Construction of Fire Control Box



# A. Making the R.C slab



The fire control box is built in the middle of the kiln, where all the chambers and chimney are connected. Formwork and slab casting (5days).

## B. Building the fire box brick wall to roof



The fire control box with the steel reinforcement for the columns, and the fire control holes in place. Building walls to kiln top (5days).

## C. Making the R.C. columns



The fire control box has 4 R.C columns in the middle for supporting the chimney. Columns cast within (3days).

## D. Inserting the fire control valves



The fire control valves installed in place. (2days)

## E. Casting the R.C. roof slab



The R.C roof slab where the chimney rests.

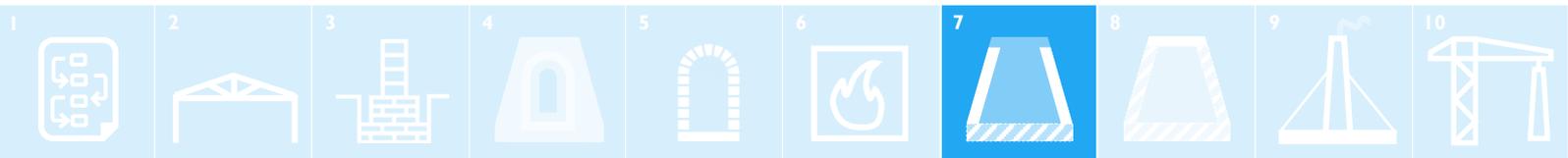
## F. Fixing the bolts for chimney anchorage



The chimney is fixed to the kiln by means of bolts and steel plates concreted and anchored to the fire box R.C roof and columns.

## Stage 7.

Walls construction to kiln top



## A. Brick laying to kiln top



Brick laying of external walls are laid to the top of the kiln, tied together by a R.C tie beam.

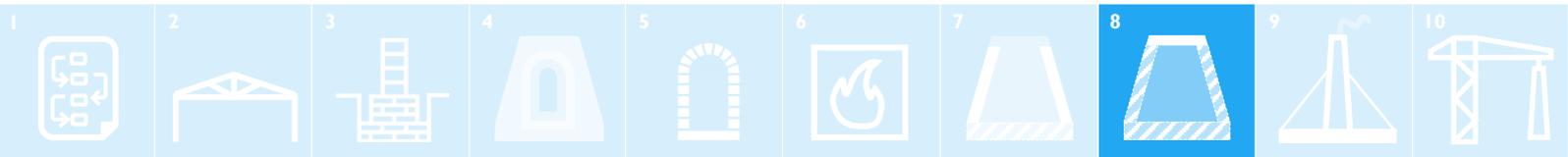
## B. Casting the top R.C Tie Beam

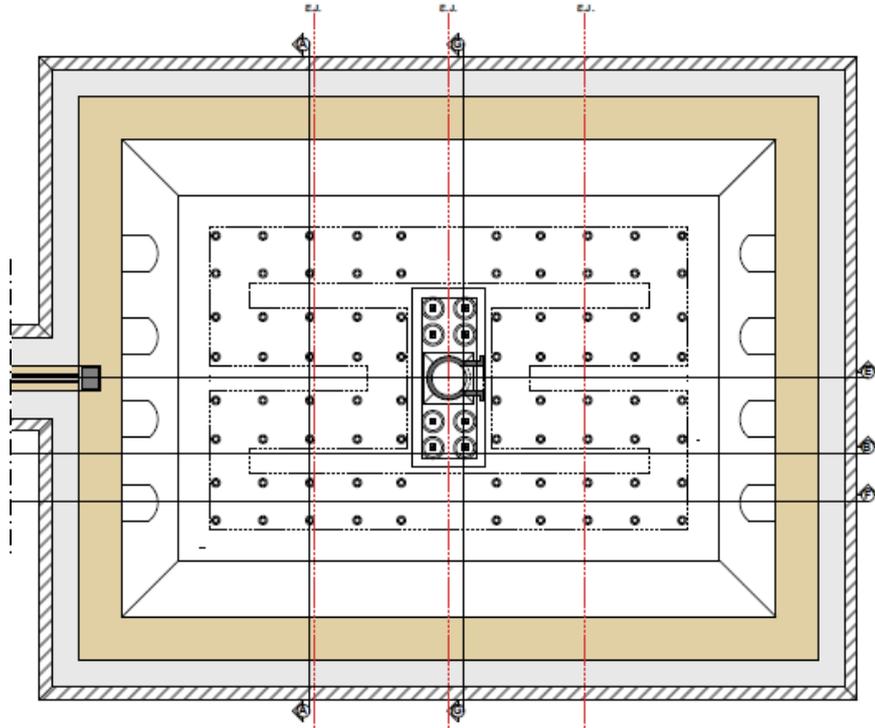


A R.C Top Tie is cast around the top of the kiln to hold it together. (2days)

## Stage 8.

# Kiln Top Level Construction





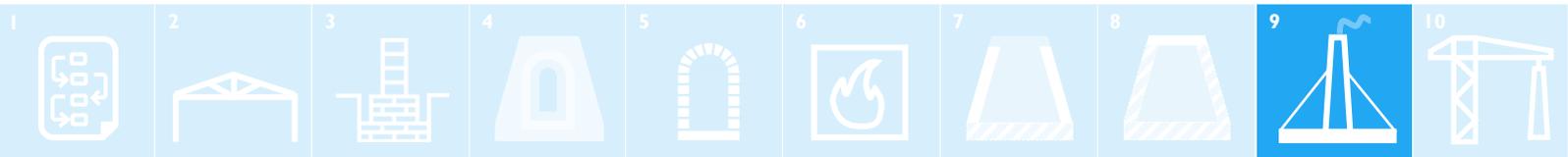
The kiln top is built with 2-layers of dry-stacked bricks following the pattern illustrated above. (3days).



The kiln top is built with 2-layers of dry-stacked bricks following the pattern illustrated above. (3days).

## Stage 9.

# Fabrication of steel chimney

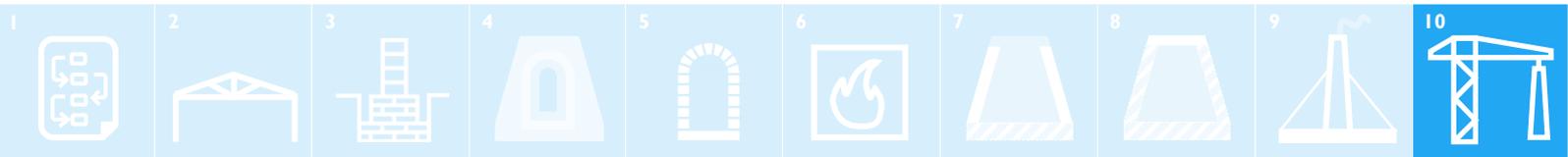




Chimney is made from non-corrosive steel as per specifications, fabricated in a workshop.(10days) 65SM of such steel is required.

## Stage 10.

# Installation of the steel chimney





# A. Casting 4-concrete anchorage pads



Four concrete columns are cast at specified corners for anchoring the chimney to the ground. (3days).

## B. Kiln anchorage bolts



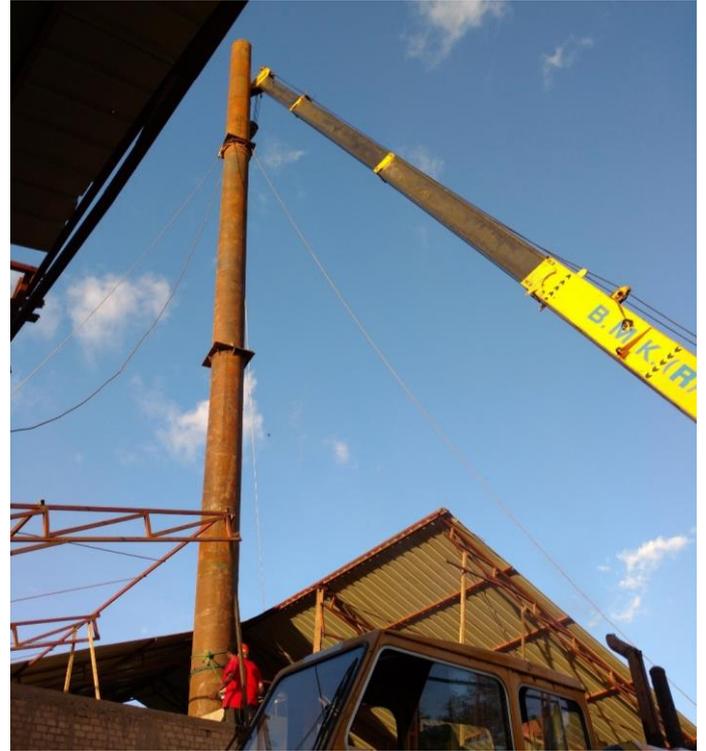
The chimney is fixed to the kiln by means of anchor bolts concreted on top of the fire control box.

## C. Placing the fire proof sealing matt



A fire proof fibre matt is placed on top of fire control box to seal gaps between the box and the chimney.

## D. Elevating the chimney to position



The chimney is elevated to position using a crane. (1 day).

## E. Positioning the chimney to position



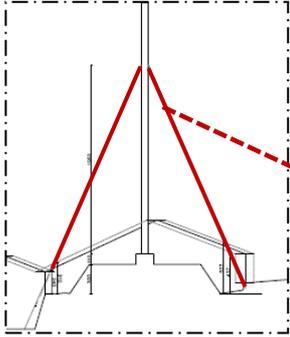
Positioning the chimney to the anchor bolts.

## F. Bolting the chimney to position



The chimney is bolted in the steel plate anchored to the concrete slab. (1 day)

# G. Bracing the chimney



The chimney is braced with 4, 16mm (Total 120m) steel cables anchored to concrete columns. (1 day).

## H. Anchoring the chimney to the concrete pads



The chimney is anchored to the 4-concrete cubes. (1 day)

# I. Making the inspection chamber



An inspection chamber is provided for inspection and maintenance of the chimney.

## J. Fixing the smoke regulator valve



A smoke valve regulator is fixed for heat control.

# The Brick Factory



# QUALITY CONTROL CHECKLIST

# Quality control checklist



No	Construction state	What to check	Observations	Recommendations
1	<b>Preliminary site visit</b> This is a basic site survey and feasibility study to determine the suitability of the site location for the brick factory	a. Is the site accessible by road and big tracks?	a. Yes/No	
		b. Have a soil topography been done?	b. Yes/No	
		c. Have you established the key raw materials available locally?	c. Yes/No	
		d. Is the site cleared of all bushes and levelled?	d. Yes/No	
2	<b>Site preparation</b> This involves clearing the site of all top soil,	a. Is the site cleared of all bushes and levelled?	a. Yes/No	
3	<b>Brick factory layout plan</b> The brick factory layout plan should be prepared in advance before any construction takes place	Has the site layout plan taken care of?		
		a. Clay & fuel storage?	a. Yes/No	
		b. Water storage?	b. Yes/No	
		c. Adequate production capacity & drying area?	c. Yes/No	
		d. Kiln site?	d. Yes/No	
		e. Storage for ready bricks?	e. Yes/No	
		f. Office?	f. Yes/No	

# Quality control checklist



No	Construction state	What to check	Observations	Recommendations
4	<b>Hangar Construction</b> The kiln hangar must be built before the construction of the kiln starts. This is to protect the kiln from rain damage	a. Is the hangar built yet?	a. Yes/No	
5	<b>Setting out</b> This is mapping out on the ground the floor plan of the kiln	a. Check that the setting out is accurately done by checking if the diagonals are equal	a. Yes/No	
6	<b>Excavation works</b> The kiln construction starts at a depth of 1.05 metres below the ground level	a. Check if the excavation of the kiln foundation is done to a depth of 1.05	a. Yes/No	
7	<b>Soil Compaction</b> This should be done with a mechanical vibrator	Has the soil been compacted with a mechanical vibrator to a load bearing capacity of 2kg/cm <sup>2</sup> ?	Yes/No	
8	<b>Gravel compaction</b>	Has the gravel been compacted to a depth of 0.4M?	Yes/No	
9	<b>Mapping out the position of foundation concrete pads</b>	Are the concrete pads correctly marked on the ground as per the drawing?	Yes/No	
10	<b>Making the formwork for foundation concrete pads</b>	Is the formwork accurately set and firmly fixed to the ground?	Yes/No	
11	<b>Foundation concrete pads</b> The concrete for foundation pads is made from a mix ratio of 1:2:4 (1-cement,2-sand,4-gravel measured using a bucket)	a. Has the sand and gravel been tested for quality required?	a. Yes/No	
		b. is there a batch box or bucket used to accurately measured the concret ratio?	b. Yes/No	

# Quality control checklist



No	Construction state	What to check	Observations	Recommendations
12	<b>Positioning the drain pipe</b> A drain pipe is required to drain off any water that may find its way under the kiln	The drain pipe must be fixed when the foundation works is in progress. Is the drain pipe gradient (1:40) and drains out water from the lower end of the kiln?	Yes/No	
13	<b>Construction of external walls</b> The walls are built using ordinary bricks with 25% perforation laid in cement/sand mortar	a. Are the macons soaking the bricks in water before laying them?	a. Yes/No	
		b. Are the joints betwwen the bricks 5mm?	b. Yes/No	
		c. Is the cement mortar used a ratio of 1:5 (1-cement to 5-sand)?	c. Yes/No	
14	<b>Tunnels construction</b> Tunnels are constructed using semi-refractory bricks	a. Are the joints betwwen the bricks 5mm thick?	a. Yes/No	
		B. Are the joints filled with clay mortar made from 50% clay, 35% kaolin and 15% chamotte?	b. Yes/No	
15	<b>Kiln floor</b> The kiln floor is built with refractory bricks laid on edge	Is the space between the foundations to the kiln floor level is filled firmly with well compact broken burnt bricks or other approved materials?	Yes/No	
16	<b>Chimney &amp; fire control box</b> Careful attention in required in building walls for the	a. Are the chimney and fire control box accurately set in the right place?	a. Yes/No	
		b. Are semi-refractory bricks used laid in clay mortar?	b. Yes/No	
		c. Is the first floor slab for the fire control cast in concrete?	c. Yes/No	
		d. Are the 4-concrete columns that support the concrete roof of the heat control box cast as per specifications?	d. Yes/No	

# Quality control checklist



No	Construction state	What to check	Observations	Recommendations
17	<b>Construction of vaults</b> The are built with refractory bricks laid in day mortar	Check and verify:		
		a. the accurate making and erection of the vaults formwork	a. Yes/No	
		b. That the wedge - shaped bricks are tightly laid against each other	b. Yes/No	
18	<b>Fuel feeding inlet holes</b>	Are the fuel feeding holes correctly positioned as per specifications?		
19	<b>Construction works to roof top</b>	Check the following:		
		a. That filling the space between the vaults and kiln roof is filled with approved materials	a. Yes/No	
		b. That bricks are tightly laid against each other on edge to form the roof	b. Yes/No	
20	<b>Construction of the fire control box</b>	Check the following:		
		a. Are the fire control valves well fixed?	a. Yes/No	
		b. Is the area around valves well concreted?	b. Yes/No	

# Quality control checklist



No	Construction state	What to check	Observations	Recommendations
21	<b>Chimney installation</b>	a. Are the steel plates and bolts for fixing the chimney on top of the heat control box accurately and securely	a. Yes/No	
		b. Is the chimney anchored on top of the fire control box with bolts tightly?	b. Yes/No	
22	<b>Bracing the chimney</b> The chimney is anchored and braced to concrete pads	Check the following:		
		a. Are the 4-concrete columns cast to specified depths and widths?	a. Yes/No	
		b. Is the chimney firmly braced and strutted to the concrete with 16 mm thick steel cable?	b. Yes/No	
23	<b>Chimney control</b> A door is made in the chimney for inspection, where a valve is fixed for heat and smoke control	Check:		
		a. If the valve is flexible , moving when turned?	a. Yes/No	
		B. Does the door seal tightly when closed?	b. Yes/No	

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