TARA

VERTICAL SHAFT BRICK KILN

CONSTRUCTION MANUAL

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A Practical Guide
On how to construct a Vertical Shaft Brick Kiln

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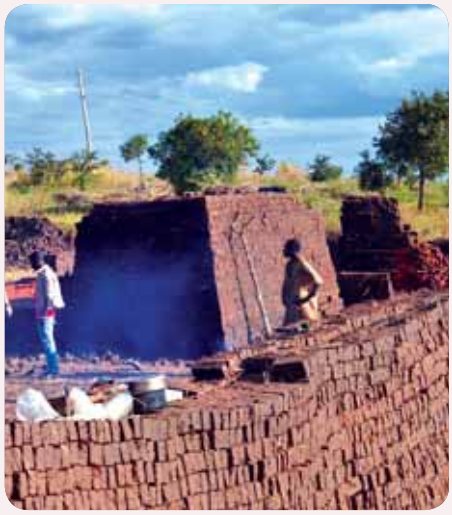
Preface



Knowledge in public domain is the key to success for accelerated dissemination of Vertical Shaft Brick Kiln (VSBK) technology on a global scale. This manual is aimed to popularise the VSBK technology as far as possible by providing easy, step by step access to the construction process with all relevant designs and useful photographs

The present “state of the art” VSBK construction technology is based on the practical working experience of constructing more than 200 VSBK’s, in India, Nepal, Pakistan, Afghanistan and Bangladesh.

This is the first attempt to document and disseminate knowledge on the VSBK construction technology. This construction manual will help the entrepreneurs to understand the intricacies of the VSBK structure and the methods of construction. The document serves as a template for the present VSBK construction training manual.

Who is it meant for:

This construction manual is meant to serve as a basic reference guide to engineers and supervisors constructing a VSBK. This manual should not be used as a standard guide for future VSBK’s. On the contrary, the construction team should stipulate and generate new ways and ideas to further improve/simplify the VSBK construction technology in Malawi for wider dissemination.

Who is it not meant for:

This construction manual is not a suitable tool for the “Do it yourself” approach, as the VSBK construction basically demands a lot of precision work, requiring thorough fundamentals of civil construction. Every VSBK has a different approach with a substantial amount of technical details. Thus design techniques and construction drawings have to be developed individually for each such unit

A construction manual is never complete or perfect:

VSBK can be constructed in many ways. Thus, this manual does not claim to be complete or perfect. It is in the hands of the users to utilise it in the best possible manner, using it as a reference for further construction improvements. The VSBK project, Malawi would appreciate if you could share your ideas and work experiences to further improve this VSBK construction manual.

Society for Technology and Action for Rural Advancement, India

Acknowledgments

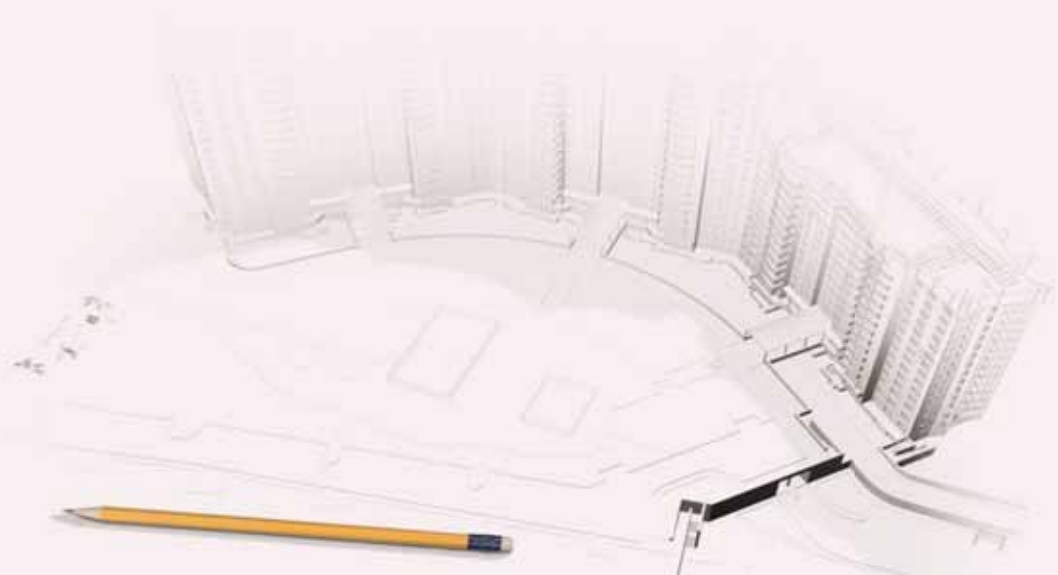
During the course of developing this manual, every effort was made to include the existing knowledge base, along with interactions between personnel associated with the VSBK technology.

We would like to acknowledge the support of various organizations, The Swiss Agency for Development and Cooperation, India; TARA Machines and Tech. Services Pvt. Ltd., India; Centre for Community Organization and Development (CCODE), Lilongwe, Malawi; Eco bricks Limited, Lilongwe, Malawi and IPE Global, New Delhi; who have whole heartedly contributed towards developing the same.

Our sincere thanks to various individuals, whose views have been accessed personally, through one-to-one interactions, the internet and printed documents. Special thank to Heini Muller, Skat Nepal for developing the first manuals. His inspirations and guidance were invaluable in designing many more.

The research efforts captured in this manual would not have been possible without the institutional support given to the project organisations by Deutsche Gesellschalt fur Internationale Zusammenarbeit(GIZ) GmbH and the Knowledge Partnership Programme (KPP) of the Department of International Development (DFID), India. Managed and supported by IPE Global, the KPP aims to step up collaboration around ideas, knowledge, evidence, accountability, technology and innovation, impacting the delivery of global public goods and services and leverage Indian experiences to reduce poverty in LDCs.

Society for Technology & Action for Rural Advancement, India



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Chapter 1

Introduction

Conventional burnt clay bricks will continue to be the main walling material required in meeting the huge demand for housing in the foreseeable future, notwithstanding substantial efforts to develop alternatives. The current technologies for brick production, such as Bull's Trench kilns (BTKs), Zig Zag kilns, Hoffmann and tunnel kilns, consume large quantities of fuel, such as coal, natural gas and also firewood. The devastating effect of the pollution caused by huge amount of emissions from the brick industry has attracted the attention of the government and various international agencies. Efforts are being made to minimise air pollution from the brick sector by introducing and demonstrating cleaner production techniques and practices and simultaneous demonstration of clean alternate technologies.

The Vertical Shaft Brick Kiln technology, developed in China, is an energy-efficient, environment-friendly and economically-viable means to produce quality bricks. Given below are the main factors that have favoured this technology.

Vertical Shaft Brick Kiln Technology

- Lower emissions compared to other brick firing technologies like Clamps or BTKs
- 40 to 50% energy savings when compared to local clamps and 30 to 40%, when compared to BTKs
- Less working capital
- Occupies less space
- Can be operated throughout the year

The Vertical Shaft Brick Kiln is a civil structure consisting of insulated vertical shafts in which bricks are fired. This is a continuous operation kiln, capable of round-the-year operations. Through VSBK, production can be easily scaled up or down to meet different levels of demand. Preliminary assessment indicates that unlike other brick kilns like BTK's, Hoffman kilns etc., the working capital of VSBK is less. Maintenance is also negligible. The construction cost of a VSBK in Malawi is approximately between USD 35,000 to USD 40,000, excluding ramp. The kiln costs being apportioned are as follows:

Items	Percentage of Kiln Costs
Burnt bricks	20%
Labour	17%
Refractory brick	15%
Roofing, cement & other materials	26%
Steel & unloading device	22%

The kiln can be built within eight to twelve weeks; provided all the materials like bricks, cement and steel are available well in time. The kilns are built by cement mortar and refractory bricks shaft lining of fire clay mortar. A skilled fabricator is required for trusses, metal chimney, brick guides, lid covers, square bars and unloading trolley track. Typical items like trolleys and an unloading mechanism require specialised manufacture and special attention.

The kiln construction is fairly straight forward. The most complicated section of construction is the shaft, arch and the unloading tunnel. The unloading tunnel is built by bricks, setting over a cement mortar layer on top of a metallic formwork. There is also a provision of filling insulated material to protect heat loss from the kiln.

A kiln that is built on an already existing bank of earth with adequate height can save considerable effort and cost in building the loading ramp.

The main aspects to be considered during the installation of a VSBK are:

- Soil selection
- Site selection
- Design
- Construction
- Operation
- Maintenance
- Quality control and trouble shooting
- Economics and cost control

To facilitate the understanding of the VSBK technology in a holistic manner, it was thought appropriate to produce documents on the performed construction activities that cover the above mentioned functional areas. These will not only be useful in providing information in future kiln constructions, but are also expected to become effective tools for professionals, willing to adopt this trade.

This manual is the brick by brick account for actual construction activities undertaken for the construction of VSBK.

VSBK under Construction

Chapter 2

VSBK Construction Details

2.1. Basic Features

The VSBK consists of one or more shafts located inside a rectangular hollow structure. The nominal shaft dimension is 1.00m wide and 2.00m long. The exact shaft dimension exclusively depends upon the dried green brick dimension. The shaft's inside smooth surface is made up of a refractory brick work. The gap between the shaft wall and outer wall of the kiln is filled with insulating materials like a homogeneous mixture of broken brick bats, burnt coal ash, fly ash etc. or any cheap and locally available insulating material.

The shaft is designed for accommodating 12 to 13 green brick batches. During regular operations, the shaft is loaded from the top and unloaded from the bottom. Each batch normally contains four layers (Two layers of bricks and two chulas), but a six-layer batch (three layers of bricks and three chulas) is also possible under certain conditions. The brick batch is loaded in a predetermined pattern, with a predetermined amount of coal. All the batches of bricks rest on support bars (which can be removed or inserted) resting on a pair of horizontal I-beams across the arches in the unloading tunnel.

2.2. Definition of Terms

Items	Description
Anchor bars	The vertical wall reinforcement of 12 mm MS bars provided at every outer corners of wall.
Brick guides	A rectangular frame of angle iron welded with MS flats down side of frame and situated at top of the shaft to protect flue inlets by green bricks.
Chimney	A vertical, structure whose vertical ducts evacuate exhaust gases from top portion of the shaft and creates natural draught.
I-Beam for brick support bar	These beams resting on the brickwork along the unloading tunnel take the load of the brick stack through the square support bars.
Insulation	Filling pockets around shaft construction for protecting heat loss from the kiln.

Lids	Panels either hinged or in parts used to cover the top opening of the shaft.
Loading platform	The platform at the top from where the green bricks are loaded into the shaft. It is also used for the daily storage of the green bricks.
Protection plates	3 mm thick MS plates affixed at arch inner walls in proper position to rest the support bars and protect the wall against support bars.
Ramp	A structure adjacent to the kiln whose inclined surface on the top is used for easy movement of men (mainly for lifting up green bricks).
Screw pits	A square pit of brick masonry, which exists in the exact centre of the shaft for the movement of hydraulic unloading device.
Shaft	A rectangular hollow construction with lining of refractory bricks with fire clay mortar and supported by red bricks with lime mortar, through which stack of green bricks move vertically down through the notionally designated preheating, firing and cooling zones.
Single Shaft Unloading Mechanism	A mechanism consisting of a hydraulic device with a hydraulic tank used for lifting and lowering unloading trolley with or without stack of bricks.
Spy holes/peep holes/ observation pipes	All mean the horizontal-piped holes through the kiln structure from outside to the inside of the shaft at various levels, incorporated for viewing the hot brick stack and for inserting thermocouples etc. for measuring the temperature inside the shaft.
Support bars	The steel bars, which act as beams to support the batches of bricks loaded in the shaft. The support bars could be square steel hollow bars or I shaped steel bars.
Trolley guide	Vertical channel sections secured to the kiln tunnel walls, which prevent rotation of the trolley and help move up and down vertically.
Trolley track	The angle iron track along which the trolley can move in or out of the shaft line
Unloading trolley	A steel structure with four-flanged wheel, which can move along an angle iron track. Wooden planks on its top can engage with and lift the stack of bricks in the shaft, when moved vertically by the screw unloading system.
Unloading tunnel	The vaulted opening running across the kiln along the shaft centre line, through which the unloading trolley moves in and out of the shaft line.
VSBK	A rectangular brick kiln structure consisting of one or more shafts located vertically inside the structure for burning bricks.

Chapter 3

Preparatory Work before Construction

3.1. Soil Selection

One of the most important things to do before adopting the VSBK technology is to check its technical feasibility in terms of the expected fired brick product quality. Unlike other brick making technologies, like Fixed Chimney Kilns (FCK), Moving Chimney Bull's Trench Kiln (MCBTK) Hoffman Kiln, etc, not all types of soils are suitable in a VSBK technology firing system. Too sandy soils, as well as too clayey soils are not suitable for VSBK and should be rejected. Soil containing high sand results in poor fired brick strength (strength less than 50kg/cm^2 is not acceptable for VSBK) and similarly soil with very high level of clay content causes high shrinkage and results in cracking even during the green brick making stage. Thus the soil quality must be checked before adopting the VSBK technology.

To get an idea of which soils are suitable a detailed analysis needs to be done. The scope of discussion of the same is not within the scope of this manual and can be obtained from our website www.tara.in or from the established laboratories.

3.2. Brick Kiln Siting Criteria

Malawi doesn't have a brick kiln siting criteria. However, the general criteria for the selection of the site in Malawi are mentioned below.

- Availability of suitable soils in big quantity (several 100 hectares all along the valley)
- Short distance to the tobacco industry which is the main source of fuel, thus low transport costs
- Proximity to the city, so low transport costs to the consumer

3.3. Site Selection

During the preliminary selection of a VSBK site, some important criteria must be kept in mind to ensure the best operation and business conditions.

Items	Description
Drainage	The land should have well-laid drainage systems.
Electricity	Since, VSBK is a 24 hours operation system, it is imperative to have provision for electricity. In order to prepare the best quality bricks, pug mill is required for which a three-phase electricity line is required.
Future expansion	There should be enough space for future expansion.
Soil quality	Quality of soil should be good for green-brick moulding and for producing good-fired bricks
Topography	A hillock, elevated (sloping) land, or some high ground next to the kiln should be ideally preferred in order to allow easy access to the top of the kiln for loading green bricks. It reduces the cost of construction of the ramp or a staircase.
Transportation	Location should be such that minimum time and efforts are required to transport raw material and finished products.
Trees	If possible, do not cut any tree where the proposed VSBK will be constructed.
Water	Sufficient quantity of water should be available for green brick moulding, drinking and other purposes.

3.4. Design

For determining the design of a VSBK kiln, please refer to the VSBK Design Manual.

Chapter 4

Construction Planning

It is important to finish the designing of the shaft's height and dimensions before initiating the construction phase. This is based on the test results of green and fired bricks' dimensions, shrinkage, as well as the green-brick's capacity on the loading platform (refer to VSBK Design Manual for the complete design).

The construction planning activities of VSBK can be grouped into the following:

4.1. Site Preparation and Cleaning

While preparing the site, remove shrubs, bushes and all unwanted materials from the site. All undulations should also be levelled. Keep sufficient clean space for the stacking of constructional material. The excavated soil from the foundation should be kept aside for future use. Arrangements of sufficient water should be also made for construction, curing, moulding and general use. Construct two 15' X 12' rooms for storage and office space. These rooms should be carefully planned since they will be also used during the kiln operations and the production stage.

Preparation of Site for the Construction of VSBK

4.2. VSBK Layout Procedure

While preparing the layout of VSBK, the orientation of the kiln should be such that the wind and rain does not hamper daily production operations. The kiln should be oriented parallel to the wind flow direction, i.e. the unloading tunnel should be across the wind direction to block the direct flow of the wind through the unloading tunnel. For example, if the wind blows in the north-south direction then the unloading tunnel should be made in the east-west direction.

The future expansion of the kiln also needs to be taken into consideration.

The layout procedure is listed below:

- Wind direction and future expansion
- A detailed set of drawing at site
- Tools and equipment necessary for the layout
- Proper access to the construction site

First of all the site should be cleaned and levelled properly. The detailed measurements of the VSBK must be made and permanently marked on brick masonry pillars. These brick masonry pillars must be erected at least 1.5m away from the proposed VSBK construction and should be treated with care to prevent any damage. Curing of the same should be done properly with wet jute gunny bag.

Chapter 5

Foundation and Hydraulic Unloading Device

5.1. Excavation Work for Foundation and Hydraulic Unloading Device

What?

Excavation work for foundation and hydraulic unloading device.

The foundation work requires special attention. The actual size of the foundation always depends on the type and quality of the existing soil where the VSBK is supposed to be constructed. what are the various range of foundation size exist?

In this VSBK construction manual, the VSBK design foundation is based on the assumption of a soil bearing capacity of 15 tons/m^2.

The reference drawing (Refer Figure 1) is therefore not a standard that can be followed for all situations. It is strongly recommended to consult an experienced civil or a structural engineer for the design of the VSBK foundation.

Where?

Level : +/- 00 to -1480 mm

How?

- Remove the topsoil and preserve it for using it again for agricultural purpose. Do not mix this topsoil with any other soil.
- Start excavation work up to the level of 2000 mm. The excavation needs to be made up to level – 1480 mm where the hydraulic unloading device will be constructed.
- Dump the excavated soil at a faraway place, outside the kiln body, so that no soil falls back into the pit. The soil depot should be positioned where it will not hamper the access or the construction of the VSBK.

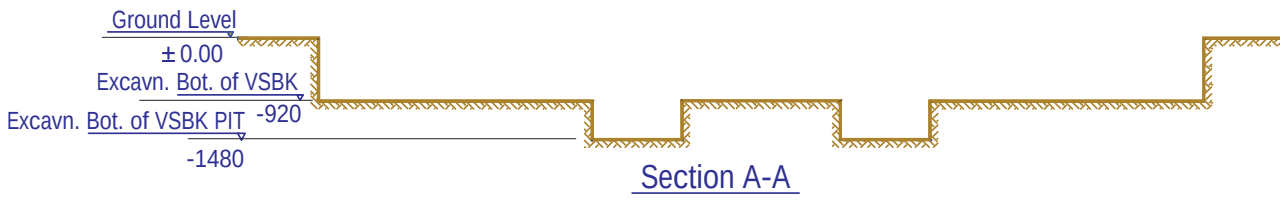


Figure 1: Foundation of a VSBK

Quality Specifications

- No loose soil should remain on the foundation base, which must be dry.
- The foundation base must be levelled and rammed properly and the pit should be excavated vertically. If the excavation is very deep or the soil is non-cohesive, the excavated wall must have some gentle slope to avoid the falling of the wall, but the excavated pit at the bottom should not be less than that mentioned in the Figure 1.
- In case of the excavation base getting wet, remove all the wet soil before starting the foundation soling work.
- In case of unexpected water logging or seepage, consult a civil engineer and a water-proofing expert.

Do & Don'ts

- Do not dig out big stone boulders, except where screw shaft excavation has to be done. These boulders can be used for soling purpose, as they provide a stable ground.
- Protect the excavated pit from any source of water, such as rain, run-off water from a tap stand, water tank, road, field etc. It is essential to have a proper drainage system.
- Protect the excavated pit with whatever material is around so that no one (especially children or animals) falls into the pit.

Alternative Ways

- Mat foundation (Black cotton soil foundation)
- Pile foundation
- Rock foundation

Manpower & Time

Estimated manpower required: 40-50 labour days

Estimated time required: 4-5 working days

Estimated time for excavator: 4 working days

Special Tools

For the VSBK excavation, it is recommended to have the following additional tools at site:

Manual:

- Spade, crow bar, pick axe
- Iron ramming tool

Machine:

- Excavators
- Mechanical rammer (Monkey jumper)

Must Supervision

For the foundation work, it is essential that the overall site in-charge/engineer is present at the site and supervises the work personally.

5.2 Brick Work for Hydraulic Device

What?

Brick Work for Hydraulic Device

Where?

Level: -1480 to 0-0 mm

How?

- Ensure that the excavation sides of the hydraulic device are solid and no loose parts are falling into the pit. Clear all the loose soil at the hydraulic device base and compact the soil properly.
- Provide a flat-brick soling layer and fill the joints with cement mortar.
- Measure the centre of the hydraulic device and mark it at the base into the cement mortar. Construct the shaft wall with a cement mortar 1:4 (cement:sand) brick masonry, stretcher bonding up to level 0-0
- Fill back the excavation with stone masonry, using a cement mortar (1:6) or with brick masonry (1:6) up to the bottom of the Plain Cement Concrete (PCC) level.

Quality Specifications

- Use only good quality bricks, since repairing the hydraulic device can be very difficult.
- Use a cement mortar mixture of 1:4.
- Maximum permissible limit of vertical deviation for the brick works up to -0–is 1 to 2 mm.

Brick Work for Hydraulic Unloading Device

- Ensure that all cement joints are smooth and properly closed.
- The hydraulic device brick work has to be made water tight.
- If the water table is high in the hydraulic device excavated area, water proofing measures should be taken to avoid water logging inside the screw shaft.

Do & Don'ts

- Do not make the back fill with stone/brick masonry too soon. This will prevent damage to the hydraulic device masonry work.
- Cover the hydraulic device hole properly so that nothing falls into the shaft and nobody gets hurt while stepping in it.
- Ensure proper curing of the brick masonry wall.

Manpower & Time

Estimated manpower required: 4 mason days

Estimated time required: 1 working days

Must Supervision

For the exact cantering of the hydraulic device, it is important that the overall site in-charge/engineer is present and personally supervises the work at the site.

5.3. Clay Soling for Foundation

What?

Clay on edge soling work for foundation

Where?

Level: -1480 to -920 mm

How?

- Level the foundation excavation and remove all loose soil and wet parts of the foundation base.
- Measure the outline of the foundation and mark it with pegs and strings.
- Place cut stones/boulders in cement mortar (CM) 1:8 at the foundation outline all around.
- Place strings from one corner to another to ensure the correct height for soling.
- Start placing the clayey sand
- Sprinkle water, ram or wedge the filled up soil into all the such a way that upper level of soil is not compressible.

Quality Specifications

The top of the soling must be horizontal, with a deviation of not more than 10 to 15 mm.

Do & Don'ts

Ram the stones and especially the cut stones very hard with a steel ramming tool.

Manpower & Time

Estimated manpower required: 4-10 mason days

Estimated time required: 4 working days

Special Tools

For Clayey soling work it is recommended to have additionally the following tools at site:

- Shovel
- 5-10 kg sledge hammer
- Iron ramming tool

5.4. Stone Soling Work for Foundation

What?

Stone Soling work for foundation (Refer Figure 2)

Where?

Level: -920 to -520 mm

How?

- Level the foundation excavation and remove all loose soil and wet parts of the foundation base.
- Measure the outline of the foundation and mark it with pegs and strings.
- Place cut stones/boulders in CM 1:8 at the foundation outline all around and level the top.
- Place strings from one corner to another to ensure the correct height for soling.
- Start placing the soling stones/boulders in CM 1:8
- Vertically from one corner and work backwards to the other corner.
- Hammer or wedge the small stones into all the gaps in such a way that there is no movement of the big stones existing and that it is as solid as rock.
- Fill the voids using well graded aggregate and sand. Spread the sand on top of soling and sprinkle the water so that the gaps between the boulders are filled completely.

Quality Specifications

- The top of the soling must be horizontal, with a deviation of not more than 10 to 15 mm.
- The CM has to be inserted in all the gaps tightly.
- No movement of stones/boulders should be allowed.
- There should be no foreign material in the soling other than stone and Cement mortar.
- Use only hard stones for soling, such as sand stones, lime stones or granite.

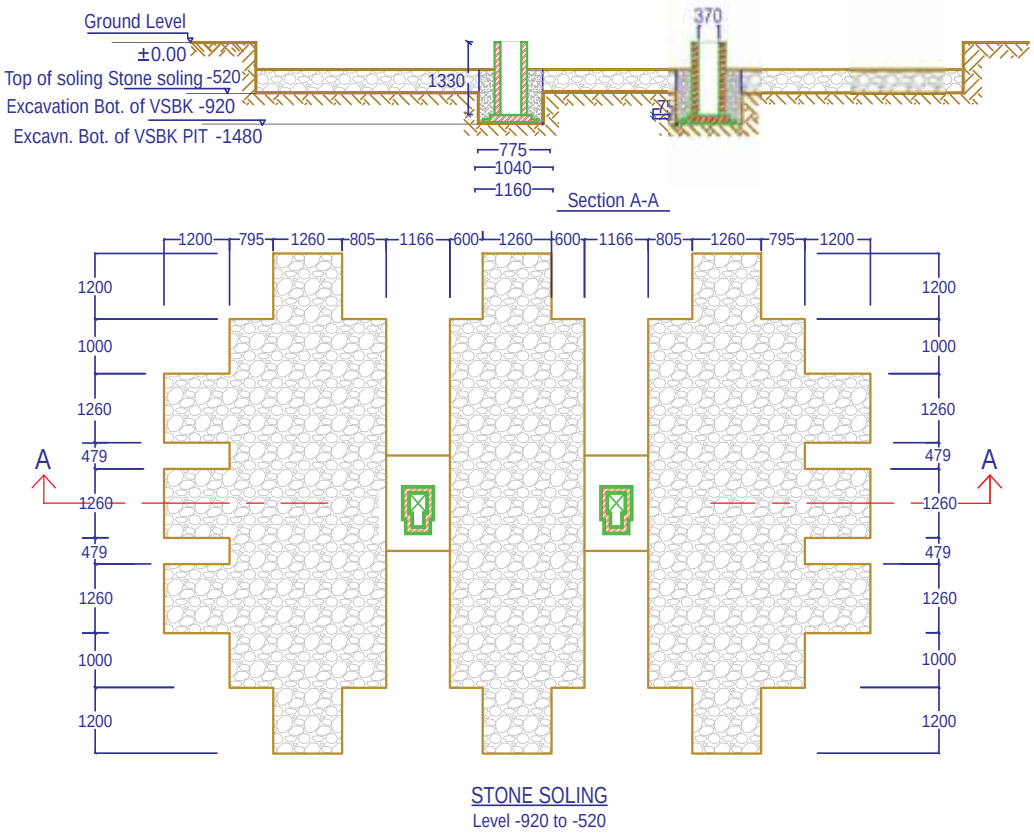


Figure 2: Stone Soling Work for Foundation

Do & Don'ts

Ram the stones and especially the cut stones very hard with a steel ramming tool.

Alternative Ways

If no stones are available, or if they are very expensive use over-burned bricks in CM 1:8, instead of a stone masonry soling.

Although a stone masonry soling foundation, if done properly, is stronger than brick-bat soling, using over-burned brick bats is still a good option and does not compromise on the quality required.

Manpower & Time

Estimated manpower required: 4-10 mason days

Estimated time required: 4 working days

Special Tools

For stone soling work it is recommended to have additionally the following tools at site:

- Water level
- Crow bar
- Sledge hammer
- Iron ramming tool

5.5. PCC (1:3:6) Work for Foundation

What?

PCC (1:3:6) work for foundation (Refer Figure 3)

Where?

Level : -520 to -445 mm

How?

- Wash and clean the top of the stone soling layer.
- Fix the string in the outer edges of soling in such a way that the top of it is exactly at the same level with the top measurement of the PCC layer. We can also make the reference levelled patches of PCC at various spots, which are exactly at the same level as the top of PCC layer. Fill and compact the concrete properly. The thickness of the concrete should be at least 75 mm.

Stone Soling Work for Foundation

Concrete over Stone Soling

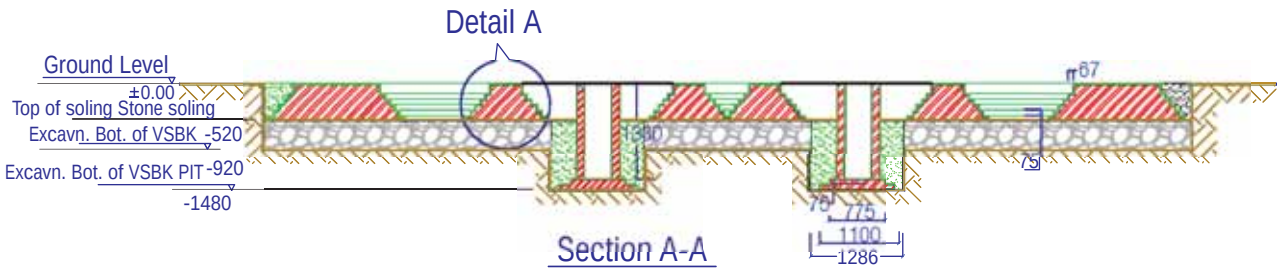


Figure 3: PCC Work for Foundation

- Cover it with jute sacks and ensure proper curing.
- Leave the concrete for at least a day. Place the next cement masonry brick course, just after completing the concrete work. This will ensure the best (fresh in fresh) bond possible.

Quality Specifications

- The PCC mix ratio must not be less than 1:3:6
- The PCC layer has to be properly levelled. The maximum allowable level deviation is 10 mm. The concrete should be properly compacted.
- The aggregate and sand for PCC should be properly washed and free from any foreign material.
- The aggregate should be well graded and 40 mm down.

Do & Don'ts

- Take special care for good curing. Cover the plain concrete layer with wet gunny bags or use pond curing.
- Do not allow the workers to walk on the fresh concrete band for at least 24 hours.

Manpower & Time

Estimated manpower required: 8-9 mason days

Estimated time required: 2 working day

Must Supervision

For the PCC layer construction work, it is extremely important that the overall site in-charge/ engineer is present at the site and personally supervises the work.

5.6. Brick Masonry Work for Foundation

What?

Brick masonry work for foundation

Where?

Level: -445 to +/- 0 mm

How?

- Clean the PCC layer surface.
- Stretch the string on the construction pillars to measure the outside wall (length and width) and define the exact position of the brick work of the foundation (400 mm distance from the outside wall line)
- Place one outer layer of brick in cement sand mortar on PCC surface to create the 1st step of the step footing

Brick Masonry Work for Foundation

- Use the same string for the exact positioning of the next step of step footing
- Place one layer of bricks and start stepping from the second layer up to the ground level. (Total stepping is 350 mm for six layers, i.e. to 70 mm per step) with the brick masonry work up to level 000
- Make the soil back filling between the brick foundation

Quality Specifications

- Use a cement mortar mixture of 1:6
- The maximum allowable level deviation is ±5 mm for the brick work
- Ensure that all joints are properly filled with cement mortar
- The reinforcement bars has to be fixed properly to avoid movement.
- Follow all the rules of brick masonry work

Important:

- The foundation brick masonry work must be properly cured. Cover the fresh cement brick works so that direct sunshine does not dry out the cement mortar, causing cracks.

Do & Don'ts

- Soak the bricks for at least one hour in water before using.
- Use only good quality bricks for the foundation work

Manpower & Time

Estimated manpower required: 12-14 mason days

Estimated time required: 5-6 working day

Must Supervision

For the foundation brick masonry work, it is important that the overall site in-charge/engineer is present at the site to personally supervise and measures the exact dimensions of the foundation.

5.7. Soil Filling Work

What?

Soil filling work

Where?

Level: -445 to +/- 0 mm

How?

- First use the soil excavated from the foundation for back fill.
- After finishing the foundation soil, transport soil from an external source.
- Always keep the soil in horizontal layers of maximum 300 mm.
- Sprinkle water on each layer and compact the layer with a steel ramming tool or mechanical compacting tool.

Important:

- The soil filling work is an ongoing process and starts right at the 'level of pit of hydraulic device. The main purpose of soil filling after arch level is to provide insulation. Therefore, it is important that the filling is properly compacted. During the rainy season, it is especially important to avoid seepage of water into the back fill.

Quality Specifications

Soil compaction should be done immediately so that no footprints are be made when normally walking on it.

A soil with approximate 10% moisture is best for compaction.

Do & Don'ts

- Do not use water for compaction after arch base level.
- Do not use the top-soil for back filling work.
- Do not involve in back fill immediately after the cement brick wall is made. Allow proper hardening of the cement joints (approximately 36 hrs.) before back filling work starts.
- While back filling, be careful that the dust of the soil does not hamper the ongoing masonry work.
- Do not make the back fill more than 400 mm thick in one go.

Special Tools

For the soil filling work, it is recommended to have the following tools at site:

- Iron ramming tool
- Wheel barrow
- Spade

Soil filling work in a VSBK

Chapter 6

Kiln Superstructure

6.1. Brick Work up to First Corbelling

What?

Brick work up to first corbelling

Where?

Level : +/- 0 to + 250 mm

How?

- Clean the top of the brick masonry wall with a brush and water.
- Make cement brick masonry work up to level 250 mm on the outside and inside walls.
- Check the level, diagonals and dimensions.

Quality Specifications

- Follow all the rules of brick masonry work.
- Use a cement sand mortar ratio of 1:6 for brick masonry and cement concrete ratio of 1:2:4 (cement:sand:aggregate) for the corner reinforcement.
- The corner wall reinforcement for the corners has to be continued.

Brick Work above First Corbelling in Progress

- The out side walls are 350 mm thick, the inside walls (tunnel walls) are 470 mm thick and the inner pocket walls are 230 mm thick from level +/- 00 to level 250 and then to level 1885 i.e till the base of the arch.

Note:

The thickness of the walls depends upon the size of the bricks. It might sometimes be a bit thinner or thicker.

Do & Don'ts

- The maximum allowable level deviation is ± 5 mm for the brick work.
- Soak the bricks for at least one hour in water before using.
- Use only good quality bricks.

Manpower & Time

Brick work up to first corbelling:

Estimated manpower required: 8-10 mason days

Estimated time required: 2 working day

Must Supervision

For the brick masonry work, it is advisable that the overall site in-charge/engineer supervises the work regularly till the first corbelling,

Special Tools

For setting up the trolley guide, it is recommended to have the following additional tools at the site

- Spirit level and water level
- Plumb bob
- Measuring tape

6.2. Brick Work Above First Corbelling

What?

Brick work above first corbelling (Refer Figure 4)

- Setting of trolley guide

Where?

Level: + 250 to + 1391 mm

How?

- Clean the top of the brick masonry wall with brush and water.
- Measure and mark the exact position where the trolley guide will be fixed.
- Make a 30-mm brick projection on both sides of the tunnel walls and continue to construct the cement-brick masonry walls, up to level 800 mm to 900 mm. Leave a gap open in the brick wall where the trolley guide will be fixed.
- Now place the trolley guide into these open gaps, measure the exact position again (vertical and horizontal) and fix them into the brick wall.
- Fill the backside gap of the trolley guides with cement concrete 1:2:4. Ensure that anchors are properly fixed.
- Continue to construct the cement brick masonry wall up to the level 1355
- Re-check the measurements

Quality Specifications

- Quality of steel should be equivalent to Malawi standards.
- Use a cement mortar mixture in the ratio of 1:6 for brick masonry and cement concrete of 1:2:4 for the corner reinforcements.
- The corner wall reinforcements have to be continuous.
- Dimensions of the trolley guide: 100x50x1105 mm
- Use a cement concrete mixture of 1:2:4 to fix the trolley guides.
- The permissible limits for trolley guide measurement deviation is a maximum of:
  - Horizontally 5 mm
  - Vertically 2 mm
- Check the dimensions for the trolley guide from the centre.

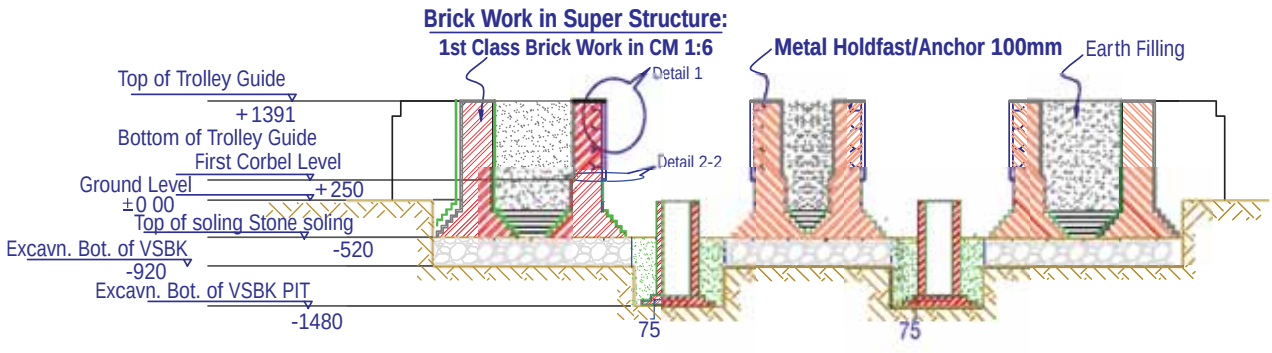


Figure 4: Brick Work above First Corbelling for Setting up of Trolley Guide

Important:

The tunnel inside the walls is exposed to an extremely high wear and tear due to the brick unloading operations. Therefore, it is important that this part of the brick wall is made with utmost care and with superior materials

Do & Don'ts

- Each trolley guide must be fixed separately.

Manpower & Time

Setting the trolley guide:

Estimated manpower required: 2 mason days

Estimated time required: 1 working day

Cement Brick Masonry Work

Estimated manpower required: 7-10 mason days

Estimated time required: 2-3 working days

Must Supervision

For setting up of the trolley guide, it is imperative that the overall site in-charge/engineer is present at site and personally supervises the work.

6.3. Setting of I-beam for Brick Supporting Bars

What?

Setting of I–beam for brick supporting bars (Refer Figure 5)

Where?

Level : + 1391 to + 1599 mm

How?

- Ensure the exact position where the I-beam will be fixed and check the height and the level of the I-beam places.
- Clean the places where the steel plates will be fixed.
- Spread a layer of cement mortar (total thickness of the cement mortar level is defined by the actual measured height). Level any difference which is bigger than 20 mm with concrete 1:2:4.
- Place a clean steel plate (325x250x8 mm) into the cement mortar bed and press/hammer gently until well embedded and levelled.
- Check the level with all the opposite steel plates.
- Place the I-beams on top of the steel plates and measure the correct distance and position.
- Measure from centre to centre of the I-beam and check the correct dimensions, as well as the diagonals.
- Always check the position of the I-beams from the shaft centre.
- Check the level (length and width) of all I-beams and make adjustments, if necessary, using metal strips.
- Transfer the centre line, using the thread stretched across the construction pillars and mark it permanently in the I-beams, using hack saw blades.

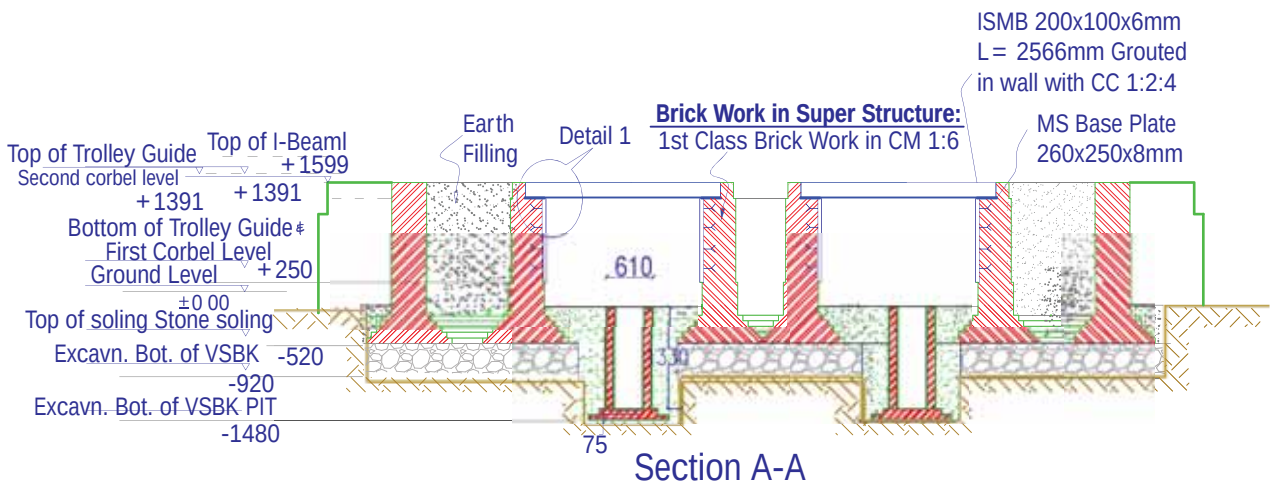


Figure 5: Plan at I-Beam Level

Quality Specifications

- Quality of steel should match the IS standards.
- Steel plate: 260 x 250 x 6 mm
- The total length of the I-beam should be 2600 mm.
- Allow minimum I-beam resting of 315 mm on both the walls.
- Use a cement mortar mixture of 1:2 for the Steel plate bedding.
- Use a concrete mixture of 1:2:4 for the gap filling around the I-beam and the brick work for the screw shaft hole.
- The maximum allowable bending of I-beams is ± 2 mm.
- The maximum allowable level deviation of I-beams is ± 2 mm.
- Ensure that all the brick joints around the I-beams are properly filled with cement mortar.
- All four steel plates must be placed at the same level.
- Hide the steel plates to approximately 45 mm (because of the 30 mm corbelling) inside the wall and cover the front with cement.
- Use a cement mortar mixture of 1:6 for brick masonry and cement concrete 1:2:4 for the corner reinforcements.
- The corner wall reinforcement should be continued.
- Ensure that the brick masonry work is at the exact level at 1363 mm.

Important:

The I-beams support the total weight of the entire brick batches during the firing process. Therefore, the quality of the supporting wall, the steel plate placing and the I-beam fixing should be of a superior quality for proper functioning and for a better life span of the VSBK.

Do & Don'ts

- Before using, put the steel plate in the water for some time or store it in a place where direct sunshine does not heat up the plate (The strength of the mortar will be considerably reduced, if a hot steel plate is placed into the mortar bed).
- Place enough cement mortar (maximum of 20 mm) below the steel plate to avoid any air pockets while pressing down.
- Allow proper cement setting for the steel plate Bedding. Put the steel plates into the mortar bed in the late afternoon and place the I-beam the next morning.

Setting up of I-Beam

Manpower & Time

Estimated manpower required: 8-9 mason days

Estimated time required: 1 working day

Special Tools

For setting up the trolley guide, it is recommended to have the following additional tools at the site

- Spirit level and water level
- Plumb bob
- Measuring tape

Must Supervision

To set up the I-beams, it is important that the overall site in charge/ engineer is present at the site and personally supervises the work

6.4 Second Corbelling and Masonry Work up to Skew Back Level for Arch Base

What?

Second Corbelling and Masonry Work Up to Skew Back Level for Arch base

Where?

Level : + 1391 to + 1846 mm

How?

- Fill in the gap around the I-beam with strong mortar and bricks up to level 1599 mm.
- Make a 30-mm brick projection (corbelling) on both the sites of the tunnel walls at level 1391 mm and continue to construct the cement brick masonry walls up to level 1846 mm.
- Instead of ordinary clay bricks, use refractory bricks between the I-beams up to level 2136 mm.
- Make a two-brick long bonding between the refractory bricks and the ordinary red bricks, especially in the area where the C-Channel will be set later.

Remarks:

A brick projection of 30 mm must be made to ensure the exact dimension of the shaft length. However, the projection of 30 mm is only approximate. The exact dimension must be measured from the shaft centre and might therefore, be less or more than 30 mm. However, ensure that the projection dimensions on both the sides are equal.

Quality Specifications

- Use standard refractory bricks for the corbelling of the distance between the brick supporting I-beams.
- Use refractory mortar for the refractory brick works only.
- Use a cement mortar mixture of 1:6 for brick masonry, a cement mortar mixture of 1:4 to fill in the gaps around the I-beam and cement concrete 1:2:4 for the corner reinforcements.
- The corner wall reinforcements have to be continued.
- Adjust (measure from the centre) the corbelling distance between the two tunnel-wall sites in such a way so as to get the exact measurements of the shaft (1970).
- Ensure that the walls are levelled at 1810 mm, especially where the skew back work for the arch construction will start

Do & Don'ts

- For all shaft-related measurements use the centre of the shaft as the reference point.

Alternative Ways

- Use good quality extruded or over burned bricks and use refractory brick mortar for the joints instead of refractory bricks.

Manpower & Time

Estimated manpower required: 15-16 mason days

Estimated time required: 2-3 working days

Must Supervision

For the second corbelling work, it is important that the overall site in-charge/engineer is present at the site to measure the correct corbelling dimensions and to supervise personally

6.5. Setting of C-channel

What?

Setting of C–Channel (Refer Figure 6)

Where?

Level : + 2003 to +2136 mm

How?

- Continue with one line refractory brick masonry work from level 1391 mm to level 2003 mm where the C-Channel will be placed.
- Use a header at the very first layer of the refractory bricks at the beginning of 2nd corbelling between the C Channels.
- Measure the exact position of the C-Channel (centre measurements)
- Clean the places where the steel plates will be fixed.
- Place a layer of cement mortar (total thickness of the cement mortar level is defined by the actual measured height).
- Place a clean steel plate (300x250x8 mm) into the cement mortar bed and press/hammer gently until it is well embedded and levelled.
- Check the level with all the opposite steel plates.
- Place the C-Channels on top of the steel plates and measure the correct distance and position.
- Check the level both way (length and width) of all C Channels and make adjustments if necessary. (Place metal strips for levelling adjustments.)
- Continue with the refractory brick work up to level 2100 mm
- As the C-Channel is fixed, grout it with cement concrete in the ratio of 1:2:4.

Quality Specifications

- Use quality steel, as per the Malawi standards.
- Ensure that both the plate, as well as the C-Channel are straight.

- The maximum bending of C-Channels allowed is ± 2 mm.
- Steel plate: 300x250x8 mm
- Total length of the C-Channel should be 2600 mm.
- The height of the C-Channel should be 125 mm, with a width of 65 mm and a thickness of 6 mm.
- Allow a minimum of 315 mm of the channel to rest on both the walls.
- Use a cement mortar mixture of 1:2 for the steel plate bedding.
- Use standard refractory bricks and refractory mortar for filling the gap around the C–Channel.
- The maximum allowable level deviation is ± 2 mm.
- All four steel plates must be exactly at the same level.
- Hide approximately 75 mm of the steel plate inside the wall and cover the front with refractory brick mortar.
- Ensure a two-brick bonding between the ordinary and the refractory bricks.

Important:

The C-Channels are carrying the total weight of the entire shaft's wall, including the chimneys Therefore, the quality of the supporting wall, the steel-plate placing and the C Channel should be extremely good to ensure proper functioning and for an increased lifespan of the VSBK.

- Before use, put the steel plate in water for some time or store it in a cool place. The strength of the mortar is considerably reduced if a hot steel plate is placed on the mortar bed.
- Place enough cement mortar below the steel plate to avoid any air pockets while pressing down.

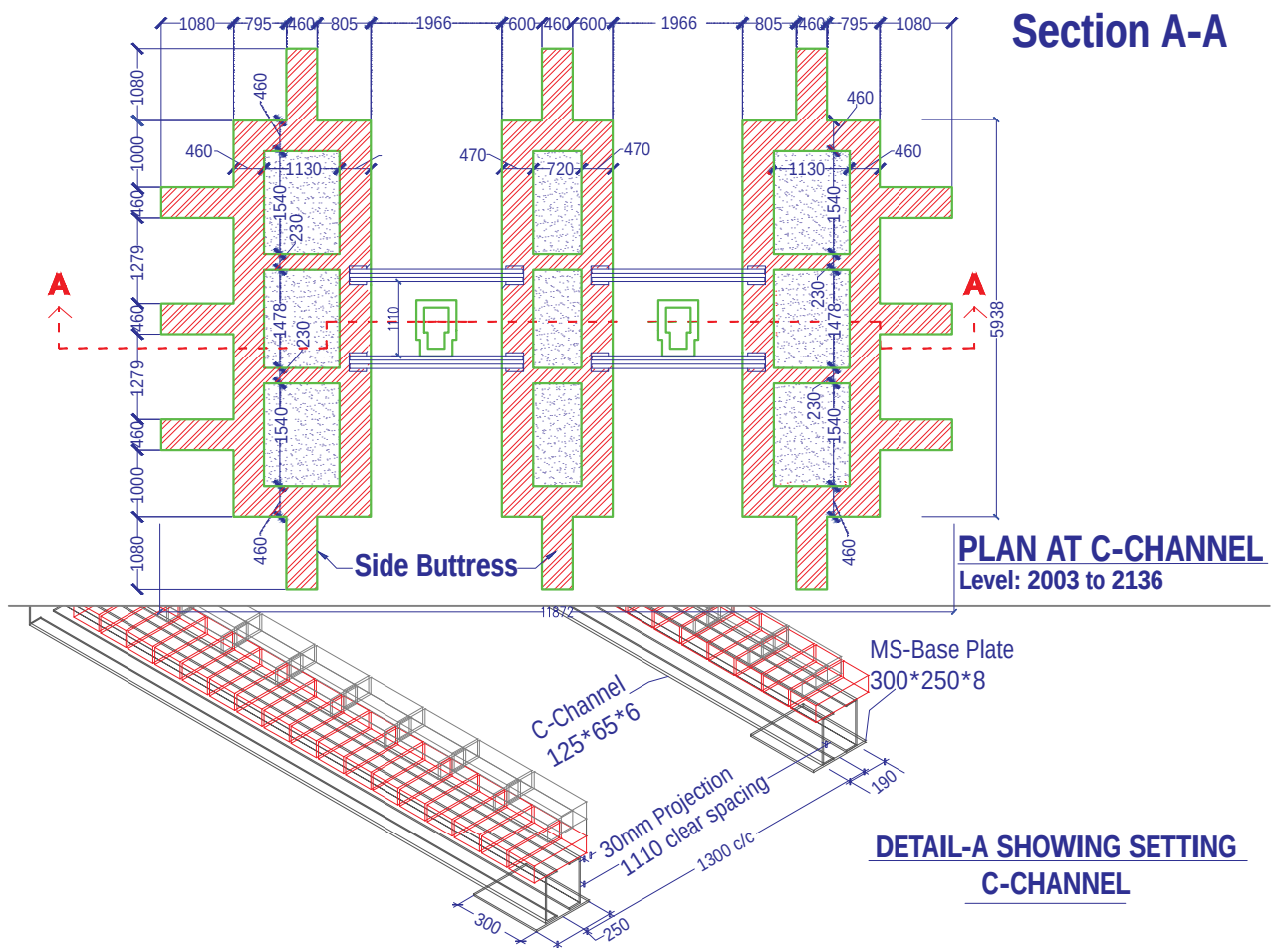


Figure 6: Drawing showing Setting of C-Channel

Setting of C-Channel

- Ensure proper cement setting for the steel plate bedding. Place the steel plates into the mortar bed in the late afternoon and place the C-Channels only the next morning.
- Avoid any bonding between the ordinary and the refractory bricks exactly below the C-Channel position. Therefore, extend the refractory brick masonry work at least 500 mm towards the girder key from level 1538 mm.

Do & Don'ts

- Before use, put the steel plate in water for some time or store it in a cool place. The strength of the mortar is considerably reduced if a hot steel plate is placed on the mortar bed. The temperature of the metal plate should not be greater than 50oC.
- Place enough cement mortar below the steel plate to avoid any air pockets while pressing down.
- Ensure proper cement setting for the steel plate bedding. Place the steel plates into the mortar bed in the late afternoon and place the C-Channels only the next morning.
- Avoid any bonding between the ordinary and the refractory bricks exactly below the C-Channel position. Therefore, extend the refractory brick

masonry work at least 500 mm towards the right from level 1538.

Manpower & Time

Masonry work

Estimated manpower required: 8-10 mason days

Estimated time required: 2 working days

C-Channel setting

Estimated manpower required: 2 masons days

Estimated time required: 1 working day

Special Tools

For C–Channel setting, the following additional tools are required at the site:

- Spirit level
- Water level
- Plum bob
- Thread
- Measuring tape

Must Supervision

For the setting of the C–Channel, it is a must that the overall site in-charge/engineer is present at the site and personally supervises the work.

6.6. Arch Construction

What?

Brick masonry arch

Where?

Level : +1846 to + 2866 mm

How?

6.6.1 Skew Back Casting for Arch Base

- Clean the top of the brick masonry wall for casting the arch base on it.
- Fix the outer and the inner timber plank for shuttering in such a way that the its top is exactly at the required shape and level with the top measurement of the arch base.
- Strengthen the Skew back shuttering in such a way that no bulging takes place while concreting.
- Clean the wall top and the shuttering with water and place the concrete into it. Compact the concrete properly. Use vibrator for the compaction if possible.
- Allow the arch base PCC for curing for at least two days, using wet jute bags.
- Take out the shuttering before starting the arch-work.

6.6.2 Arch Mould Preparation

- Clean, level and compact the soil between the two arch supporting walls.
- Make three stacks of dry red double bricks up to level 1860. (One along each wall and one in the centre).
- Place 25 mm thick wooden planks at level 1860 on top of the stacked bricks.
- Mark the centre of the arch (level 1409) and define/mark the inside height (level 2503) with a string.

Option 1:

- Pile up bricks in a honeycomb pattern according to the inside height marked with the string.
- Finish the arch mould with mud until a smooth surface has been achieved.
- Check the stability of the entire arch mould and especially the dry brick piles at the base.

Option 2:

- Prepare a wooden arch mould as per the drawing design.
- Install the arch mould on the brick stack as mentioned above and level it perfectly.
- Check the stability of the entire arch mould.

6.6.3 Arch Construction

- Clean the PCC arch base thoroughly and ensure that no mud is sticking on it.

- Use quality bricks (number one bricks) after soaking them in water.
- Place the bricks on both sides of the arch and start from the front side of the arch.
- Use the “to arch centre-line” method (extended by a string).

Quality Specifications

- Use a cement mortar mixture of 1:4 for the arch construction.
- Cement mortar joints should be a maximum of 8-15 mm.
- Use only the best possible quality bricks (number one bricks).
- Thickness of the arch masonry is 300 mm (230+10+60 mm)

Alternative Ways

- Use of a wooden or a ply wood mould.
- Use of a metal mould.

Do & Don’ts

- Do not walk on the arch before 24 hrs.
- Take special care for good curing.
- Make the arch construction in one go i.e. finish it on the same day.

Manpower & Time

Estimated manpower required: 38-40 mason days

Estimated time required: 7-8 working days

Steps in the Construction of Arch

Arch Construction

Must Supervision

For the arch construction, it important that the overall site in-charge/engineer is present at the site and personally supervises the work at site.

6.7. Outer Brick Wall

What?

Outer brick wall construction (Refer Figure 7)

Where?

Level : +/- 00 to + 6020 mm

How?

- Construct 350 mm outer walls and 230 mm inner walls in English bond with cement brick masonry wall in cement mortar 1:6 as per the drawing.
- Construct the outer kiln brick masonry wall and buttresses wall simultaneously with the inner kiln walls using a cement mortar ratio of 1: 6.

Quality Specifications

- Use a cement mortar mixture in a ratio of 1:6 for brick masonry and cement concrete in a ratio of 1:2:4 for corner reinforcements.
- The corner wall reinforcements have to be continued.
- Minimise cement joints to 10-12 mm.
- Provide smooth outside cement joints, similar to the pointings.
- Allow a maximum horizontal level deviation of 10-15 mm around the kiln.
- Allow only a maximum vertical line deviation of 10 mm from level 0-0 to the loading platform,

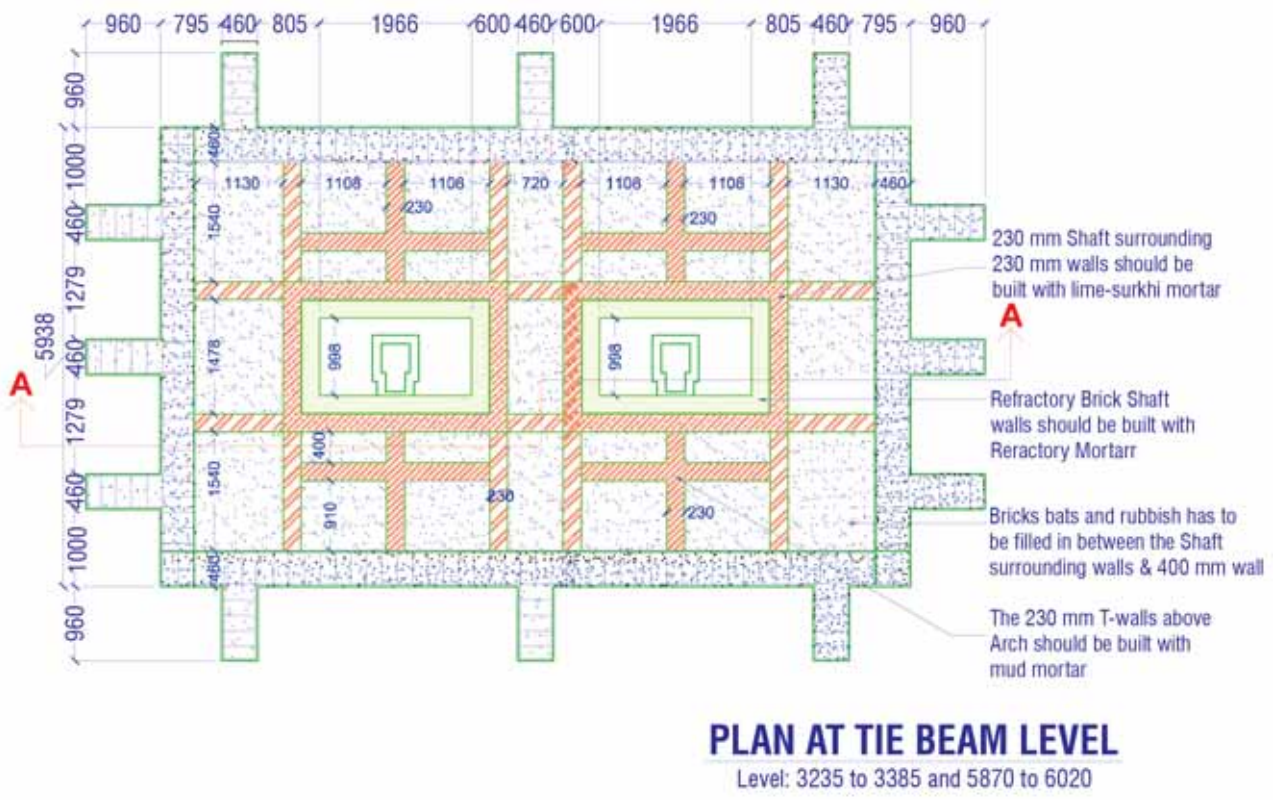


Figure 7: Drawing of a Outer Brick Wall

- Ensure proper bonding, in accordance with the masonry rules.
- Follow the general rules and regulations for cement brick masonry work
- Allow no exception to these rules.

Do & Don'ts

- Clean the top of the cement brick masonry walls before starting in the morning. No new course of bricks should be allowed on top of dry, loose sand/cement that remains on top of the brick wall.
- Take special care for good curing. Cover the top of the walls with wet gunny bags.
- Do not allow the workers to walk on a newly constructed cement masonry walls for at least 24 hours.

Manpower & Time

Since the construction of the outer VSBK brick wall is being made simultaneously with the inner kiln walls, the required manpower and time is mentioned under the respective chapters.

Must supervision

For the cement masonry brick work, it is important that the overall site in-charge/engineer ensures that the masons follow the best masonry practices.

6.8. Tie Beam and Corner Wall Reinforcement

What?

Tie–beam and corner wall reinforcement construction

Where?

Tie Beam Base Level : + 3235, 5870 mm

How?

- Clean the top of the brick masonry wall and check the height and levels for the positioning of the tie beam.

Tie Beam and Corner Wall Reinforcement

- Cut the steel bars and stir ups, as per the drawing and bend the bar accordingly.
- Place the steel reinforcements on the top of brick masonry wall and fix the stir ups and steel as per the drawing.
- Fix the outer timber plank (outside beam shuttering) in such a way that the top of it is exactly at level with the top measurement of the tie beam.
- Maintain the minimum cover of 20 mm all around for the reinforcements.
- Strengthen the entire beam shuttering in such a way that no bulging takes place while concreting the band.
- Clean the beam shuttering with water and place the concrete into the beam shuttering. Compact the concrete properly.

General rule for VSBK Tie – Beam positioning

The tie beams (concrete bands) in the outer walls should not be more than 1500 mm apart (vertically). The first band above the tunnel arch should be within 750 mm in height, above the tunnel crest.

- Use a concrete mixture of 1:2:4.
- Ensure a correct top level with maximum allowable level deviation of ± 10 mm.
- The concrete band should not be less than 350x150 mm (as per drawing).
- Follow the drawing for the tie beam reinforcement detailing.
- Use a concrete mixture of 1:2:4.
- Ensure a correct top level with maximum allowable level deviation of ± 10 mm.
- The concrete band should not be less than 350x150 mm (as per drawing).
- Follow the drawing for the tie beam reinforcement detailing.

Quality Specifications

- Cure the concrete properly. Cover the concrete band with wet gunny bags.
- Do not allow the workers to walk on the fresh concrete band for at least 24 hours.
- Use a vibrator machine for the proper compacting of the concrete.

Manpower & Time

Estimated manpower required: 8-10 mason days

Estimated time required: 2-3 working days

Must Supervision

For the tie beam placing and construction work, it is important that the overall site in-charge/engineer is present at the site and personally supervises the work.

Chapter 7

VSBK Shaft and Related Fixtures

7.1. Refractory Brick Shaft Construction

What ?

Refractory brick shaft construction (Refer Figure 8)

Where?

Tie Beam Base Level : + 2136 to 8418 mm

How?

- Make good and strong scaffolding between the CChannels.
- Clean the C–Channel and check the level.
- Mark the centre of the shaft on the C-Channels as well as on the side of the shaft with the help of centre line marks on the I-beams.
- Always use the centre of the shaft as the reference point for the shaft measurements.
- Make three layers of dry refractory bricks; establish proper bonding and measure the dimensions of the cut bricks required.
- Prepare the cut bricks and make them available at the site before starting shaft construction.

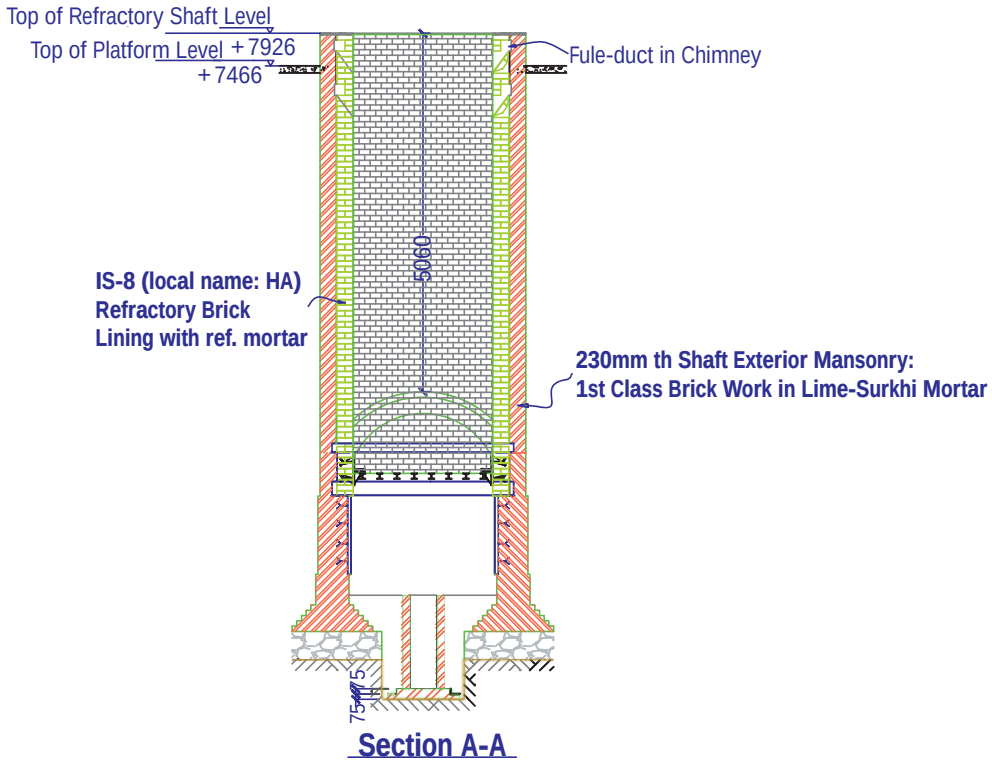


Figure 8: Drawing of Refractory Brick Shaft

- Remove the three dry brick layers and clean the CChannels.
- Make all the four corners and place the refractory bricks with mortar.
- Check the level, plumb line (verticality) and the distance of the four corners (from the shaft centre line) and adjust to the correct shaft measurements.
- Tie a string on the inside of the brick line and place the refractory bricks for one layer.
- Place the cut bricks and clean the brick layer
- Check the level and the diagonal measurements of the shaft.
- After five layers of refractory lining, build a 260 mm thick brick wall with the ordinary red bricks in Lime surkhi (1:4) mortar.
- Repeat the last six steps and construct the VSBK shaft

Refractory Brick Shaft Construction

Quality Specifications

- Basically observe all the rules for refractory brick masonry work.
- Use the standard refractory brick quality for the VSBK shaft construction.
- Use standard refractory mortar for the refractory brick masonry work and Lime surkhi (1:4) mortar for the outer side brick work.
- The total thickness of the VSBK shaft is 470 mm, whereas only the inner part (110 mm) of the shaft is lined with refractory bricks.
- The bonding pattern established is a 4-Stretcher 1-header course with a ½ brick bond.
- The maximum size of any joint is 3 mm for the refractory brick masonry.
- The Allowed measurement deviation is as follows:
  - Vertically: perimeter = ± 2 mm
  - Diagonal : ± 2 mm
  - Use only the machine-cut refractory brick pieces

Do & Don'ts

- Do not mix different refractory brick sizes or qualities.
- Use only the refractory mortar that is supplied from the RB factory.
- Clean each course with a brush or cloth before placing the refractory mortar. This will enhance the binding of the bricks.
- Use the good face of the refractory brick for the outside part and any damaged face for the inside of the wall.
- Do not compromise on the use of RB for the VSBK shaft lining. Use of other materials like extruded fired bricks would lead to:
  - High wear and tear
  - High heat loss
  - Dimension problems
  - Shrinkage/cracks
  - Over burning/brick melting etc.

Refractory Brick Mortar Binding Quality Specifications:

How to test:

A Place the RB mortar at the RB header, press it together properly (with a maximum 3 mm joint). Immediately hold the RB at one end only, lift it up horizontally, so that the total weight of the other brick is glued to the RB mortar. If it can withstand this weight, then the binding properties of the RB mortar is all right.

B Place the RB mortar on top of three RBs, press them together (with a maximum 3 mm joint). Immediately lift them up, holding only the top RB so that the total weight of the lower two RBs are glued to the RB mortar of the top RB. If it can withstand this weight, then the binding properties of the RB mortar is all right.

C. Apply the refractory mortar on the tip of the RB (smallest area) and press another RB on it. Leave the RBs for at least 15 minutes. Then lift the RBs, holding one end of the upper RB and rotating it slowly.

If the bricks remain intact, then the refractory mortar is OK.

Method of Testing the Quality of Refractory Brick Mortar

Important:

- Do not soak RB before use. Do not use water for cleaning.
- Once set, do not move the RB, otherwise the binding quality will be reduced.

Manpower & Time

Estimated manpower required: 90-100 mason days

Estimated time required: 25 working days

Special Tools

For the VSBK shaft construction, it is recommended to have the following additional tools, at the site:

- Rubber hammer
- Aluminum lag
- Angle scale
- Spirit level
- Steel brush
- Measuring tape

Must Supervision

For the construction of the VSBK shaft work, it is important that the overall site in-charge/engineer is regularly present and personally supervises the work at the site.

Special Notice:

The shaft construction requires special masonry skills. It is of paramount importance that the rules and regulations for refractory brick masonry work are followed.

7.2. Peep-hole Pipe Setting and Monitoring Platform

What?

Peep–hole pipe setting and monitoring platform (Refer Figure 9)

Where?

Level: 3696, 4132, 4628, 5124, 5620, 6116, 6612 mm

How?

- Place a 40 mm nominal bore MS pipe horizontally at the exact defined level of the shaft.
- Place the peep-hole pipes exactly where the peep-hole pipe openings are created for each batch.
- The steel pipe should rest on both the walls, the outer kiln wall (350 mm) and the VSBK shaft wall (470 mm).

Quality Specifications

- Keep the pipe approximately 35 mm recessed inside the refractory brick, to prevent any disruption due to brick batch movement.
- The pipe should be kept approximately 300 mm outside the outer kiln wall.
- The pipe must be placed straight and at a uniform level, free from the inside defects that may hamper a clear and through view.

Construction of Setting and Monitoring Platform

Do & Don'ts

- Do not use very small or very big peep-hole pipes. Pipes that are too small may not allow proper view and very big-peep hole pipes may be a source of heat loss.
- To avoid any heat loss, keep the outer ends of the peephole pipes closed with plugs, when not in use.
- Close the gaps around the peep-hole pipes properly, especially at the refractory brick masonry part to minimise heat loss.
- Have a minimum of five peep-hole pipes, even when not being used in the beginning. It might be handy to have them in place to meet further technology development, especially fire control mechanisms.

Alternative Ways

- To prevent the peep-hole pipes from bending down (late soil setting) join all of them with a vertical pipe (instead of making a dry brick pillar)

Manpower & Time

For five peep-hole pipes

Estimated manpower required: 2 mason days

Estimated time required: 2 working days

Must Supervision

For the setting of the first peep-hole pipe, it is important that the overall site in-charge/engineer is present at the site and personally supervises the work.

7.3. Flue Duct System

What?

Flue duct system construction

Where?

Level : + 7095 to + 8340 mm

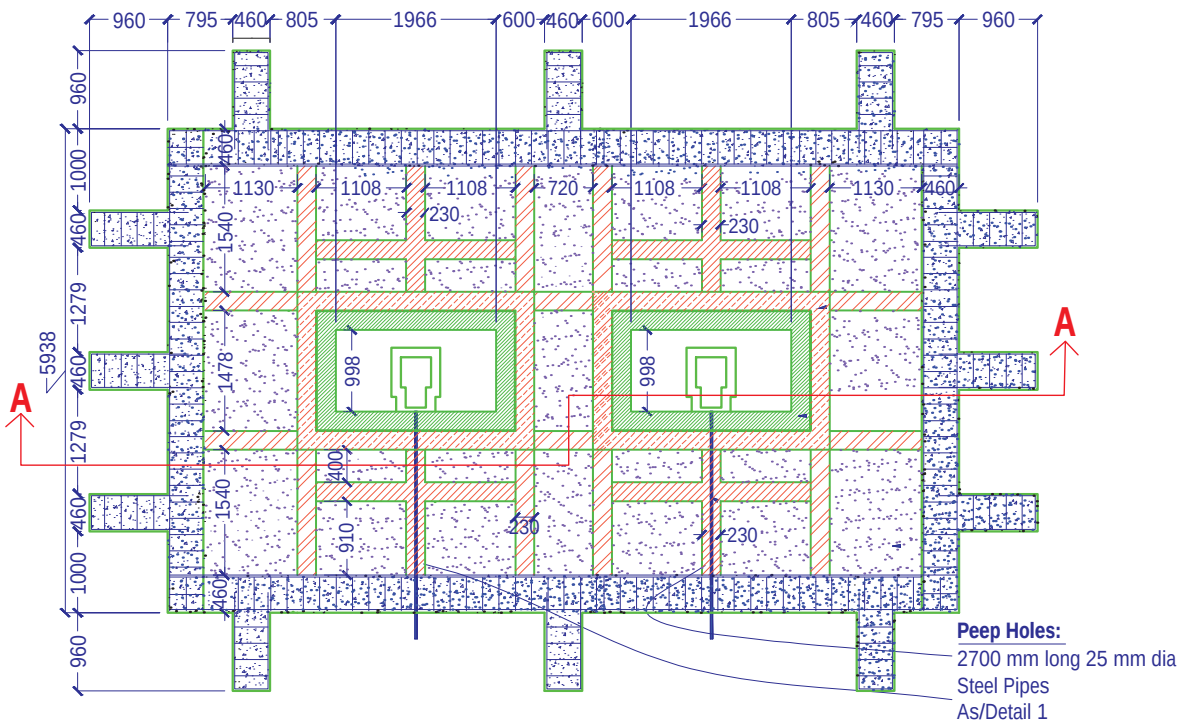


Figure 9: Drawing showing Peephole Position

How?

A. Lower Flue Duct

- After completing the last refractory header course, clean the shaft walls.
- Place a layer of refractory bricks horizontally to create a total of four equal-sized flue exit holes on the short side and eight equal-sized flue exit holes on the long shaft side of the shaft.
- Place the second, third and the fourth refractory brick layers exactly on top of the first layer.
- Build up 240 mm backside of these four layers with the ordinary red bricks in lime surkhi mortar.
- The fifth refractory-brick layer is a continuous stretcher, vertically placed and facing the inside of the shaft. This layer bridges the gaps of the four lower refractory layers.
- A layer of refractory or red bricks are placed in lime surkhi mortar on the backside, forming a tunnel of 140x110 mm, leaving a distance of 140 mm on the backside of the previously mentioned continuous, vertically stretcher course.
- The next course of refractory bricks, laid horizontally, and facing the inner shaft is used to close and cover this tunnel.
- On the backside, a layer of red bricks is placed so that the top of this course is completed and is at level.

B. Upper Flue Duct.

- Place six new courses on top of the last course +6906 up to level +7529 mm of the refractory bricks in the same way as below the lower flue duct. (Every fifth course must be a header).

Construction of Lower Flue Duct

Note:

The top of the sixth course of the first flue duct is the base for the lower flue gas damper. Both the damper frames are placed in chimney construction. The upper flue gas damper is placed on top of the sixth course of the second flue duct. Please follow the instructions given with the drawings and construct it with the help of an expert VSBK engineer.

Construction of Upper Flue Duct

Quality Specifications

- Make the flue gas ducts as smooth as possible to avoid any flue gas turbulences.
- Clean the flue gas ducts after completion.
- Use lime mortar for the backside red brick masonry work.

Do & Don'ts

- Do not make flue duct tunnels smaller than 100 mm.

Manpower & Time

Estimated manpower required: 12-16 mason days

Estimated time required: 2-3 working days

Must Supervision

For the lower and upper flue duct construction work, it is important that the overall site in-charge/ engineer is present at the site and personally supervises the work.

Chapter 8

Loading Platform

8.1. Shaft Top Construction

What?

Shaft top construction (Refer Figure 10)

Where?

Level: + 8418 to + 8500 mm

How?

- Clean the top of the masonry brick wall.
- Fix a timber plank on the inside and the outside of the shaft wall and level it.
- Make a steel reinforcement (3 pc 10 mm steel bars) and place it on top of the brick wall and cast it with a 50 mm-thick cement concrete (1:2:4).
- Provide a cement slurry finish on top of the concrete.
- Plaster the outside of the shaft with mud mortar.

Quality Specifications

- Use cement concrete mix for the top part of the shaft.
- Make the shaft's top size 470x50 mm.
- Provide good curing, place a wet gunny bag on top of the cement concrete work.

Do & Don'ts

- Break the corners of the shaft top or make then reasonable round.
- Avoid any cement slurry flows into the inside of the shaft, clean it immediately.
- Do not make cement plaster at the outside of the shaft; mud mortar is much easier to repair.

Alternative Ways

- Stone slates

Manpower & Time

Estimated manpower required: 5-6 masons days

Estimated time required: One working day

8.2. Loading Platform

What?

Loading platform construction

Where?

Level: + 6970 to + 7070 mm

How?

- Fill up with insulation materials and compact it to make a plain surface, one inch below the brick masonry walls.
- Place fired brick soling with flat bricks over insulation (75 mm).
- Erect form work for platform projection over buttress wall all around the kiln. Leave space for a conveyer and the stairs.
- Erect steel for the RCC platform; tie the top beam and roof columns as per the drawing.
- Make an outward slope in brick soling for easy drainage of rain water.

- Place form work as per the requirements.
- Concreting of 1:2:4, keeping a proper cover and thickness of 100 mm.
- Ensure proper ramming and out ward slope with a roof column vertical alignment, as well as spacing with respect to a roof truss position.
- Allow concrete to set and gain strength for at least 14 days.
- Leave the steel bars all around the edge for parapet masonry anchoring.
- Leave the reinforcement for chimney cone grouting.

Quality Specifications

- The sand and coarse aggregate used should be clear from dirt, dust and any impurity.
- Steel bars should not be rusted and should be as per country specifications.
- Any older stock of cement should be avoided.
- Keep cover, spacing and binding as per drawing.
- Adequate vapour release holes should be provided in the outer masonry wall, just below the RCC loading platform.
- Reinforcements should be provided, as per specified in the drawing.
- Do not use dirty sand and grit, as well as impure water in concrete.
- Do not walk over newly-laid concrete.
- Curing should be done for at least 10 days continuously.
- Do not remove form work before 14 days.
- No reinforcements should be visible on the outside after concreting.
- Do not use rusted reinforcements.

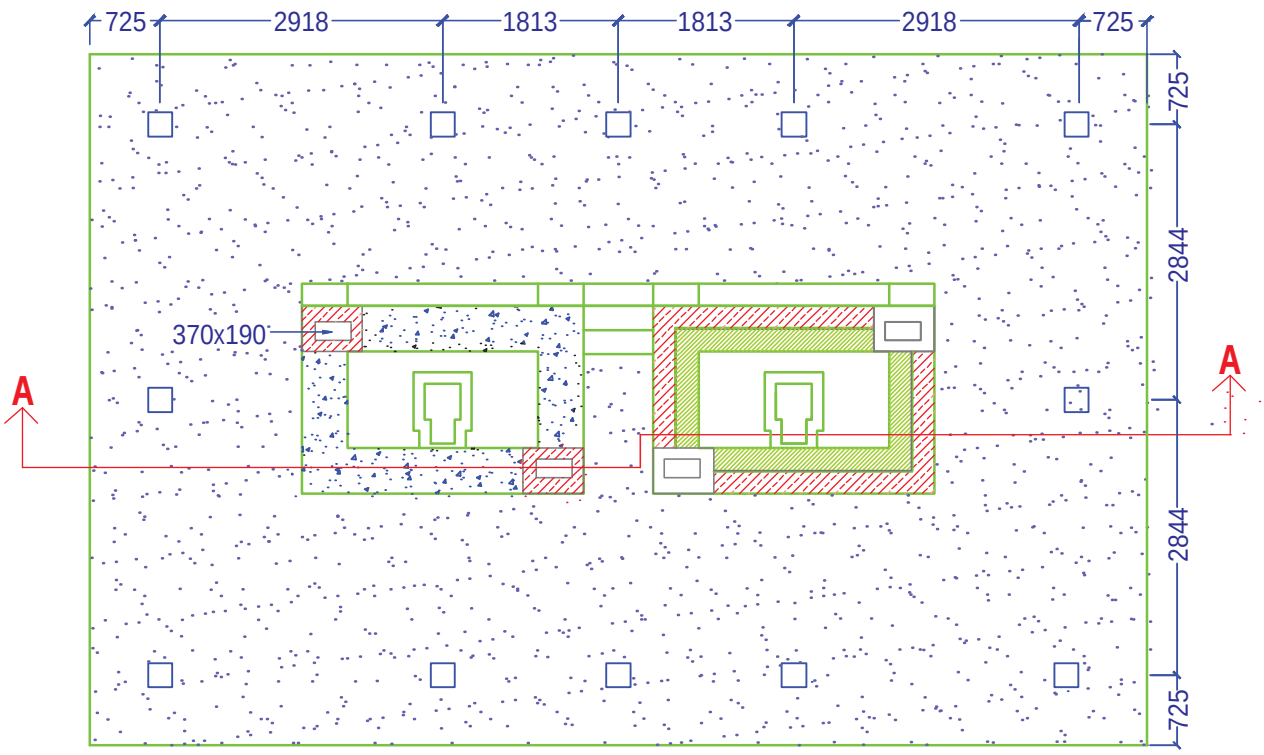


Figure 10: Drawing of the Top of the Shaft

Estimated manpower required: 4-5 masons days

Estimated labour required: 25-30 man days

Estimated time required: 3-4 working days

During RCC loading platform construction, the site in charge/civil engineer must be present at the site to supervise the soling, formwork reinforcements, erection and concreting work.

Do & Don'ts

- Do not use dirty sand and grit, as well as impure water in concrete.
- Do not walk over newly-laid concrete.
- Curing should be done for at least 10 days continuously.
- Do not remove form work before 14 days.
- No reinforcements should be visible on the outside after concreting.
- Do not use rusted reinforcements.

Manpower & Time

Estimated manpower required: 4-5 masons days

Estimated labour required: 25-30 man days

Estimated time required: 3-4 working days

Must Supervision

During RCC loading platform construction, the site in charge/civil engineer must be present at the site to supervise the soling, formwork reinforcements, erection and concreting work.

8.3. Guard Walls

What?

Loading platform guard wall construction

Where?

Level : + 7070 to + 7820 mm

How?

- Clean the loading platform and mark the position of the guard wall (parapet wall), leaving 50 mm space all around from the outer edge.
- The masonry wall's thickness should be at least half a brick thick (110 mm) with 1:4 cement mortar.
- Mark each 2 m distance of the guard wall, including the four corners, keeping the brick masonry pillar one brick thick (230 mm) and reinforcing it with steel upto the shaft's height above the platform.
- Provide a 50 mm top coping in 1:2:4 cement concrete with two 6 mm parallel bars. The distance between the two bars should be 30 mm.
- Anchor all platform bars inside the parapet masonry.

Quality Specifications

- Use good quality bricks and avoid dirt, dust and any impurities in the sand and water.
- Use 1:4 cement mortar.
- Curing is required continuously for at least seven days.
- All the platform bars should extended up to the top of the parapet wall.
- Water-soaked bricks should be used in masonry.

Do & Don'ts

- Do not use soil, which is mixed with sand.
- Do not stress the wall by putting force during the curing period.
- Mortar joint should not be more than 15 mm.
- Do not use dry fired bricks.
- Do not use different-sized bricks. This affects the quality of construction.

Manpower & Time

Estimated manpower required: 10-12 mason days

Estimated time required: 2-3 working days

Chapter 9

Exhaust System

9.1. Damper System

What?

Dampers construction

Where?

Level : 7482 to + 8040 mm

How?

Lower Damper

- The damper frame for the lower flue gas is positioned just one course below the upper flue duct base.
- Place the damper frame for the lower flue gas vertically into the chimney masonry work.
- Continue with the chimney wall construction and ensure that the damper frame is well and smoothly covered with lime mortar inside the chimney.

Upper Damper

- Place the damper frame for the upper flue gas vertically at the base course of the upper flue duct, at approximately 150 mm distance to the chimney inlet.
- Ensure that the upper damper frame is placed well inside the masonry wall and does not obstruct the smooth flow of the hot gases.
- Close all gaps around the damper frame with lime mortar.
- The flue duct cross section should increase towards the chimney inlet from the damper onwards. This is made by cutting the backside placed red bricks to the same size as that of the chimney's outside wall brick dimensions.

Quality Specifications

- Ensure that there are no gaps around the damper frames, Mangal gates and that they are firmly fixed so that they don't fall out during operations.
- Check the damper frame to ensure that no lime mortar or other material is blocking the passage of the damper.

Do & Don'ts

- Do not place the damper without a frame. A damper without a frame cannot control the air flow.
- Do have all the damper frames ready while starting the first flue duct.

Manpower & Time

Estimated manpower required: 2 mason days

Estimated time required: One working day

Must Supervision

For the damper frame setting work, it is important that the overall site in-charge/engineer is present at the site and personally supervises the work.

9.2. Chimney Construction

What?

Chimney construction (Refer Figure 11)

Where?

Level: 8500 to + 13000 mm

How?

- The chimney's inner dimensions (215x405 mm) need to be constructed above the shaft top, at the two selected chimney corners.
- Construct the chimney simultaneously with a flue duct system.
- Make a 110 mm thick brick masonry work with lime surkhi (1:4) work, according to the defined chimney measurements, as given in the designs.
- Provide a 50 mm thick RCC band on every interval of 600 mm for the stability of the chimney.
- Tie all the four chimneys at the top with the MS angle. It will also give support to the individuals chimneys from the RCC column.

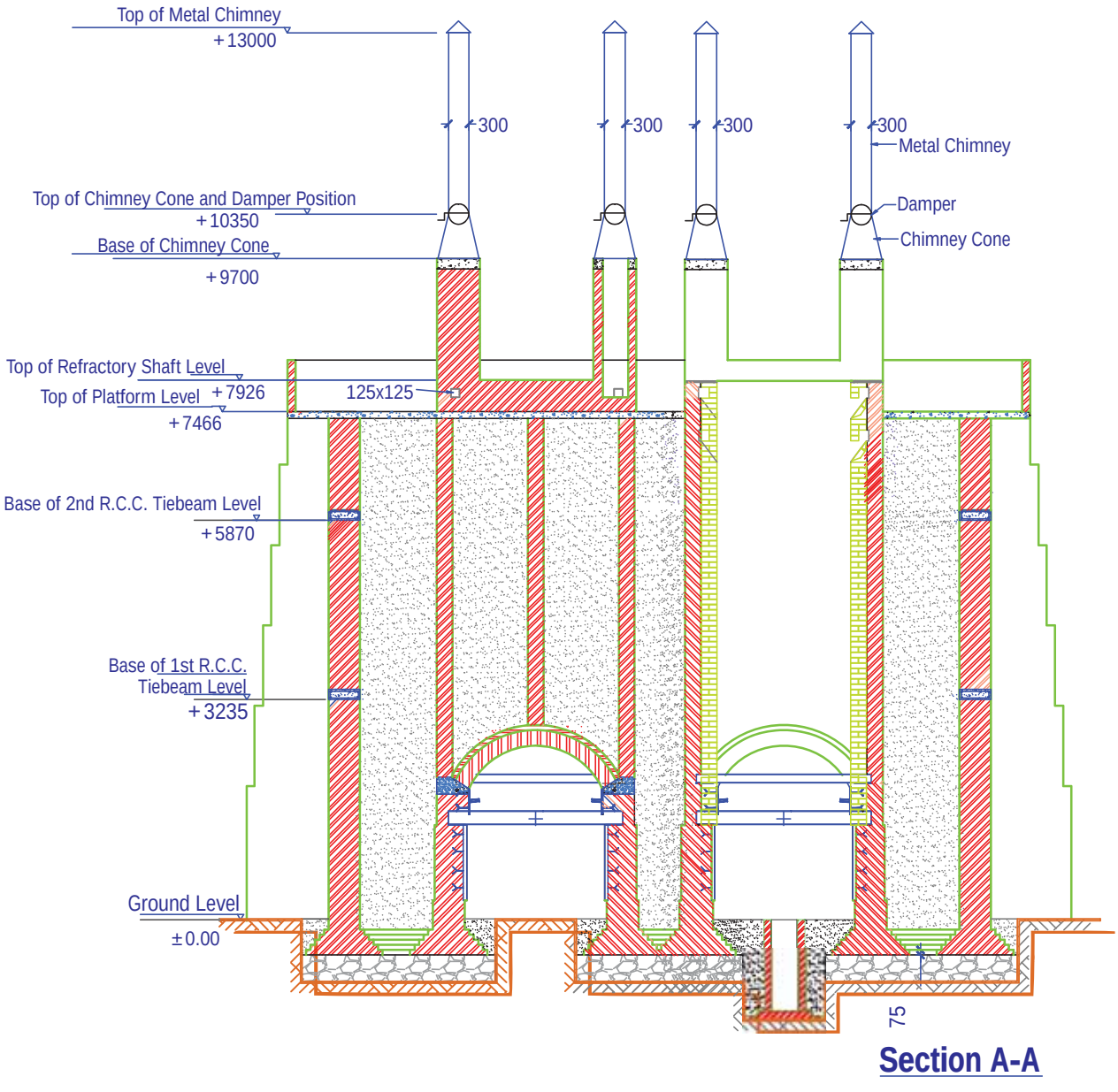
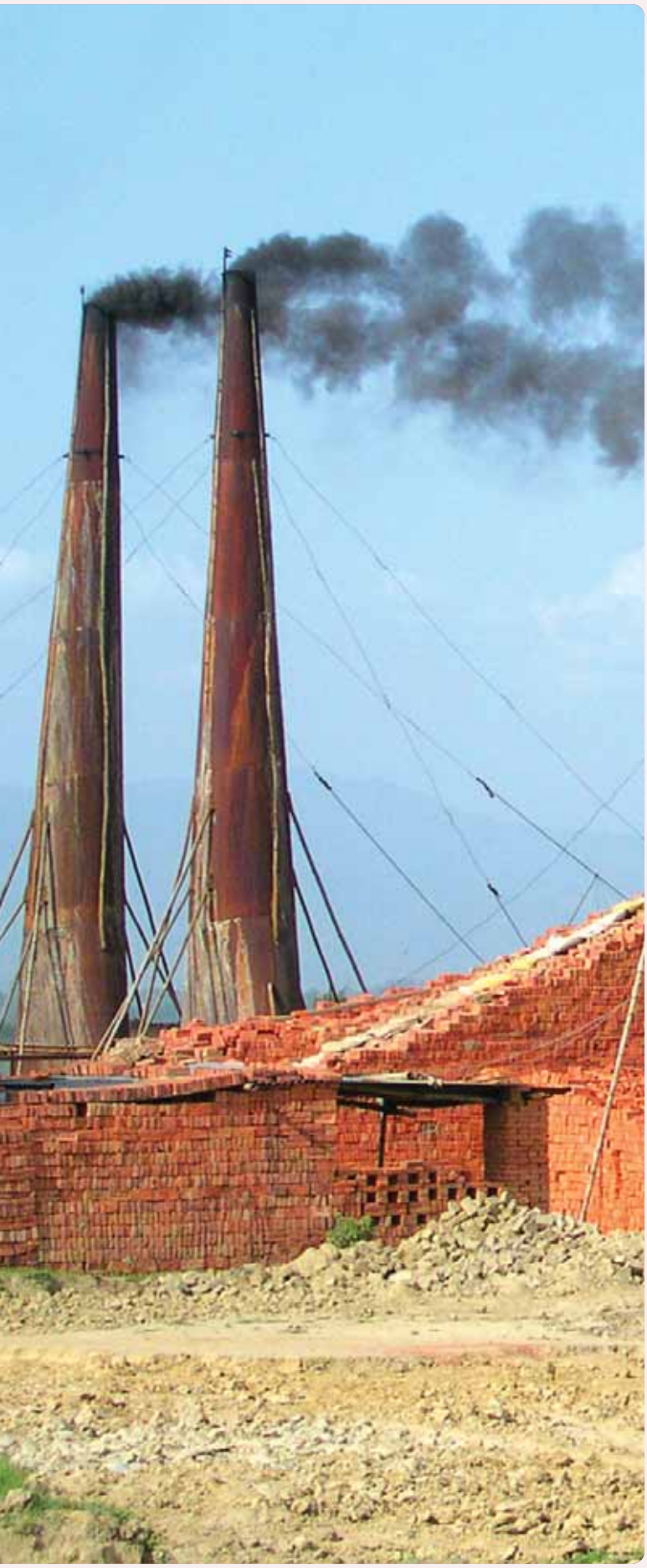


Figure 11: Drawing of Chimneys



- Provide a hole on each chimney for the environmental monitoring purpose.

Quality Specifications

- Two chimneys per shaft.
- The internal cross section should be 215 x 405 mm.
- Use only good-quality bricks.
- Use lime surkhi (1:4) mortar (also add 2–3% of cement) for the joints.
- The concrete band should not be exposed to the flue gas inside the chimney.
- Ensure a smooth inside surface of the chimney.
- Ensure proper ½ brick bonding
- Allow a maximum vertical deviation of 1 mm per metre of the chimney's height.
- A total height of a brick masonry chimney should be at least 4.5 m higher than the shaft top.

Do & Don'ts

- Keeps the brick frog facing the outside of the chimney wall.
- Make a thin lime surkhi mortar joint, a maximum of 10 to 12 mm.
- The top of the chimney must remain open. No chimney hat must be allowed to be constructed, as it could hamper the air flow with the existing low draft.

Alternative Ways

- Single chimney
- Metal chimney
- Concrete Hume pipe chimney
- Stone ware glazed pipes

Manpower & Time

For Eight chimneys

Estimated manpower required: 14-16mason days

Estimated time required: 3-4 working days

Chapter 10

Roof Construction

What?

Roof construction (Refer Figure 12)

Where?

Level of column top : 9813 mm

How?

Note:

A roof is required to protect the workers from sunshine and rainfall and is very essential in tropical climates.

A roof also protects the VSBK platform so that no water can penetrate into the shaft and insulation material, causing a serious damage to the VSBK.

There are many types of roof and the main criteria are not the material, but the proper roof anchorage systems, avoiding costly damages during heavy winds and even cyclones.

In this construction manual, a very common type of roof has been designed. The design ensures the principles of an open platform so that the working environment for the workers loading the bricks is safe and poses no health hazards.

Quality Specifications

- Ensure that the wooden pillars are well connected to the top tie beam.
- Wooden pillars should stick out of the roof support ring beam in order to properly weld and tie the roof trusses.

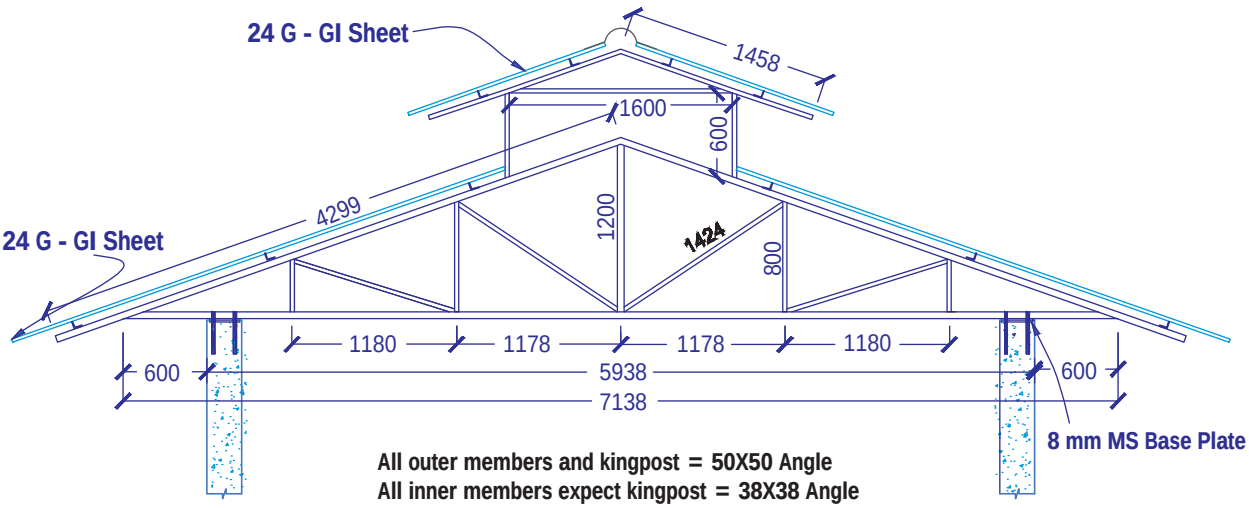


Figure 12: Drawing of the Roof

- A roof monitor with a minimum gap of 700 mm, ensuring proper roof top ventilation must be constructed.
- The roofing material must be properly fixed to the purling.

Do & Don'ts

- Do not use roofing materials such as straw that catches fire easily.
- In case of damage, repair the roof immediately.
- Do not close the platform walls.
- Provide the wall opening a protection from horizontal rainfall.
- Make the roof overhang as big as possible to protect the platform and the kiln body

Alternative Ways

- Bamboo sheet roofing
- MCR tile roof
- Wooden truss

Manpower & Time

Estimated manpower required: 40 mason days

Estimated time required: 5 working days

Must Supervision

For the roof construction work it is important that the overall site in-charge/engineer is regularly present for supervision.

Construction of the Roof of the Kiln

Chapter 11

Access to Kiln Platform

What?

Stair and Conveyor Belt

How?

Note:

A ramp or a staircase is required to access the platform and to transport the green bricks up to the loading platform.

There are many ramp designs possible and one should always look out for a place where a high ground is adjacent to the kiln in order to save the construction cost of the ramp.

In this construction manual a very common type of staircase and ramp has been designed. Basically all previous mentioned principles for foundation and masonry work also apply for the construction of the staircase. Therefore, no detailed construction process is mentioned in this chapter.

The construction of the staircase should start preferably once the VSBK arch construction is complete. The staircase must be completed and should be in a usable condition when the VSBK construction reaches the platform level.

Alternative Ways

- Metal stair case
- Earthen or concrete ramp
- Removable dry green brick ramp
- Removable bamboo ramp
- Removable timber ramp

Manpower & Time

Estimated manpower required: 60-80 labour days
25-30 mason days

Estimated time required: 8-10 working days

Must Supervision

For the staircase or ramp construction work, it is important that the overall site in-charge/engineer is regularly present for supervision, especially during the construction of the foundation and the arches.

Kiln with a Conveyor Belt

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