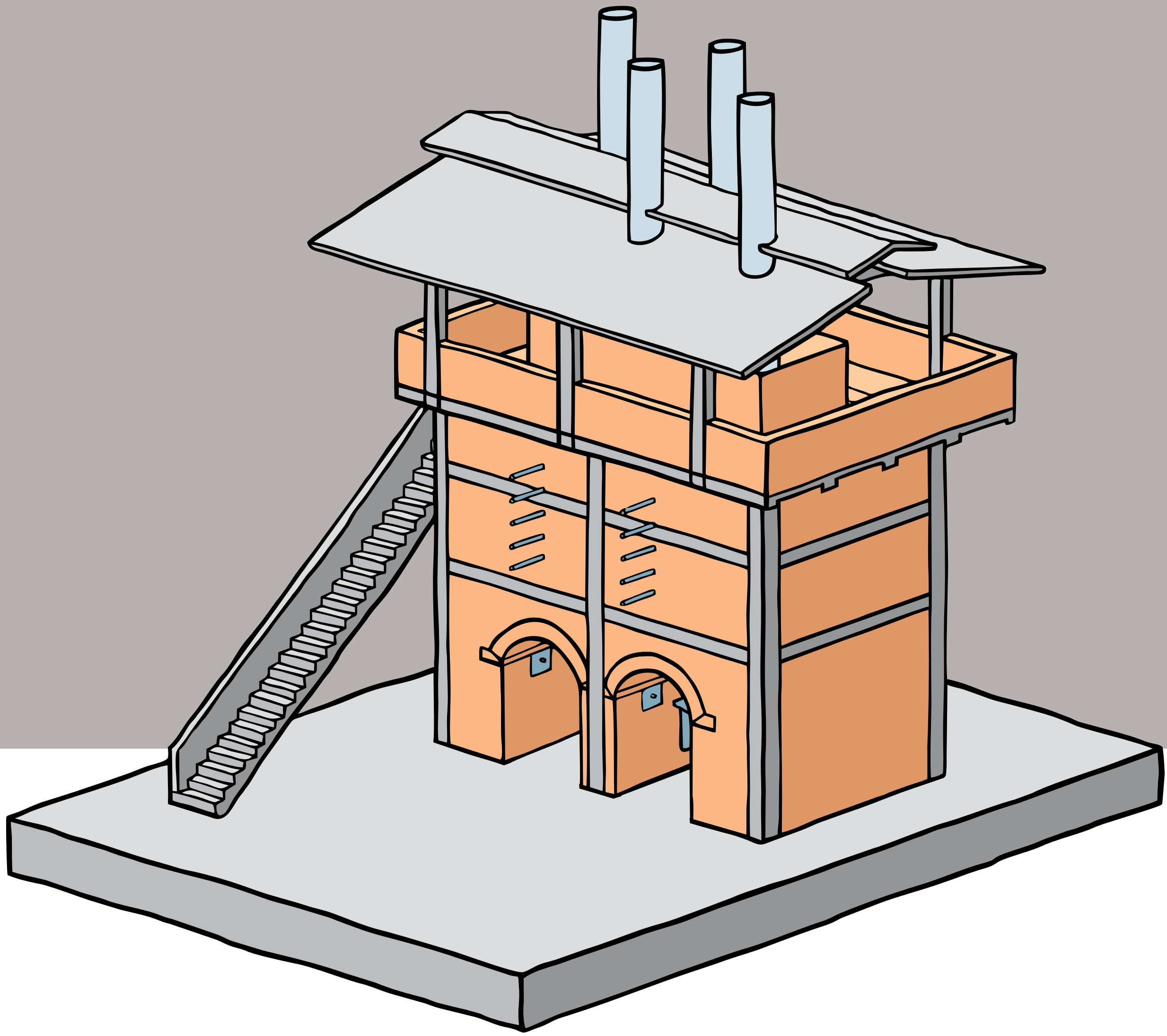
VSBK DESIGN OPTION Guidelines



DESIGN FUNCTIONALLY
BUILD ECONOMICALLY!

VSBK Design Option Guidelines

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This document is not intended to be a construction guide and entrepreneurs who consider constructing a VSBK are strongly advised to contact an experienced local or regional VSBK expert/consultant.

Contents

Acknowledgements

The Vertical Shaft Brick Kiln (VSBK) development process documentation started during its applied Research & Development stage in 1997 and reached a first important milestone in the legendary "Brick by Brick - The Herculean Task of Cleaning up the Asian Brick Industry" in 2008. Yet the actual construction development process has been continued since. In particular the "South – South" VSBK technology transfer to South Africa lifted the VSBK technology significantly. Additional construction options have been realized that promote the VSBK technology as a globally recognized clean brick production system. However, the result of this process has until now never been systematically documented and updated.

Skat would like to express its sincere appreciation to Swiss Development Cooperation (SDC) for its continued support to the development of the VSBK technology and its adaption to specific local contexts. Without this persistent commitment and trust into the involved partners over a period of more than a decade the development of the VSBK technology as a technical and economical viable environment friendly alternative to traditional brick production systems would not have been possible.

Skat likes to express sincere thanks to the piloting entrepreneurs from various countries who made the VSBK technology learning and development possible. Only through the spirit of VSBK pioneers, who were and are prepared to practically test new approaches and at the same time take some risks, the VSBK technology could be exposed and tested in the practical business environment.

Skat is also very grateful to all partner organizations and individual professionals from various countries, who each in their own way contributed towards important "puzzles" in order to up-grade and perfect the VSBK technology. They made a South-South technology transfer possible.

Special thanks to all those who contributed to the development and compilation of this documentation, in particular to the European experts in energy & environment, kiln construction and ceramics, Mr. Max Müller, Germany, Mr. Hans Schmid, Switzerland, Mr. Ekhard Rimpel, Germany, and Mr. Alois Müller, Switzerland, as well as to Mr. Urs Hagnauer, former VSBK Project Manager, Nepal.

Last but not least Skat, as the partner in charge for the technology transfer to South Africa would also like to acknowledge the VSBK Project in South Africa which financed the development and publication of this document as well as our consortia partner, Swisscontact, who facilitated the project implementation.

Karl Wehrle
Skat Consultancy

Background

This publication is part of the ongoing efforts of the VSBK technology transfer process from Asia to South Africa. It is part of the tasks entrusted to Skat in an overall process of knowledge transfer. The focus of this publication are both the main design options as well as construction elements of the Vertical Shaft Brick Kiln. The VSBK is the most energy efficient coal fired clay brick production technology. Ever since SDC supported the systematic VSBK technology transfer from China to India in 1996 a lot of local and international VSBK working experience has been accumulated. In its quest to contribute to cleaner clay brick firing systems, and thereby to a cleaner environment, SDC also supported the VSBK technology transfer to Nepal, Vietnam, Afghanistan, Pakistan and since 2009 to South Africa.

In the VSBK technology transfer to the above mentioned countries, except to Vietnam, Skat Consultancy is the only international organisation that has been a constant partner to SDC's environmental endeavour since 1996. This professional trust was continually acknowledged by Skat Consultancy with its principle working strategy; to locally anchor the VSBK technology and thereby building local VSBK experts while at the same time creating and overseeing an international network of experts and specialists to sustain the VSBK technology as well as its constant improvements, documentation and international dissemination, therefore making best use of the investments made by SDC and all other partners.

The VSBK technology is not patented. Since its commercial, environmental and social development was financed by SDC this technology is considered an "open source" technology. The results of 17 years of VSBK design/construction experience and knowledge from all stages of the various VSBK technology transfers have been collected and compiled as **"VSBK Design Option Guidelines"**.

This documentation is the result of professional involvement of experienced European brick kiln experts with global VSBK technology experts and local practitioners/ entrepreneurs. Hence this documentation considers both; the current state-of-art brick kiln know-how at European level as well as globally applied practical and technical options.

However, latest adaptations to local contexts by local experts in South Africa could not be included in this document since they are being claimed as intellectual property. Depending on interest they may be made available through a consultancy contract.

Purpose of this documentation

Through the SDC supported "South – South" VSBK technology transfer to South Africa new thinking, new views, new experts and thereby new potentials were leading to additional construction options. Awareness of the unique energy and environmental advantages of the VSBK technology is rapidly being disseminated at a global level. With this document, experts not only in South Africa but also at global level are enabled to make an educated decision of how to adapt the VSBK technology and therefore contribute towards an increased global VSBK demand while at the same time reducing the greenhouse gas emission from a polluting industrial sector.

The purpose of this documentation is to provide a general overview of different VSBK construction options and makes it clear that there is no 'One-size-fits-all'. For a profitable VSBK business experienced professionals should be involved who assess the appropriateness of a given option to a given situation and this document aims to be a valuable resource for decision makers.

Potentials and limits of this documentation

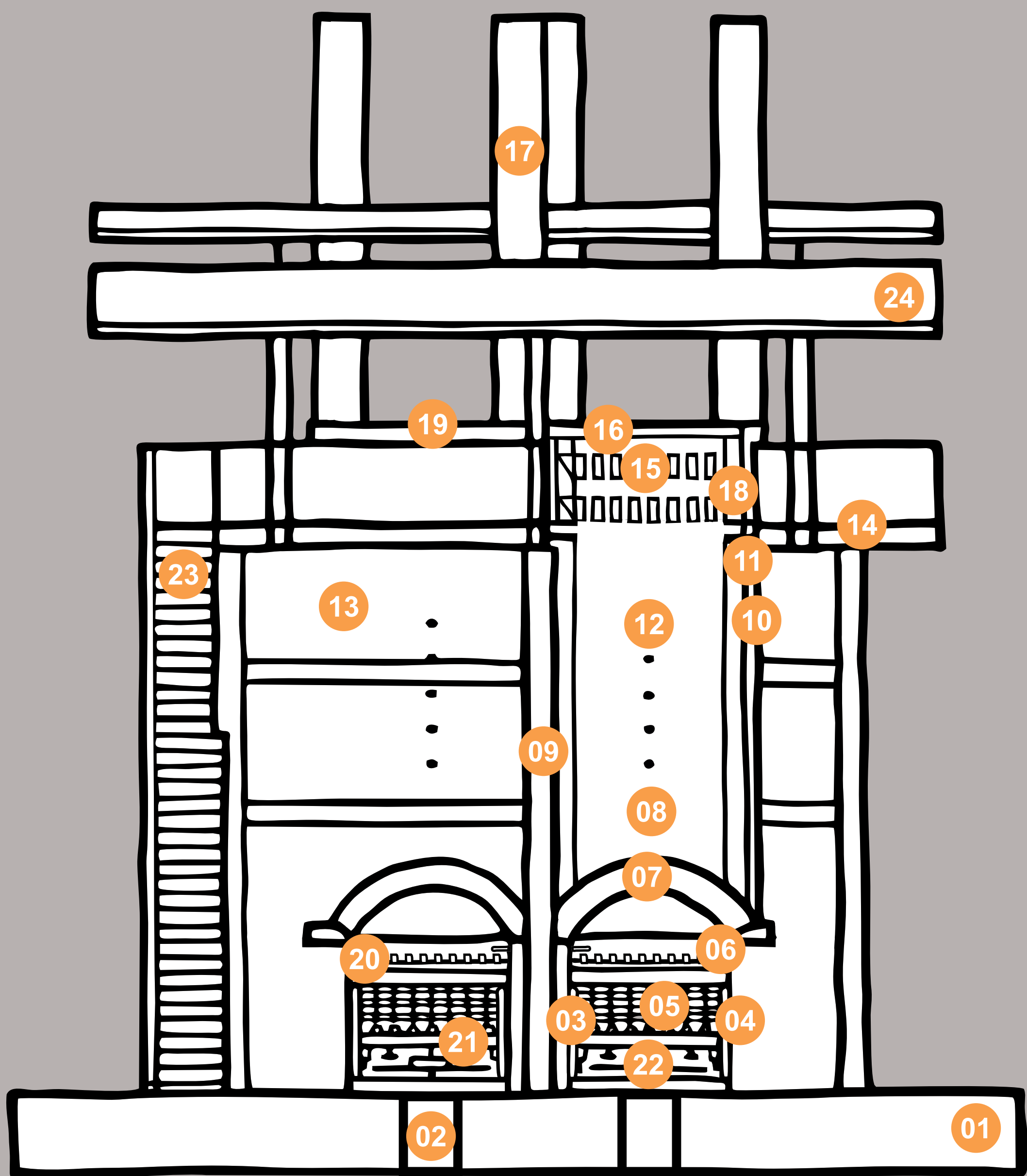
VSBK construction options are always linked to, and with the purpose of, brick firing and its related economics. Although numerous VSBK construction options are globally implemented by various organizations, experts and entrepreneurs, the authors utilized a two-shaft VSBK design as reference and purposefully limited the number of possible construction options in this document in order to focus on proven practical and economical practices. For individuals with limited access to high tech solutions and high up-front financial investment, for whatever reasons, current industrialized 'state of the art' kiln construction materials and techniques need to be down scaled into practical solutions. This documentation not only shows practical options but also presents potential future options that will require local fine-tuning for viable final adaption to the local context. It would be way out of the scope of this document to explain the detailed aspects of the VSBK construction. This document tries to provide basic rationales and explanations where deemed essential. It is sometimes difficult to precisely and appropriately provide sketches and explanations to fully comprehend detailed construction drawings of different options. They can be made available through a consultancy contract with any of the VSBK technology service providers.

This document is not intended to be a construction guide and entrepreneurs who consider constructing a VSBK are strongly advised to contact an experienced local or regional VSBK expert/consultant.

Feedback and up-grading of this documentation

Any feedback and additional experiences regarding the various technical options is most welcomed and can be directed to Skat Foundation (info@skat.ch). Skat Foundation, along with the respective experts and authors, will accordingly secure future up-dates to this document and make the collected information available to a broader audience, with reference to the source of information.

Overview of VSBK



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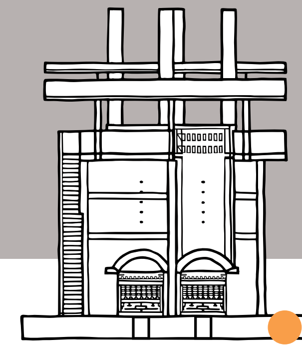
01 FOUNDATION



Function

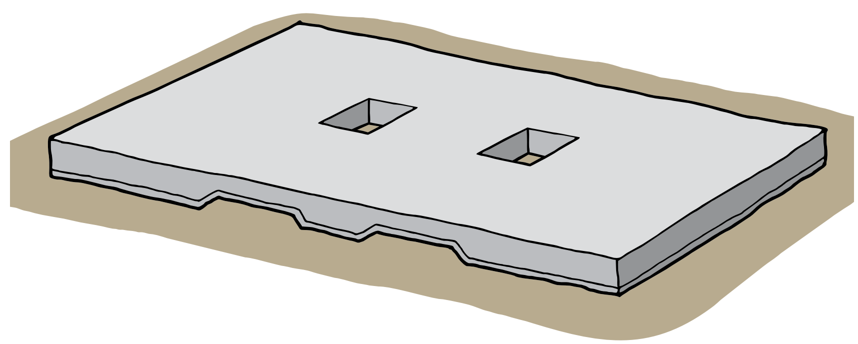
The foundation is the part of the VSBK that is in direct contact with the ground and through which structural loads, including the weight of green bricks, coal storage and movements are being transferred.

Design principles

A universal foundation design for all types of ground is technically and economically not feasible since key parameters vary according to the local situation and context. Therefore, the foundation has to be professionally designed, case by case and according to local contexts.

A VSBK should never be constructed on back-filled soil or landslide-prone areas. Special design precautions must be taken for areas having a high ground water table or earthquake experience.

OPTION 1 : R.C.C. raft foundation (Suitable for non-cohesive soils)	
Advantages	**Disadvantages & Limits**
• Equal load distribution on any type of natural grown soil • Employed working personnel can work on a clean and safe platform • Ground water penetration can be minimized	• Expensive construction option due to the use of mass concrete and reinforcement steel



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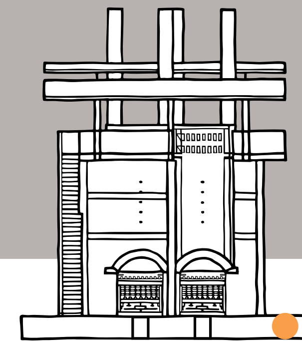


OPTION 2 : Brick footing

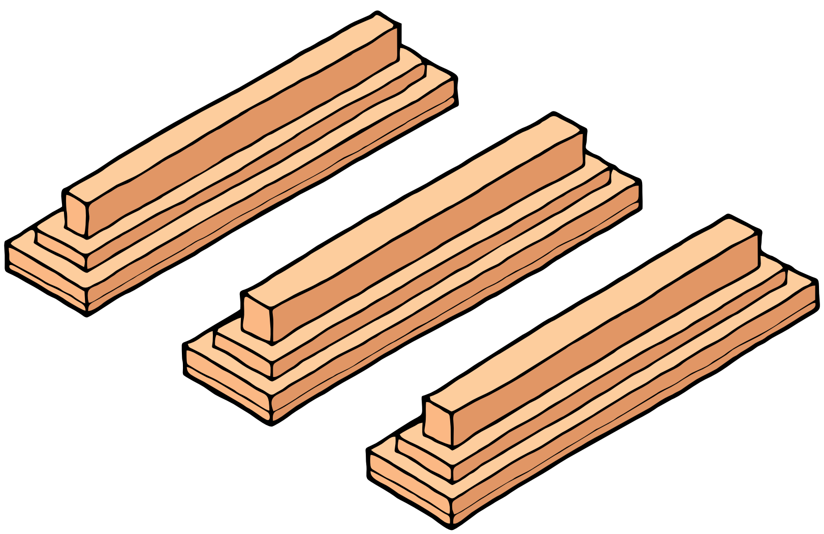
(Suitable for cohesive soils)

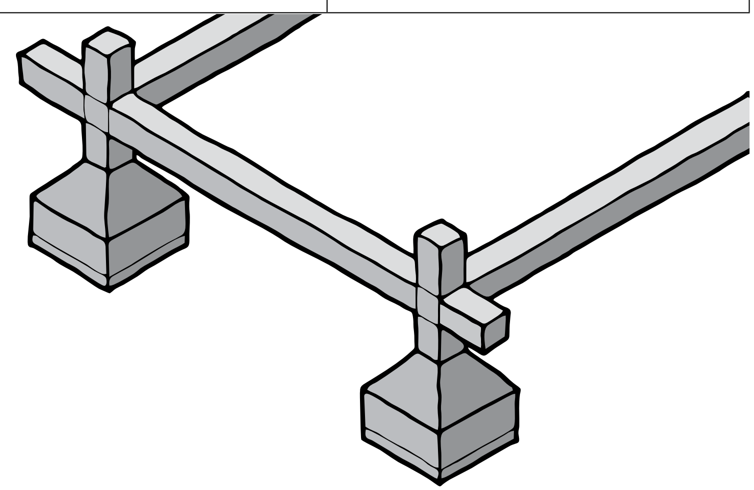
Advantages	Disadvantages & Limits
• A Brick entrepreneur can use his/her own bricks for this foundation option and can therefore optimize expenses	• Not applicable for all types of grounds and especially not an optimal option in cases of high ground water table • Requires good brick quality

OPTION 3 : Pillar foundation

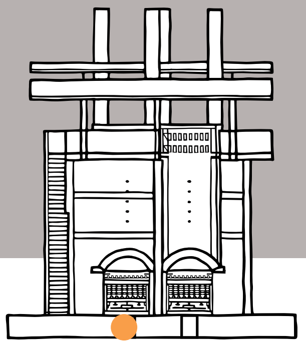
(Suitable for both cohesive and non-cohesive soils)

Advantages	Disadvantages & Limits
• Suitable option for a frame structure VSBK construction	• Generally requires horizontal concrete tie-beam connection • Considerable amounts of shuttering material is required • Depending on the required depth of the pillars a relatively expensive construction method • Demanding in skill (preciseness) and supervision





02 UNLOADING MECHANISM SUPPORT UNIT



Function

The unloading mechanism support unit accommodates the height of the hydraulic piston or screw, protects the unloading mechanism from potentially being blocked during operation and bears the load of the entire brick setting inside the shaft during unloading procedures.

Design principles

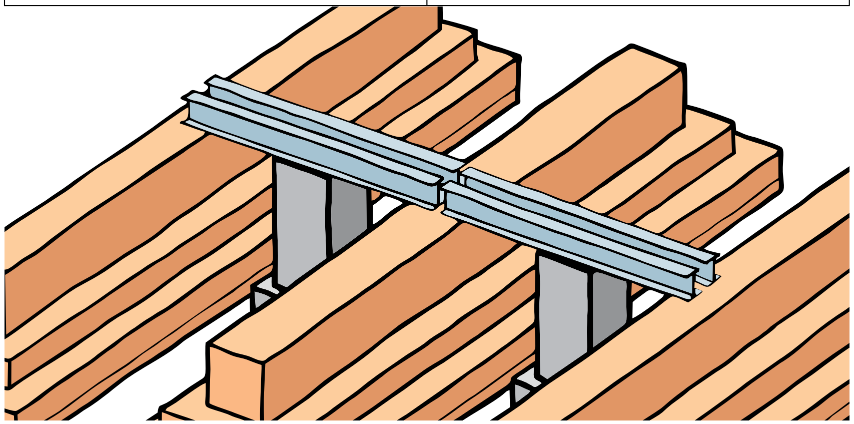
The unloading mechanism support unit must bear the entire brick setting load and its unloading system in such a way that no structural settings/ damages will hinder the unloading operation.

The related pit should be protected from the nearby filled soil and ground water so that the unloading mechanism can move freely.

OPTION 1 : M.S. I-beams

Note : M.S. I-beams are installed perpendicular to the arch walls in order to transfer the load of the bricks setting inside the shaft to the kiln foundation.

Advantages	Disadvantages & Limits
• Economical option due to the utilisation of the arch wall foundations • Can accommodate both hydraulic and manual unloading mechanisms	• Foreign material could fall into the pit structure which could create complications for unloading procedures and are likely difficult to clean • In areas of high water table, a watertight pit structure should be ensured in order to avoid water contact with the unloading mechanism



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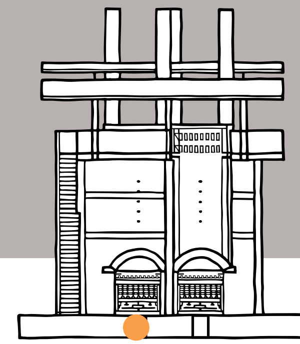
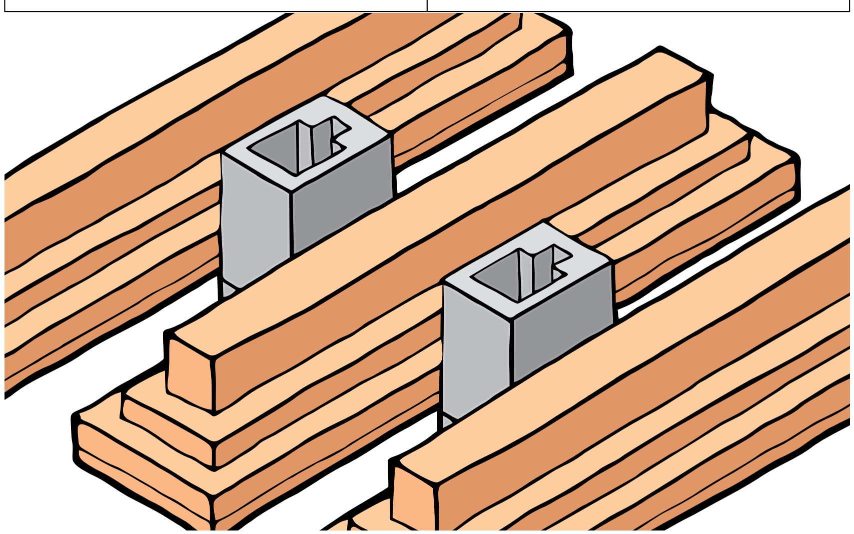


OPTION 2 : R.C.C. load bearing unit

Note : This unit is separated from the kiln structure. It bears the entire load of the brick setting inside the shaft on its own foundation.

Advantages	Disadvantages & Limits
• Pit structure is maintenance friendly	• Does not utilise the arch wall foundation for support, its construction requires heavy duty concrete and steel reinforcement and is therefore considered expensive • Only feasible on ground with sufficient bearing capacity



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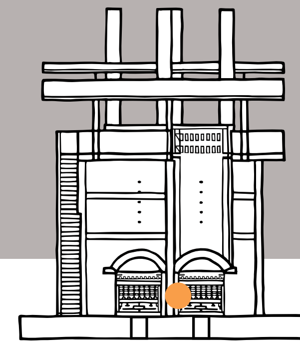
03 TROLLEY GUIDE



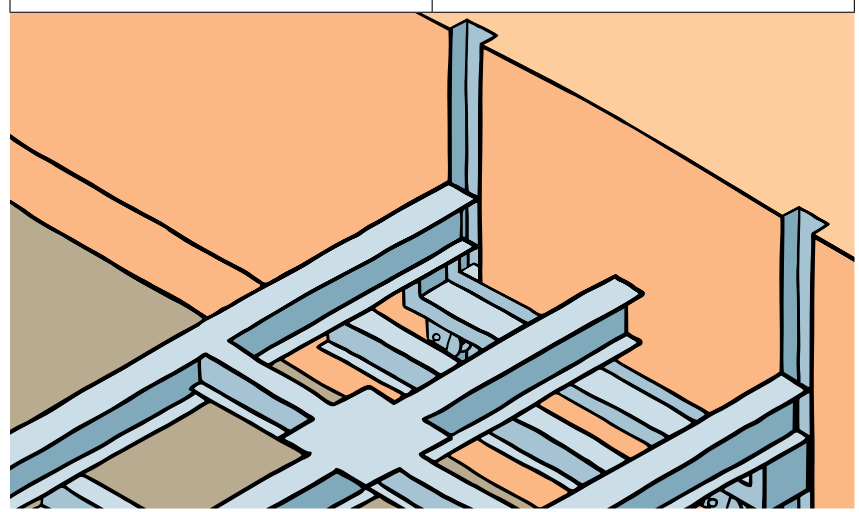
Function

The trolley guide assists in correctly positioning the trolley for unloading procedures and, when the unloading trolley is correctly positioned, acts as a safety feature to prevent unevenly loaded trolleys from toppling.

Design principles

The trolley guides are made with MS C-Channels and are properly anchored into the arch walls.

OPTION 1 : Recessed MS C-channels	
Advantages	**Disadvantages & Limits**
• Low wear & tear of the masonry walls during unloading • Correct positioning of trolleys below the shaft is ensured • Trolleys and the unloaded fired bricks are prevented from becoming wedged between the shaft supporting walls during unloading procedures	• Wall corbellings are required near ground level, hence the wall construction becomes more labour intensive and therefore costly



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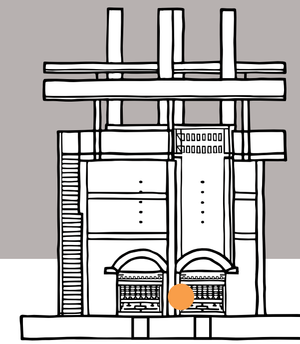
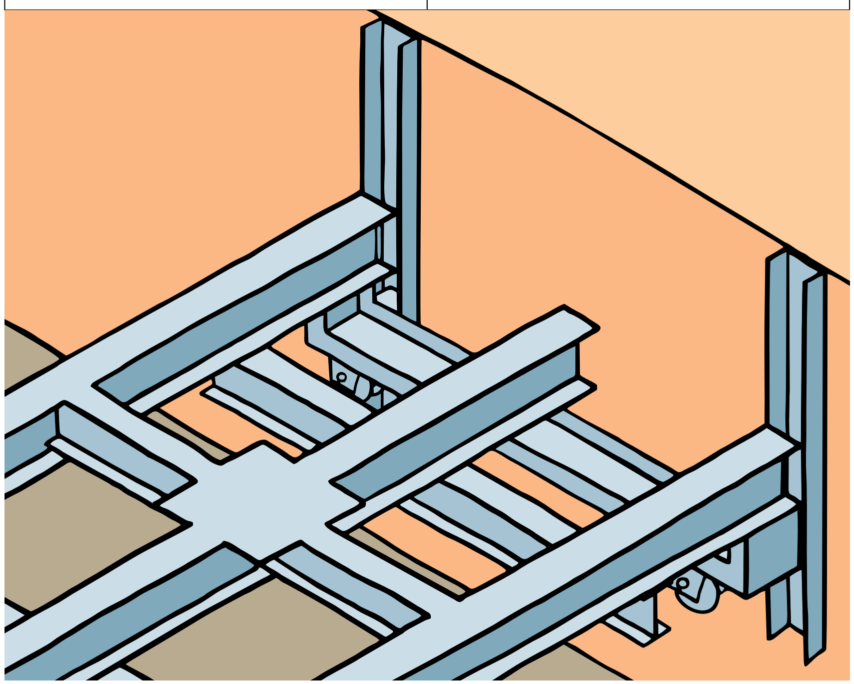
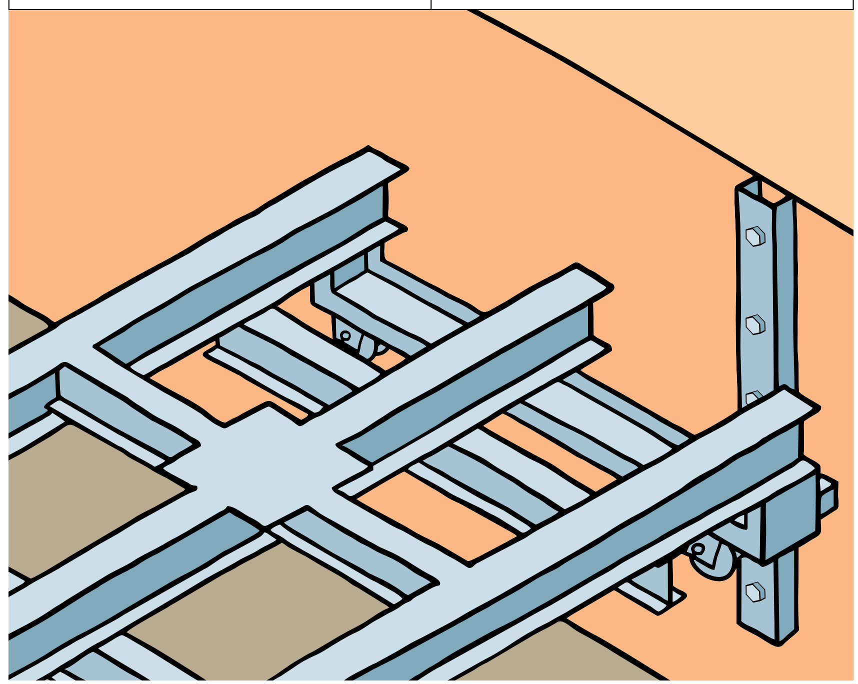


OPTION 2 : Protruded M.S. C-channels	
Advantages	**Disadvantages & Limits**
• Wall brick corbelling is not required, hence the construction becomes less time consuming and therefore less costly	• Chances of injuries during unloading procedures



FUTURE OPTION 1: Screwed-on guides	
Advantages	**Disadvantages & Limits**
• Low construction cost • Simplified trolley locks hence no movable parts • Easy maintenance	• None



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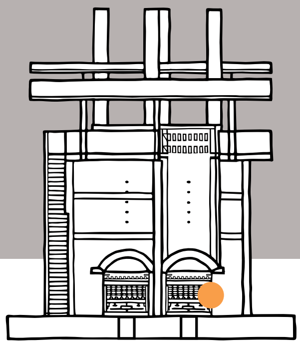
04 BRICK CORBELLING



Function

The brick corbellings increase the arch wall distance for unhindered unloading of the fired bricks and movement of the trolley

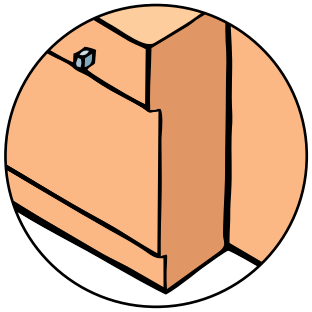
Design principles

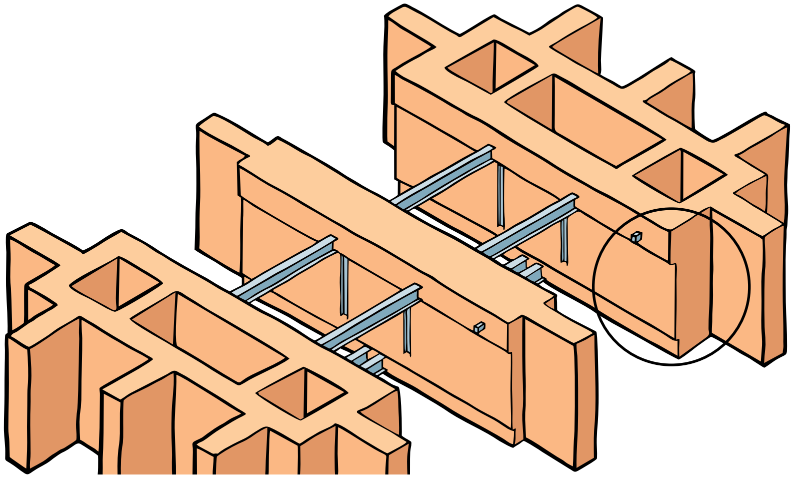
The brick corbelling of a given brick course should ideally not exceed 3cm.

Wall corbellings can be made, but as a matter of fact, are optional depending on the quality of green bricks, firing and operation practices.

Since the arch masonry walls distance and the shaft size have different measurements the refractory shaft corbelling is advisable to avoid damages during operation.

OPTION 1 : Two arch wall corbellings (1st and 2nd, on each side of the arch supporting walls)	
Advantages • Reduced risk of fired bricks tumbling from the unloading trolley • Less wear & tear due to M.S. C-Channel trolley guides constructed flush with the arch wall support masonry	**Disadvantages & Limits** • Arch side wall brick corbelling construction becomes time consuming and therefore costly • Could hinder pulling out the trolley due to the small gap of 3 cm between the wall and the trolley during emergency unloading





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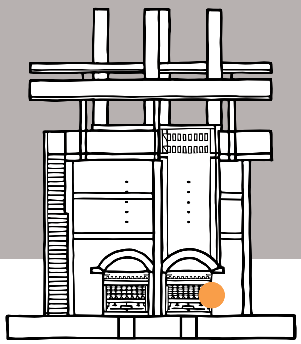
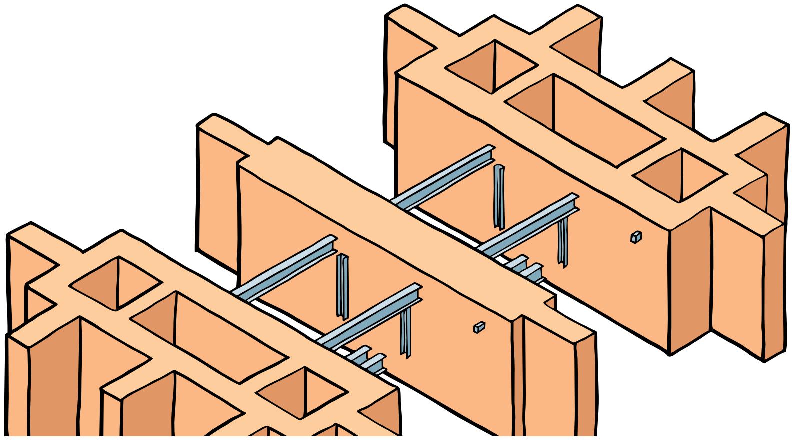
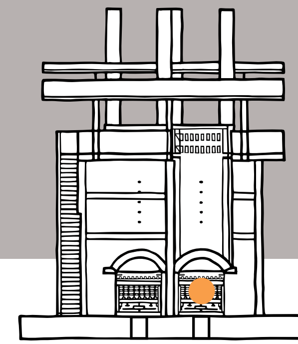


OPTION 2 : Corbelling at refractory brick shaft level	
Advantages • Easy to pull and push the trolley due to increased side space • Construction of the arch side walls is less time consuming and therefore less costly • More economical because the shaft supporting corbelling layer can be constructed just before the first refractory brick layer of the shaft	**Disadvantages & Limits** • Protruded M.S. C-channel trolley guides (see 3, option 2) must be fixed otherwise the trolley guide lock becomes too long which could be difficult during unloading • Increased risk of fired bricks tumbling from the unloading trolley due to increased side space



05 BRICK SUPPORT I-BEAMS



Function

The brick support I-beam is the resting place for unloading bars and the girder system during operation. Between unloading procedures the beam supports the entire brick setting load inside the shaft and transfers it to the arch supporting wall.

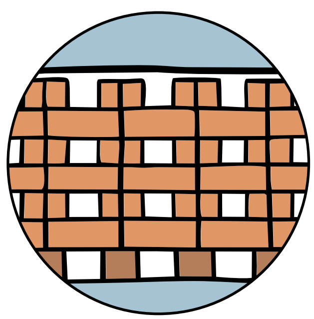
Design principles

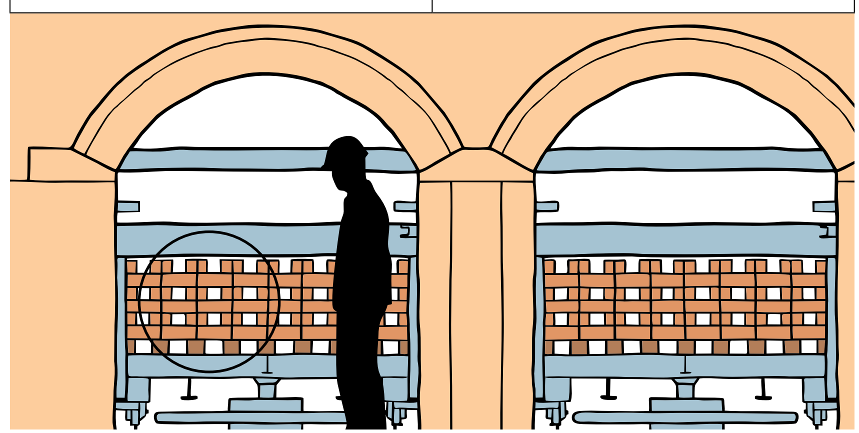
The brick support I-beams must be designed to carry the entire brick setting within the shaft.

The temperature at the unloading place can at times be as high as 400°C, which needs to be considered when estimating the I-beam dimensions. The I-beams should be completely straight, never even slightly twisted or bent and must be positioned parallel to each other.

OPTION 1 : Brick support beam positioned for unloading 6 layers of bricks

Advantages	Disadvantages & Limits
• Higher unloading capacity, also during emergency situations • Reduced workload for personnel during regular operation since less unloading procedures are performed for the same number of bricks being unloaded • Friendly working environment due to less heat exposure • Increased cooling down rate possibility	• The dimensions of the unloading screw/hydraulic piston increases due to the increased lift height





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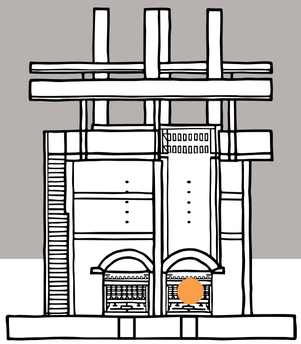
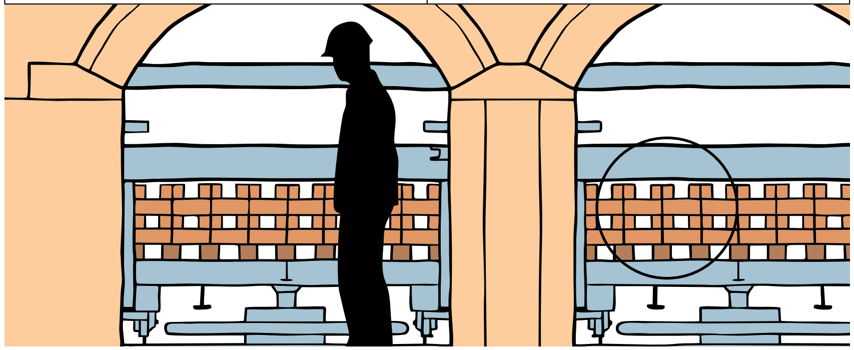
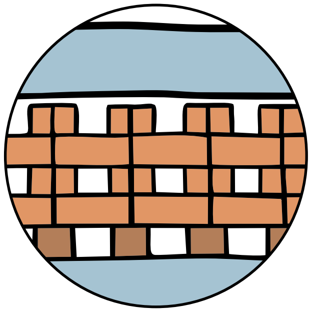
05 BRICK SUPPORT I-BEAMS



OPTION 2 : Brick support I-beam positioned for unloading 4 layers of bricks (including a lower arch and reduced overall kiln height)	
Advantages • Due to the decreased lift height the dimensions of the unloading screw/hydraulic piston decreases • Decreases overall construction costs due to the reduced kiln height	**Disadvantages & Limits** • Unloading difficulties during emergency situations; hence an experienced & disciplined working crew is required • Increased workload for personnel during regular operation since more unloading procedures are performed for the same number of bricks being unloaded • Increased heat exposure to working personnel





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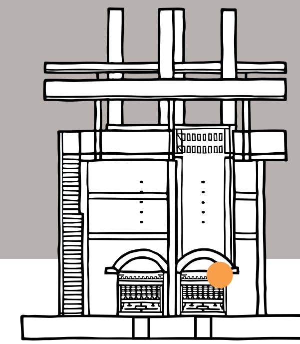
06 GIRDER SYSTEM



Function

After the trolley is securely positioned beneath the fired bricks, the Girder system facilitates the release of the unloading bars and hence the load of the entire brick setting is transferred to the trolley and the unloading system.

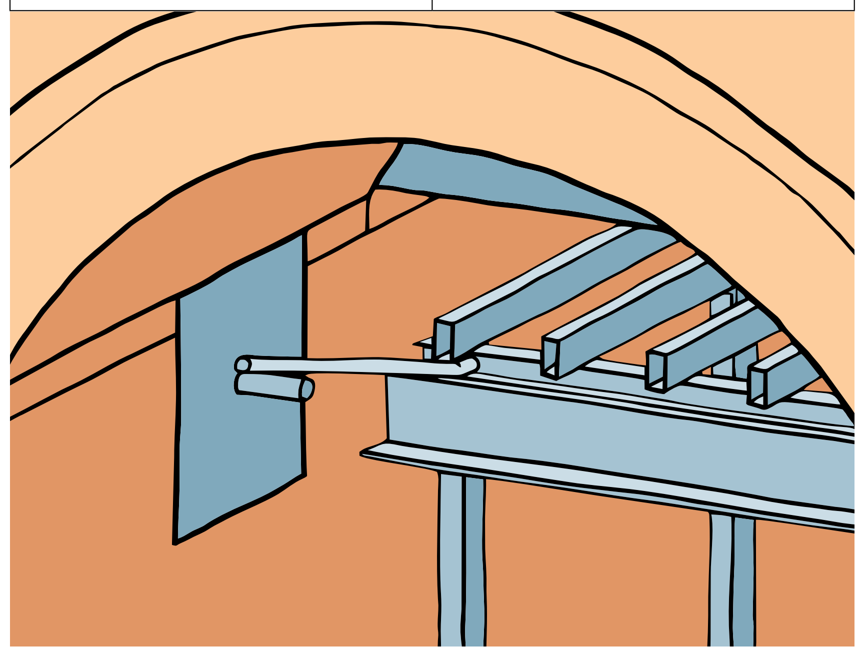
Design principles

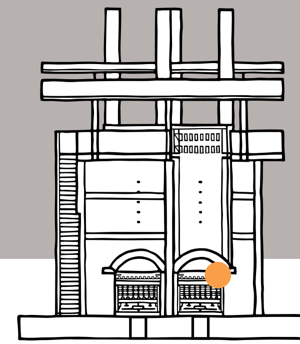
The girder system needs to be designed in a way that it is able to carry the entire brick load. Further, it has be ensured that the release mechanism cannot be triggered accidently (or unintentionally) and the brick load can be transferred onto the trolley without potentially injuring working personnel when releasing the system.

When a hydraulic unloading system is in place the whole girder system is not required.

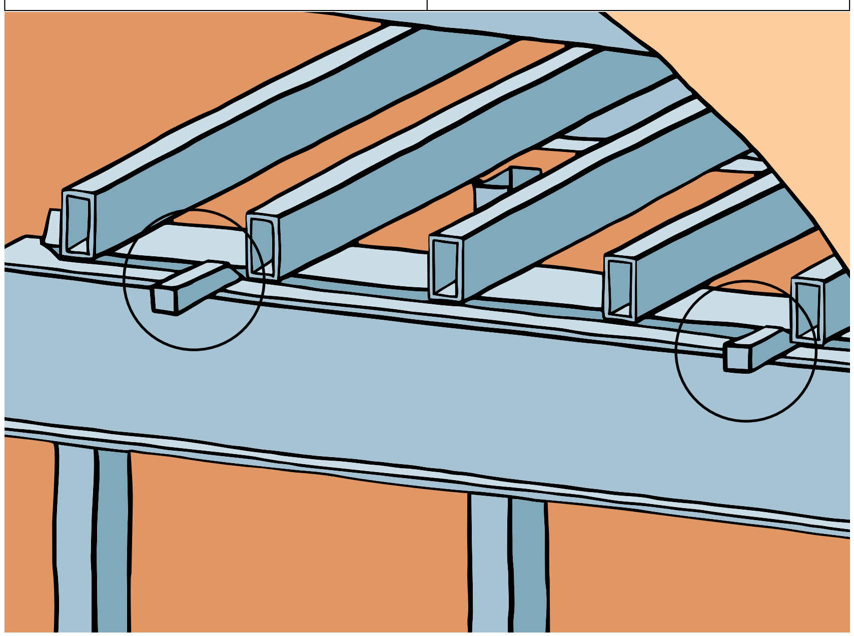
OPTION 1 : Girder system with side locks

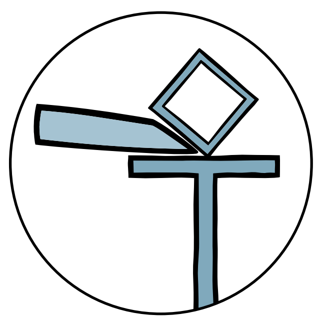
Advantages	**Disadvantages & Limits**
• No electricity required • Less uplift movement of screw/hydraulic piston and therefore easier for working personnel	• Girder rail prone to bending due to heat radiation and constant load • Increases construction time due to fixing of all the related metal parts



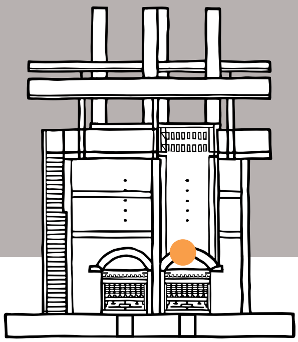


OPTION 2 : Girder system with wedge locks (MS square rod/wedge)	
Advantages	**Disadvantages & Limits**
• Cost effective • No electricity required • Less uplift movement of screw/hydraulic piston and therefore easier for working personnel	• None





07 ARCH/SLAB



Function

The arch/slab structure ensures safe access to unload the fired bricks. It also distributes the loads of above build structural and non-structural loads into its supporting walls. Further, air entering through this access opening is aiding both the combustion and the brick cooling process.

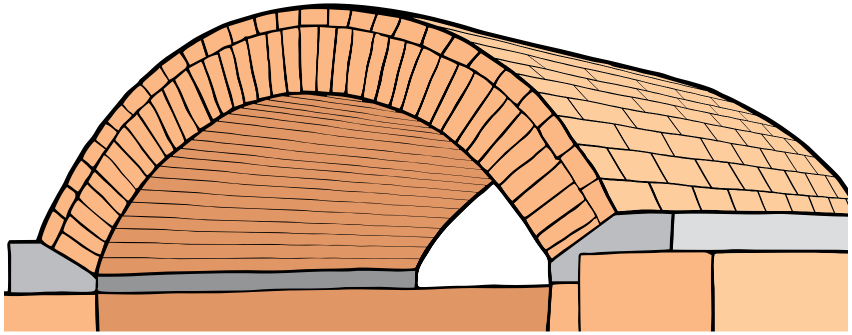
Design principles

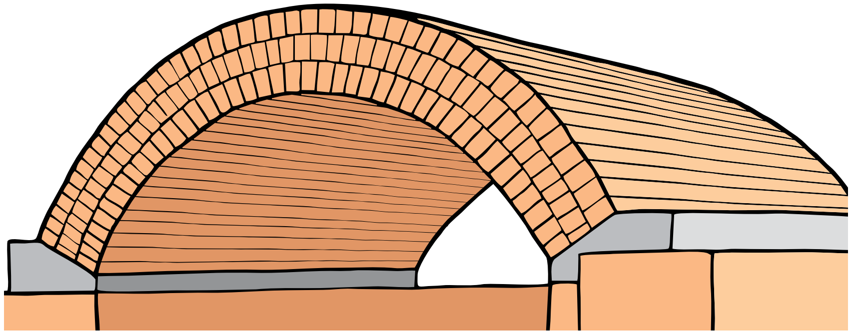
Different Arch types can be designed.

Concrete beams and arches; in situ or prefabricated; are viable alternatives to brick arches. A few of them are shown as options in this document.

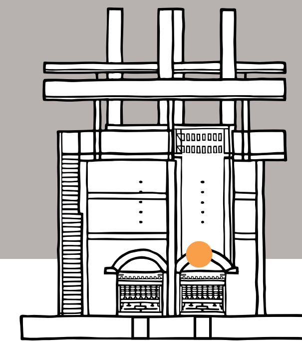
Being arch, beam or slab, the fundamental design criteria is that the structure is safely bearing the load placed on top of it. Concrete based structures should not be exposed to temperatures above 300°C.

OPTION 1 : Arch constructed with brick	
Advantages • Locally available bricks can be used, therefore reduced construction costs	**Disadvantages & Limits** • Requires an arch mould • Arch construction will increase the overall kiln construction time



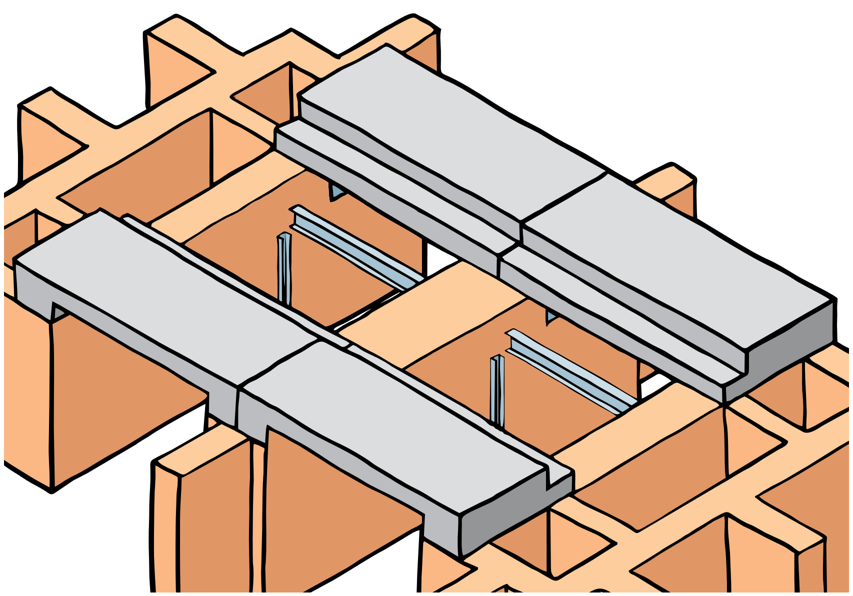


07 ARCH/SLAB



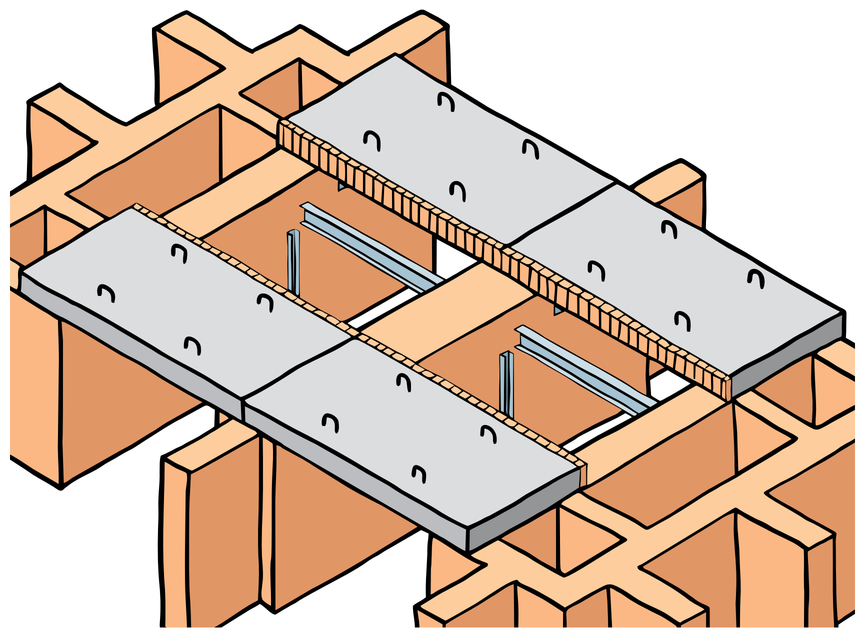
OPTION 2 : In situ R.C.C. beam and slab

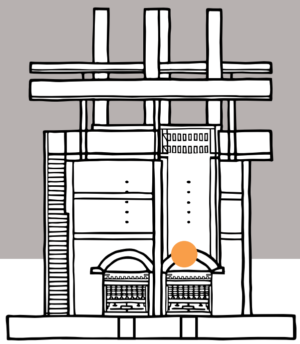
Advantages	Disadvantages & Limits
• Saves on overall number of fired bricks for the kiln construction • No arch construction skill required	• Requires shuttering material • Will increase the overall kiln construction time • Will likely get some damage in case of high temperature exposure (e.g. brick melting inside the shaft)



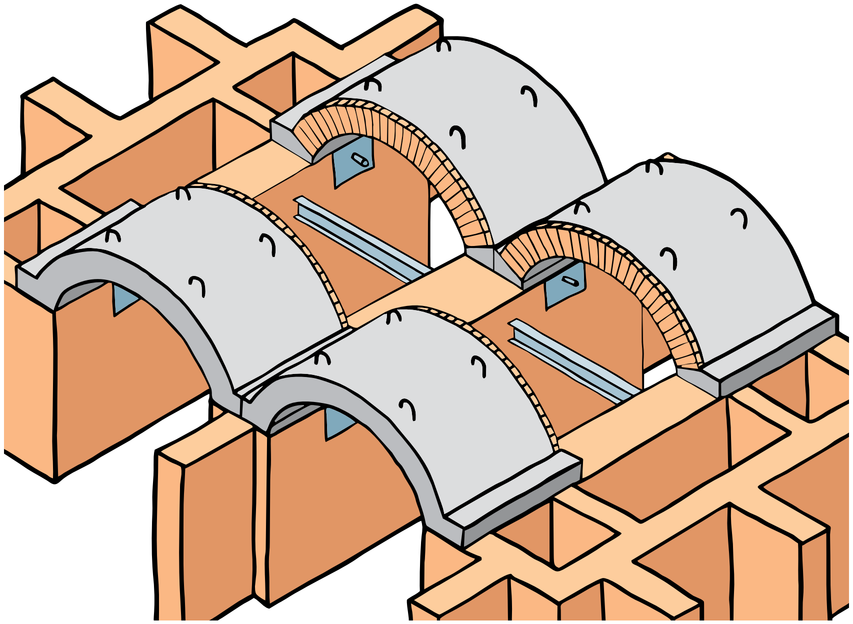
FUTURE OPTION 1 : Precast R.C.C. beams with 1 layer of front bricks attached as insulation and protection

Advantages	Disadvantages & Limits
• Reduces overall kiln construction time in case the pre-fabrication is done in factories	• Requires a mechanical lifting device to place it • For achieving economical advantages a large number of shafts need to be constructed

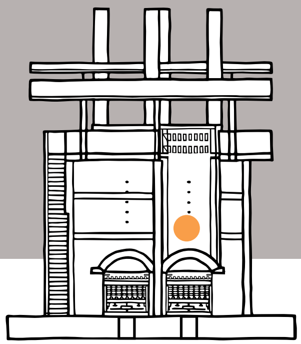




FUTURE OPTION 2 : Precast R.C.C. arch with 1 layer of front bricks attached	
Advantages • Reduces overall kiln construction time in case the pre-fabrication is done in factories	**Disadvantages & Limits** • Requires a mechanical lifting device to place it • For achieving economical advantages a large number of shafts need to be constructed



08 SHAFT



Function

The shaft is the core element of the kiln and has to accommodate the firing of the bricks as per the appropriate fire schedule as well as to provide resistance to mechanical wear and tear from vertical movement of the loaded bricks.

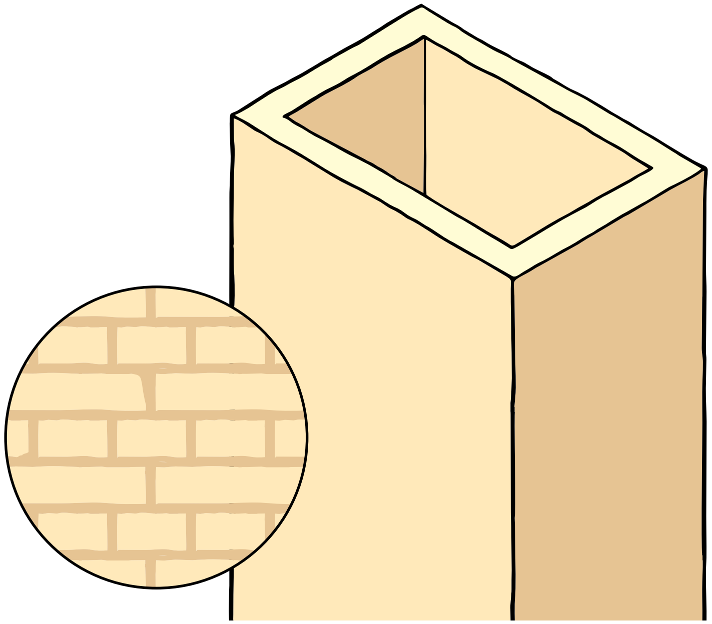
Design principles

The shaft dimension must be designed according to the dry green brick size and maximum production capacity.

Further, the following design criteria should be considered to allow for trouble-free brick firing:

- Heat resistance of the shaft walling material in the central firing zone up to 1200°C
- Acidic emission resistance in the pre-heating zone
- Structural expansion properties
- Perfect verticality
- Self supporting structure

OPTION 1 : English bond refractory masonry without expansion joints	
Advantages • Uniform expansion and contraction properties • Uniform thermal mass properties	**Disadvantages & Limits** • Special masonry skills required • Expansion will develop uncontrolled masonry cracks



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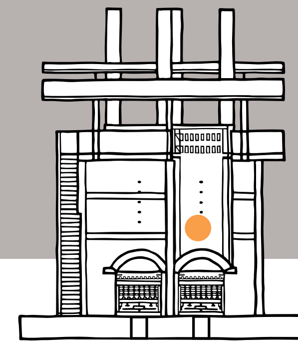


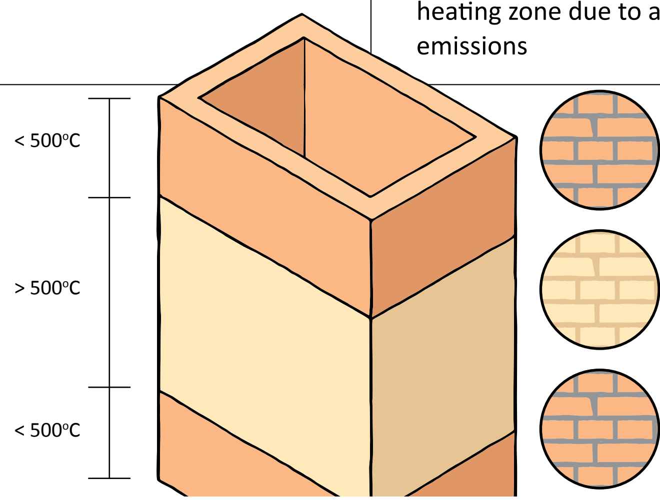
OPTION 2 : English bond refractory masonry; substituted with fired bricks in sections with temperatures below 500°C (pre-heating and cooling zone)

Advantages

- Most economical option under the condition that the firing zone is always maintained at the centre of the shaft

Disadvantages & Limits

- Chances of shaft damages if the fire position is not properly maintained at the centre of the shaft
- Fire position adjustment is limited to refractory masonry area
- Potential damages to fired brick masonry in the pre-heating zone due to acidic emissions



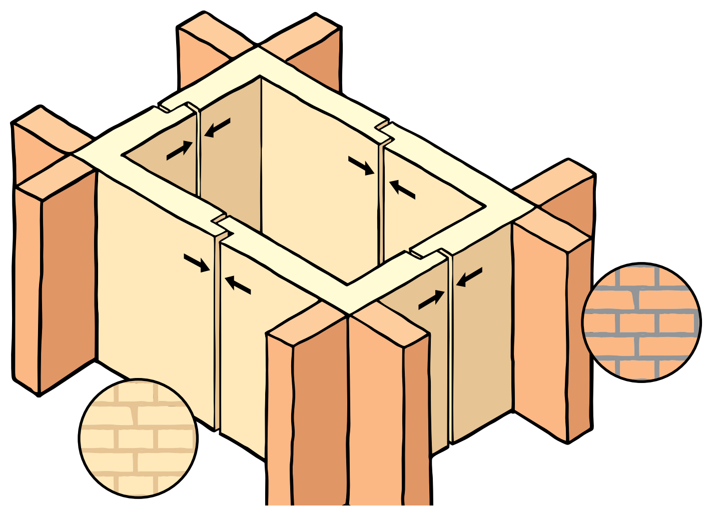
FUTURE OPTION 1 : English bond refractory brick masonry with expansion joints

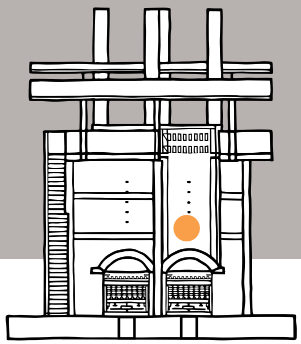
Advantages

- Uniform expansion and contraction properties
- Uniform thermal mass properties
- Controlled expansion will avoid uncontrolled masonry cracks, hence lower maintenance

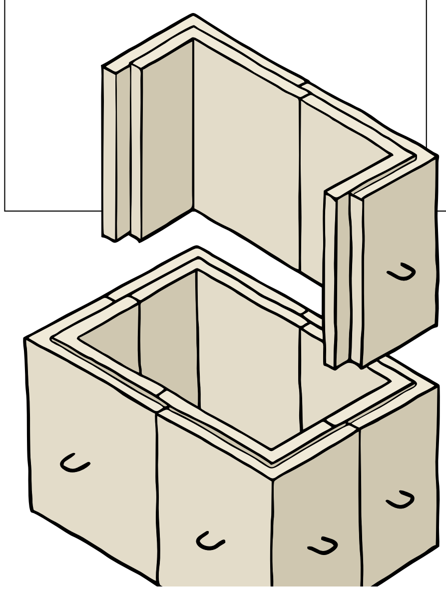
Disadvantages & Limits

- Special masonry skills are required and the construction system is time consuming, therefore costly
- Requires special brick blocks or cuttings
- Special corner support essential to ensure expansion at defined joints



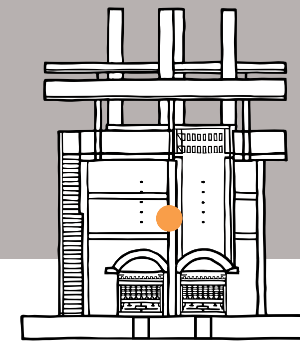


FUTURE OPTION 2 : Prefabricated fire resistance refractory concrete elements Note : This possible future option requires professional overall kiln construction planning and practical detail designs.	
Advantages • Reduced shaft construction time • The shape of the element can be both vertical or horizontal	**Disadvantages & Limits** • Requires a mechanical lifting device to place it • Skill to maintain the total verticality of the shaft is required • Fire resistant refractory concrete is considered expensive • Will develop uncontrolled cracks if no expansion joints are provided



DESIGN FUNCTIONALLY BUILD ECONOMICALLY!

09 CAVITY BETWEEN SHAFT AND SHAFT SUPPORT STRUCTURE



Function

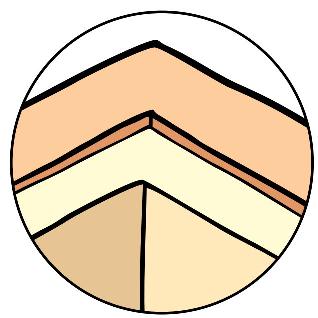
The cavity is required to ensure structurally independent expansion and contraction of the shaft structure.

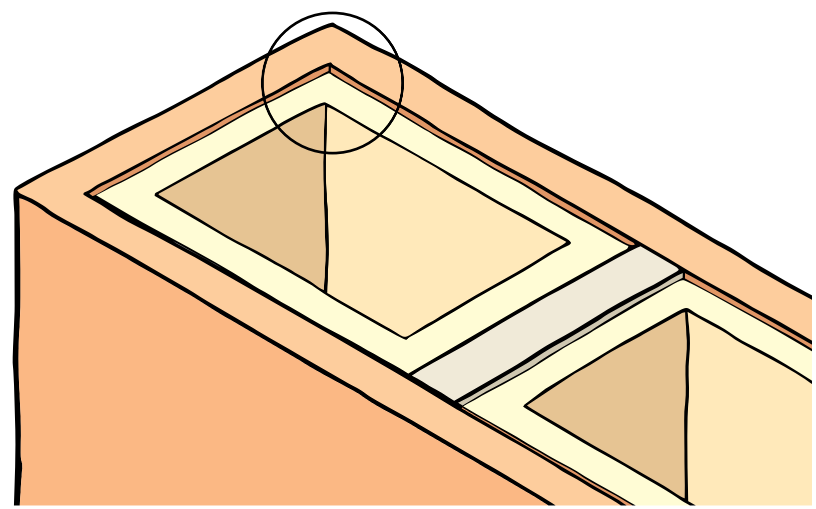
Design principles

The main principle for designing this cavitiy is to ensure the structural integrity of the shaft.

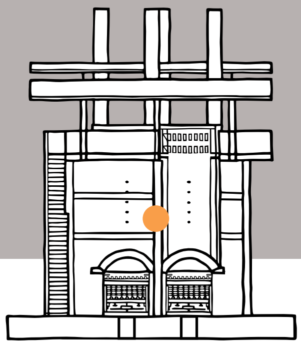
The top and bottom of this cavity should be closed with a flexible material after the kiln is fully dried out in order to avoid heat loss.

OPTION 1 : Unfilled cavity (2-3 cm approx.)	
Advantages	**Disadvantages & Limits**
• Basically no expenses (However to ensure an equal cavity size it is of advantage to place a low cost thermocol board. This thermocol board will melt as soon as the kiln is in operation and a uniform cavity will remain)	• Some heat loss due to air movement, hence reduced insulation value • Risk of mortar and other material filling up the cavity if not carefully protected during construction • Increased heat exposure at the shaft top area

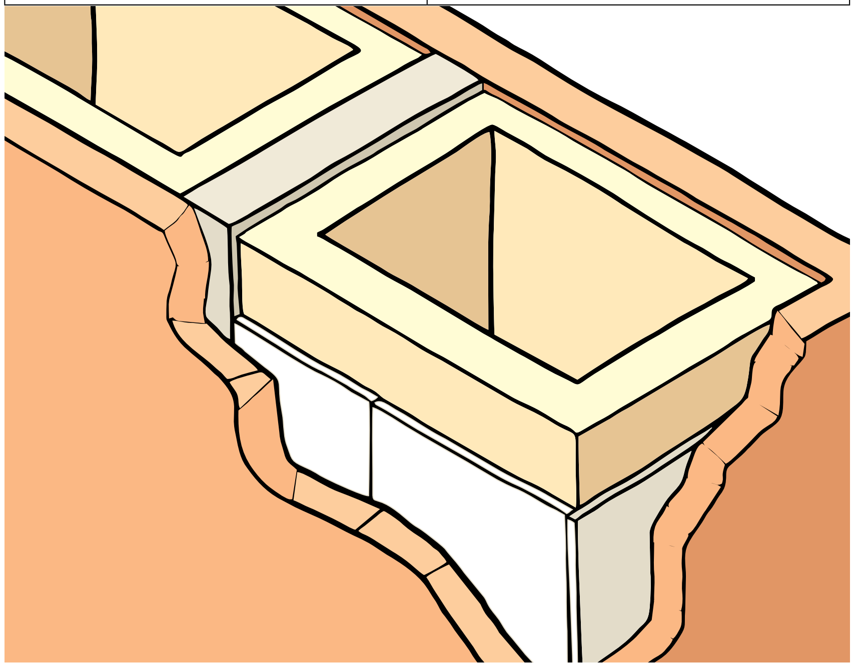




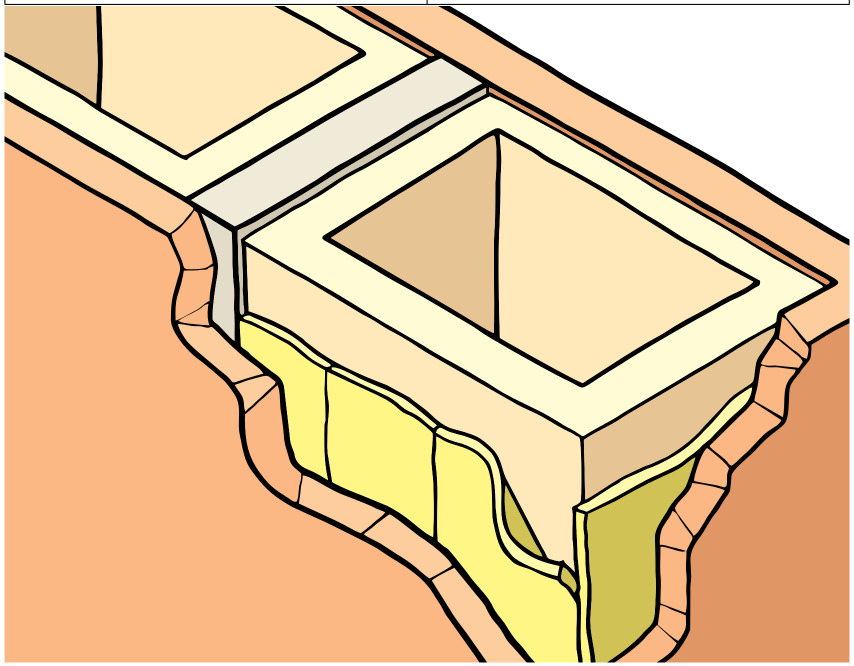
09 CAVITY BETWEEN SHAFT AND SHAFT SUPPORT STRUCTURE

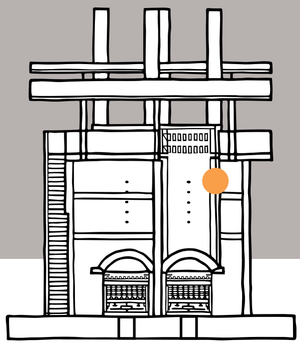


OPTION 2 : Filled cavitiy (Calcium silicate board)	
Advantages	**Disadvantages & Limits**
• Easy to install since they are available as self supporting boards	• Damage potential if exposed to contact with water • Could be a costly option depending on selected material quality



FUTURE OPTION 1 : Filled cavity (Stone wool or glass wool insulation blanket/board)	
Advantages	**Disadvantages & Limits**
• Cost benefit factor is good	• Risk of sagging when fixing insulation blankets to a vertical surface





10 SHAFT SUPPORT WALL

Function

The shaft-support wall ensures the independent working (expansion/contraction) of the shaft, reduces lateral pressure and acts as an insulation layer. The chimneys are usually constructed on top of the shaft supporting wall.

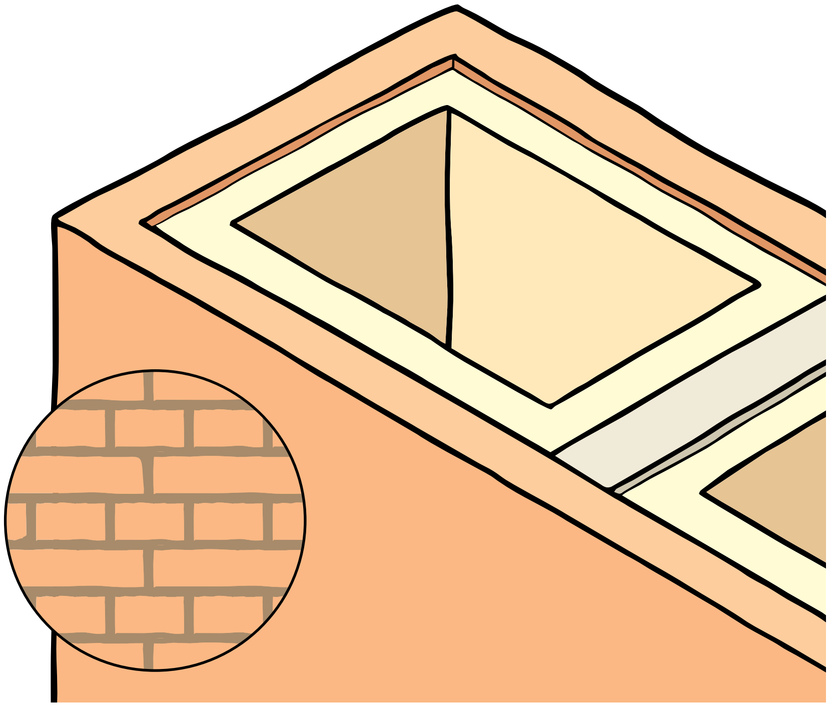
Design principles

There are many shaft support wall construction systems possible, all depending on economical insulating building materials.

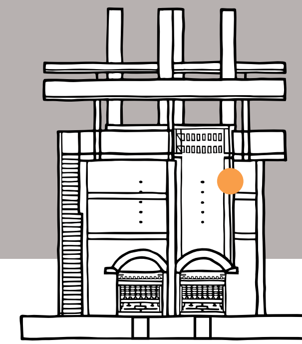
Note : Using a 'K-value' calculator for selecting the size of the most economical insulation material/ structure is recommended.

Note : If a shaft is constructed with expansion joints, the shaft corners must be supported to ensure correct expansion direction. (see 8, future option 1)

OPTION 1 : English bond brick masonry in mud mortar	
Advantages	**Disadvantages & Limits**
• Low construction cost • Provides reasonable stability for chimney system	• Chances of wall sagging due to mud mortar shrinkage



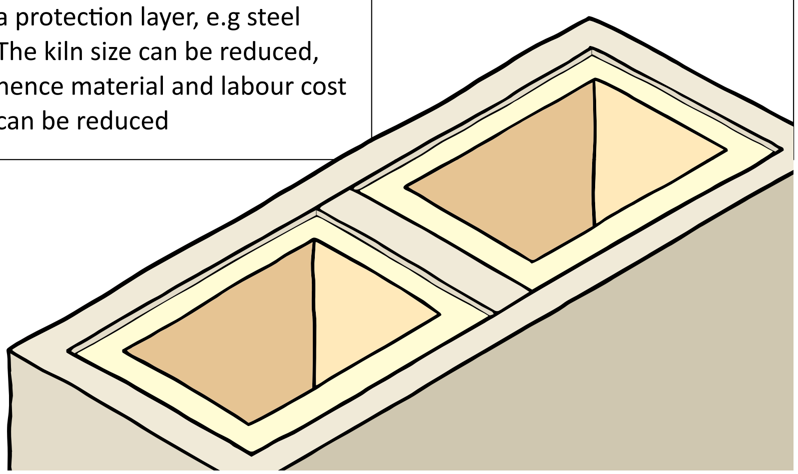
10 SHAFT SUPPORT WALL



FUTURE OPTION 1 : Vermiculite concrete

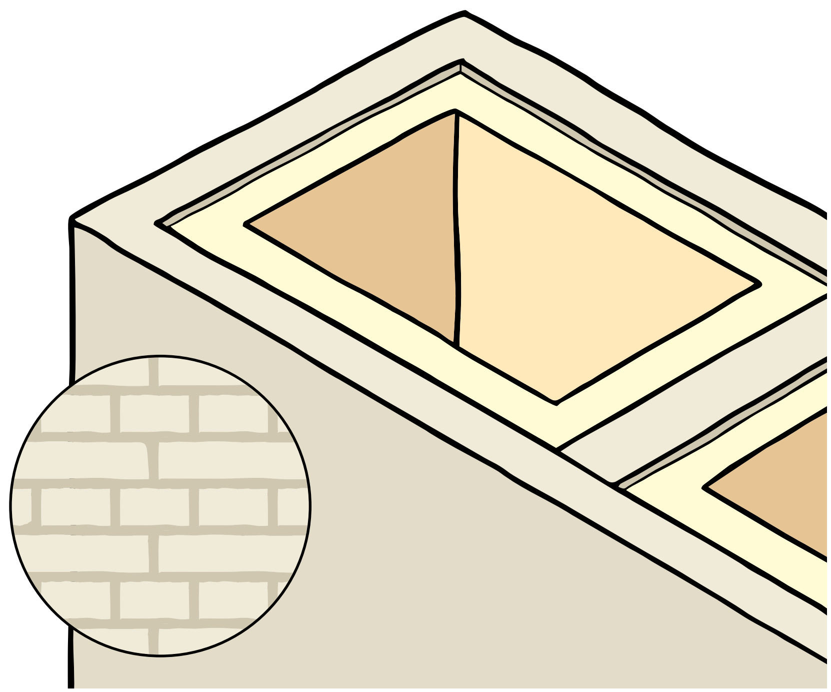
Note : Vermiculite can also be used as insulation material between both structures; the shaft and the supporting wall.
Note : It is necessary to consult professionals who are experienced in practical application of vermiculite concrete technology for a kiln construction.

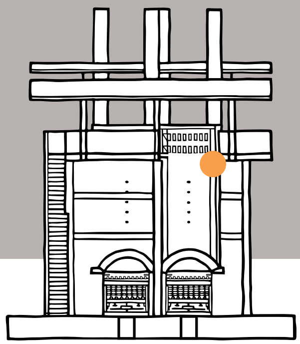
Advantages	Disadvantages & Limits
• Low thermal conductivity material, hence good insulation • Can be precast or constructed in-situ • Does not require any further insulation or structure, except a protection layer, e.g steel • The kiln size can be reduced, hence material and labour cost can be reduced	• Is an expensive insulation material • Vermiculite concrete has reduced load bearing capacity



FUTURE OPTION 2 : Insulation bricks walls

Advantages	Disadvantages & Limits
• Potential of slim kiln structure and cost reduction.	• Insulation bricks are expensive • Insulation bricks have reduced load bearing capacity





11 KILN INSULATION BOXES

Function

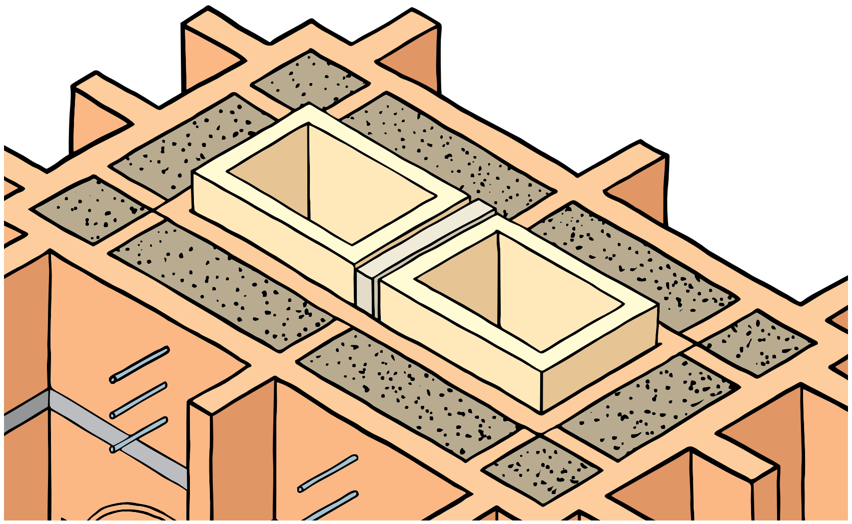
Kiln insulation boxes are constructed to distribute the load of insulation material used to minimize energy losses. They also provide rigidity to the kiln structure and define the size of the working platform.

Design principles

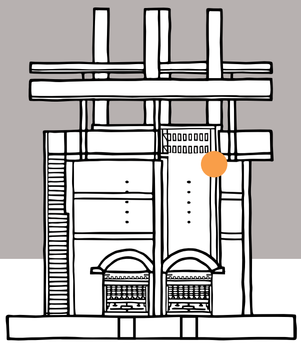
The box dimensions must be related to the insulation material value to be used and the required working space and type of platform. The top of the insulation boxes (platform) should ideally be covered to avoid heat loss.

Note : Filling material should be as dry as possible.

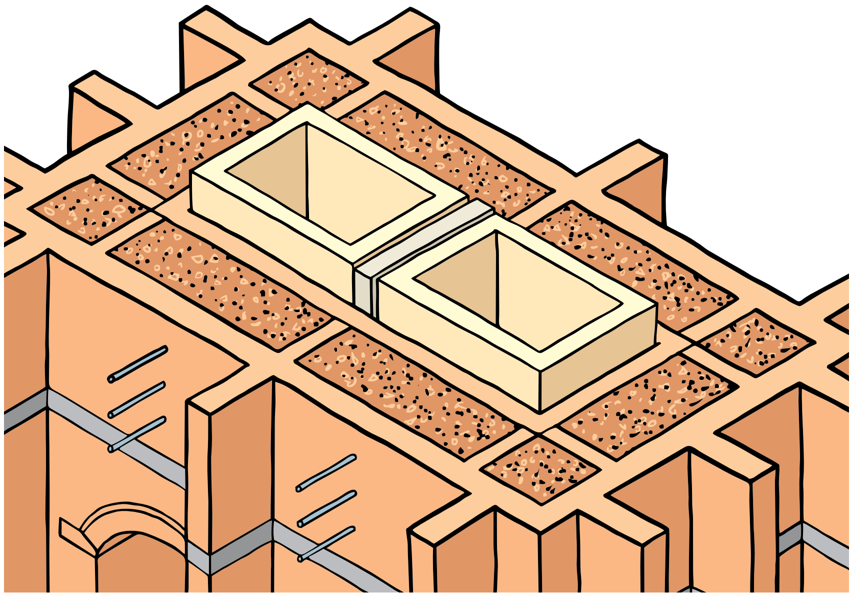
OPTION 1 : Filled with ungraded soil	
Advantages	**Disadvantages & Limits**
• Cheapest and easily available filling material	• Low insulation value, the heat loss is relatively high • Difficult to avoid water penetration during construction • Chances of shaft bulging increases with the frequency of shutdowns due to repeated compacting of fine particles



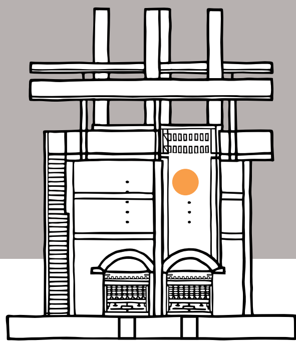
11 KILN INSULATION BOXES



OPTION 2 : Filled with graded brick gravel	
Advantages • In relation to the insulation value it is a good and economical filling material • Enhanced insulation properties due to creation of micro-pores • Decreased risk of shaft bulging	**Disadvantages & Limits** • Difficult to maintain proper material grading during filling process • Difficult to avoid water penetration during construction



DESIGN FUNCTIONALLY BUILD ECONOMICALLY!



12 PEEP-HOLE PIPES

Function

Peep-hole pipes are narrow openings in the kiln structure which allow a visual and/or mechanical fire temperature monitoring.

Design principles

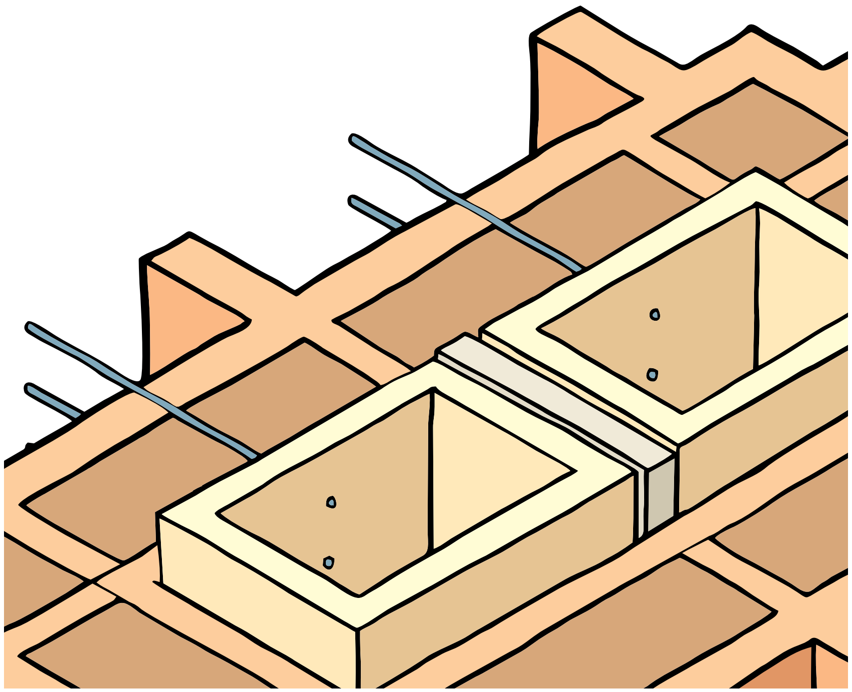
Peep-holes must be designed to allow visual monitoring of the fire position and/or insert fire monitoring equipment (thermocouples) from the outside of the kiln structure.

Further, they should be positioned in a way that they do not bend under the weight of the insulation filling.

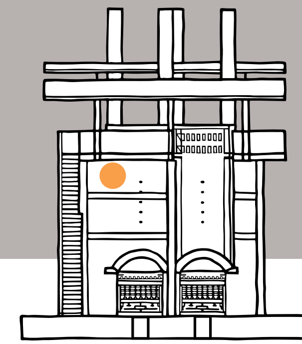
The exactness of the fire schedule plotting increases with the number of built-in peep-hole pipes.

The respective batch height and the soil shrinkage defines the position and distance of the peep-hole pipes.

OPTION 1 : M.S. pipes	
Advantages	**Disadvantages & Limits**
• A straight-forward, practical and economical system for fire position/temperature monitoring	• Potential of excess air entering the shaft if the pipes are not properly sealed during operation



13 OUTER KILN WALL STRUCTURE



Function

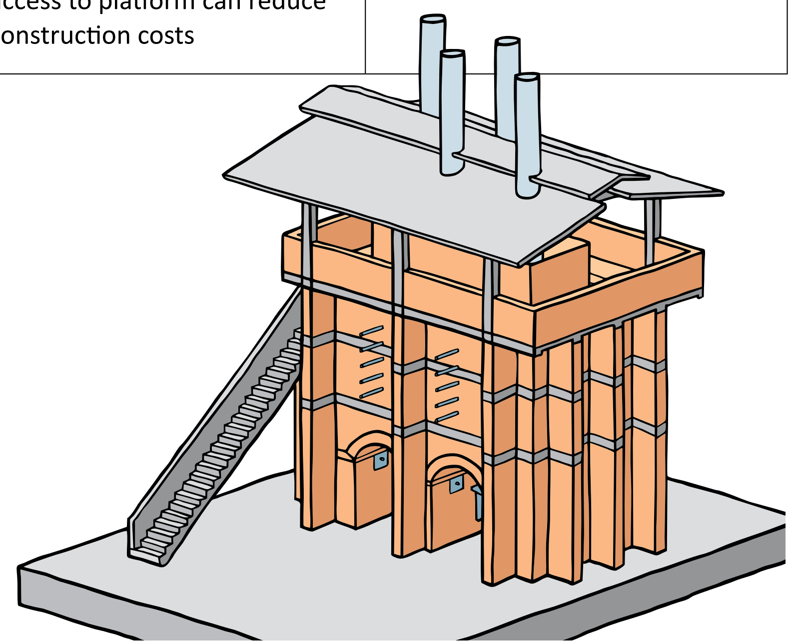
The outer kiln wall structure encases the insulation filling around the shaft supporting walls and ensures structural rigidity and protection against the elements.

Design principles

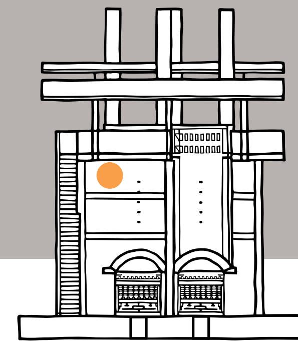
The outer kiln wall structure must be designed so that it can protect the insulation and the shaft structure against mechanical impact.

Note : Sufficient weep holes must be provided to avoid kiln structure damages due to water evaporation during the initial firing. These weep hole should be closed only after the kiln is completely dried out.

OPTION 1 : Load bearing brick masonry with buttresses	
Advantages • Can support above built structures (loading platform, roof, mechanical transporting devices etc.) and green brick storage • Buttresses supporting the access to platform can reduce construction costs	**Disadvantages & Limits** • Buttresses increase the required construction area



13 OUTER KILN WALL STRUCTURE



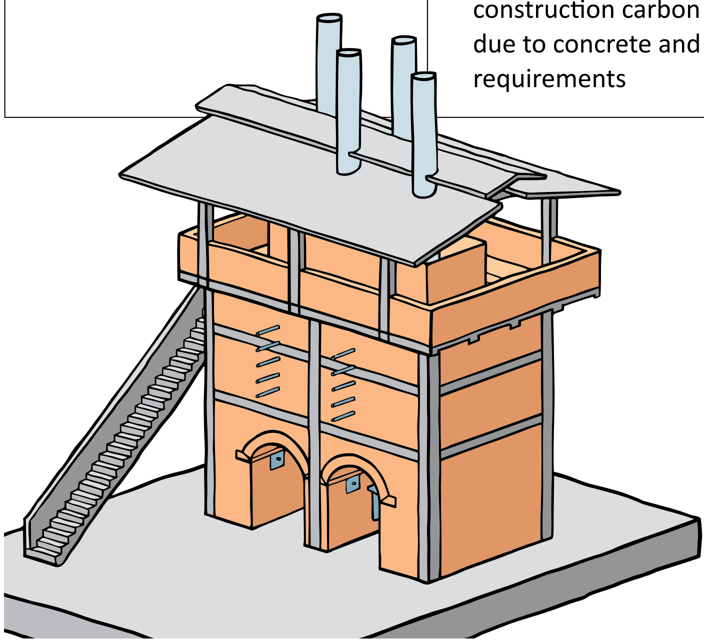
OPTION 2 : Concrete frame structure with in-filled brick masonry

Advantages

- Slim kiln structure possible since no buttresses are required
- Overall construction time reduction possible

Disadvantages & Limits

- Scaffolding and formwork increase the construction costs
- Additional cost for reinforcement steel and concrete
- Relatively unfavourable construction carbon foot print due to concrete and steel requirements



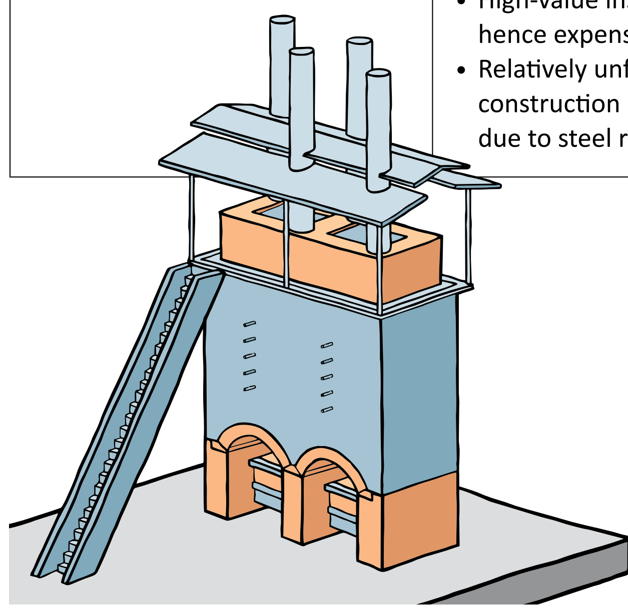
OPTION 3 : Metal

Advantages

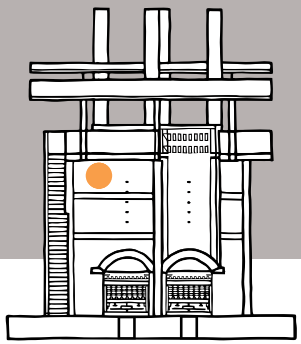
- Can be prefabricated, hence reduces construction time
- Slimmest structure possible
- Mass pre-fabrication potential

Disadvantages & Limits

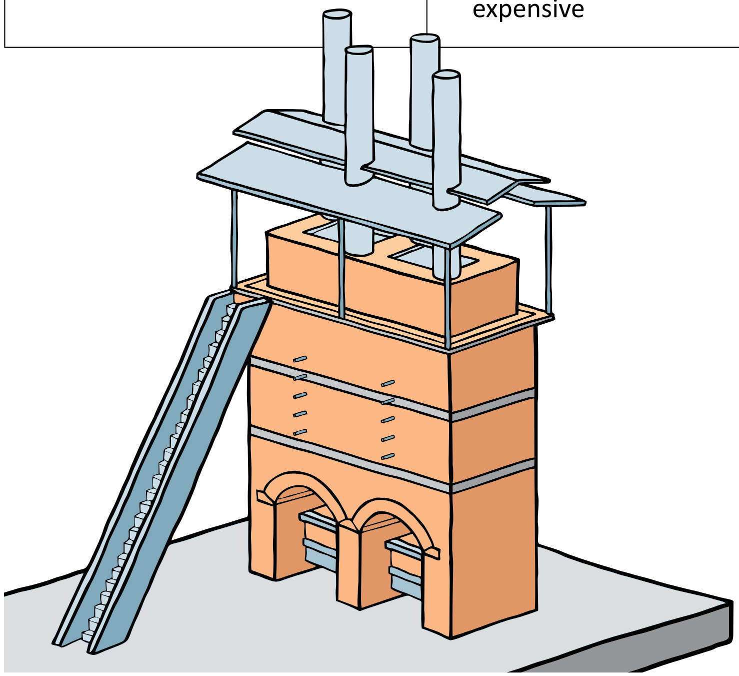
- Metal corrosion is likely the main problem, hence high expenses for maintenance work
- Separate platform for brick storage required
- Requires a mechanical lifting device to construct it
- High-value insulation required, hence expensive
- Relatively unfavourable construction carbon foot print due to steel requirements



13 OUTER KILN WALL STRUCTURE



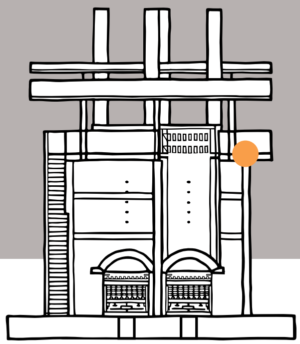
FUTURE OPTION 1 : Load bearing brick masonry without buttresses	
Advantages • Potential of slim kiln structure. • No bulky insulation boxes required	**Disadvantages & Limits** • Separate platform structure required for movement and storage • High-value insulation material required, hence is considered expensive



DESIGN FUNCTIONALLY BUILD ECONOMICALLY!

14

WORKING PLATFORM



Function

The working platform is constructed for free movement of personnel and for storage space.

Design principles

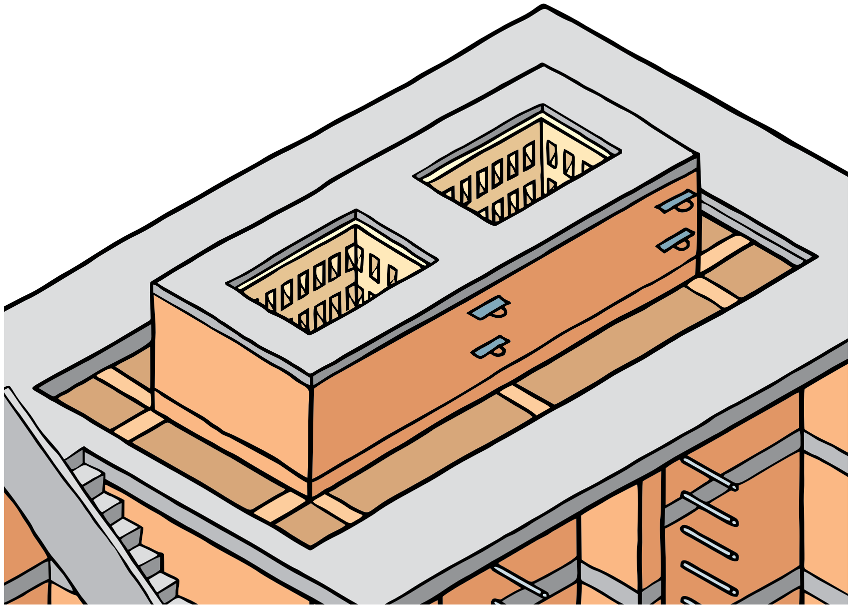
The working platform design is based on both load bearing (buttress) structure or frame structure options.

However, the working platform must be open, ventilated and provide enough space so that working personnel can move along and load green bricks into the shaft without hindrance by any structure or equipment.

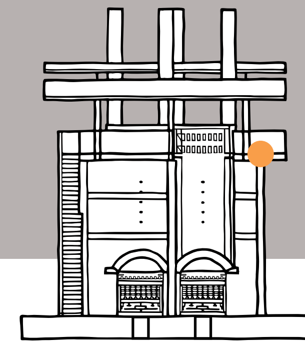
Note : In case of a slim VSBK structure, e.g. metal, a separate platform structure is required.

OPTION 1 : Partial R.C.C. working platform on buttress

Advantages	Disadvantages & Limits
• Requires less reinforcement steel due to support by masonry buttresses • Box insulation filling material can be topped up	• Increased dust exposure potential • Time consuming because of shuttering work, concrete curing time and de-shuttering work

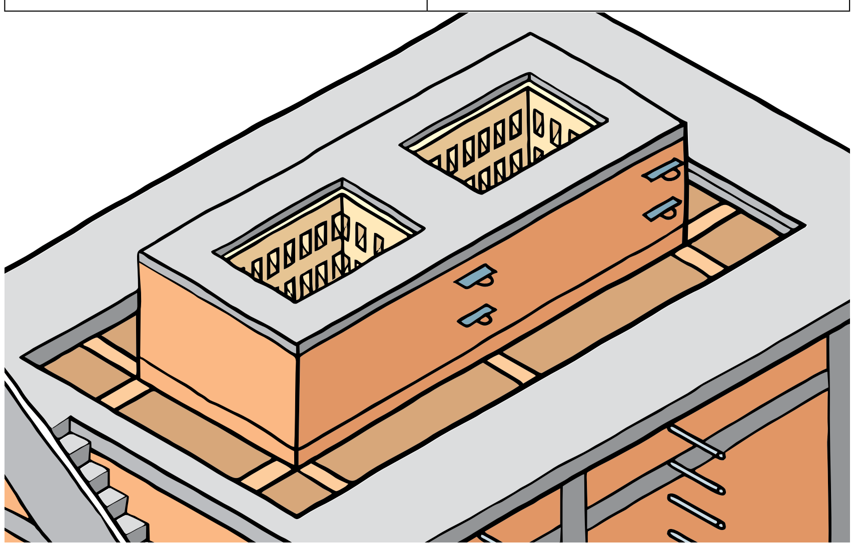


14 WORKING PLATFORM



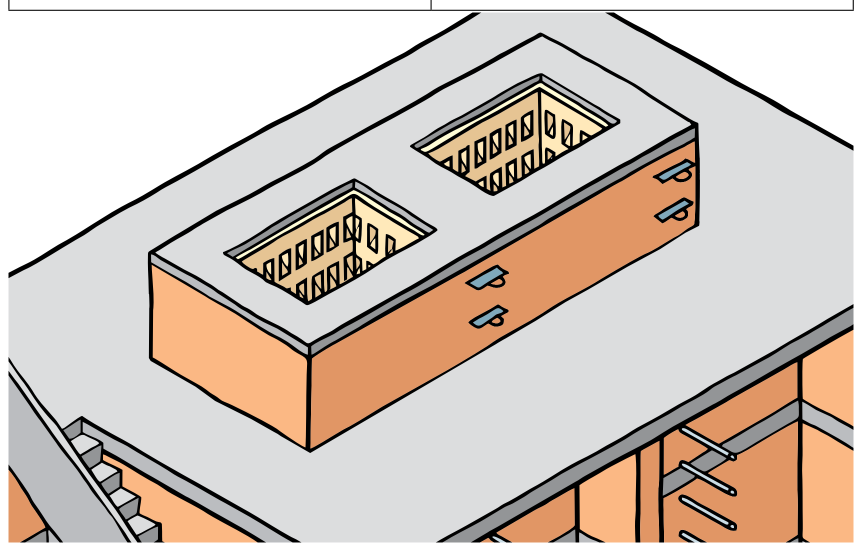
OPTION 2 : Partial R.C.C. working platform on cantilever

Advantages	Disadvantages & Limits
• Box insulation filling material can be topped up	• Increased reinforcement steel and concrete requirement, hence an expensive option • Time consuming because of shuttering requirement, concrete curing time and de-shuttering work • Increased dust exposure potential

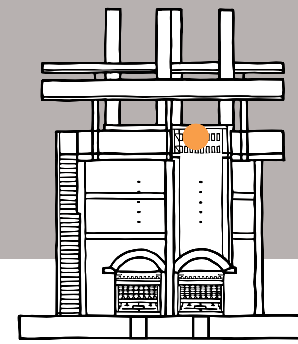


OPTION 3 : Full R.C.C. working platform

Advantages	Disadvantages & Limits
• Adds considerable rigidity to the kiln structure • Mechanical green brick transportation possible • Low dust working environment achievable • Decreased heat loss at platform level	• High construction cost • Due to the settling of the box insulation filling material a gap is created in between the insulation fill and the platform • Adds weight to the foundation



15 FLUE-DUCTS



Function

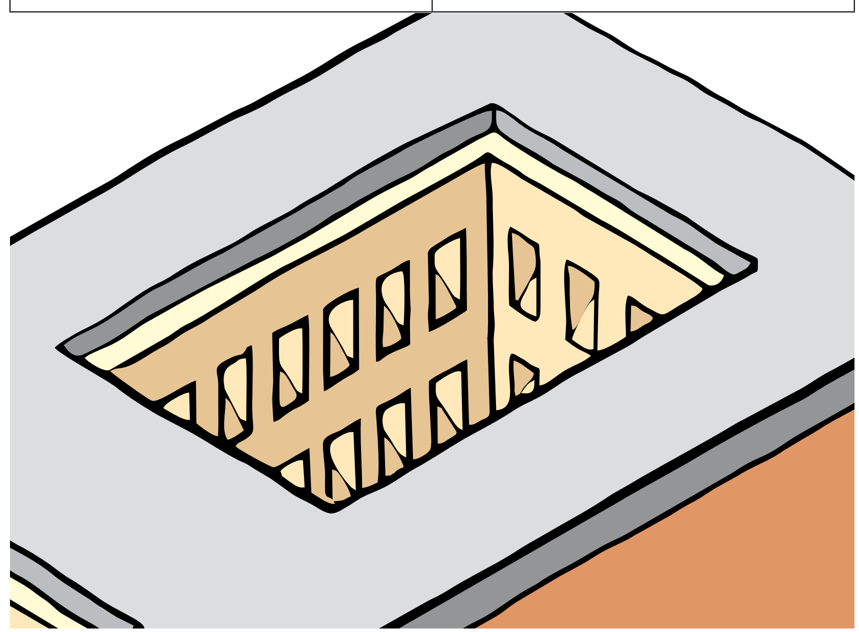
The flue-ducts are the lower section of the shaft emission exhaust system which systematically channels the flue gases into the chimneys.

Design principles

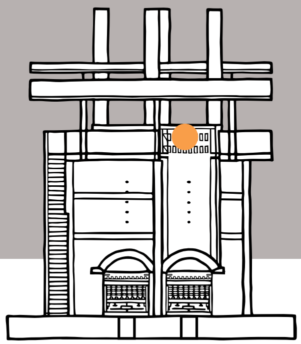
The flue ducts must be designed to function in a way that all flue gasses are passing through the exhaust gas system (natural and forced draught system) without posing health hazards to working personnel. Further it must be ensured that the least amount of excess air can enter the system at the top of the upper flue ducts during unloading.

The flue duct system should be constructed with acid-resistant materials since acidic gases are released during the firing process.

OPTION 1 : Lower and upper flue-duct system constructed with refractory/fired bricks	
Advantages	**Disadvantages & Limits**
• Simple cleaning system possible • Best suited for natural draught system • Cost savings potential if constructed with fired bricks	• The flue duct system is the weakest part of the shaft, hence periodical maintenance is required • Time consuming brick cutting work during construction

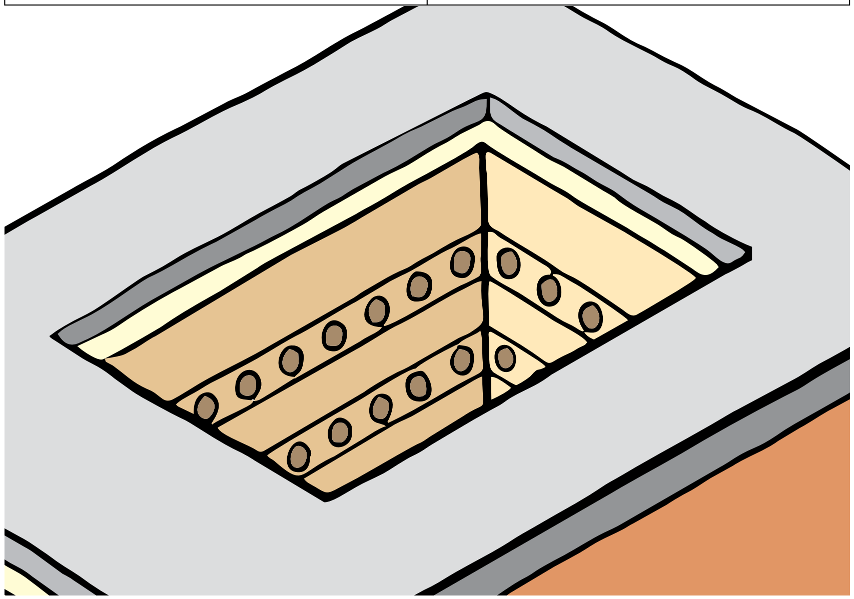


15 FLUE-DUCTS

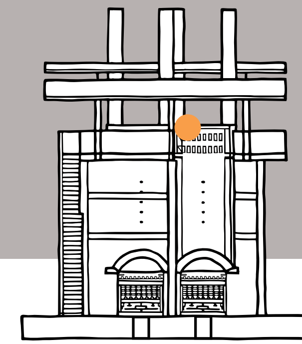


FUTURE OPTION 1 : Lower and upper flue-duct system constructed with refractory castables

Advantages	Disadvantages & Limits
• Reduced construction time • Best suited for forced draught system • Calibration of individual flue openings possible • Economic viability increases with numbers	• Limited to countries with fire resistant concrete casting experience



16 SHAFT TOP STRUCTURE



Function

The shaft top protects the flue duct system from mechanical and live load impacts. Further it provides a base for the lid cover and usually also for natural draught chimneys.

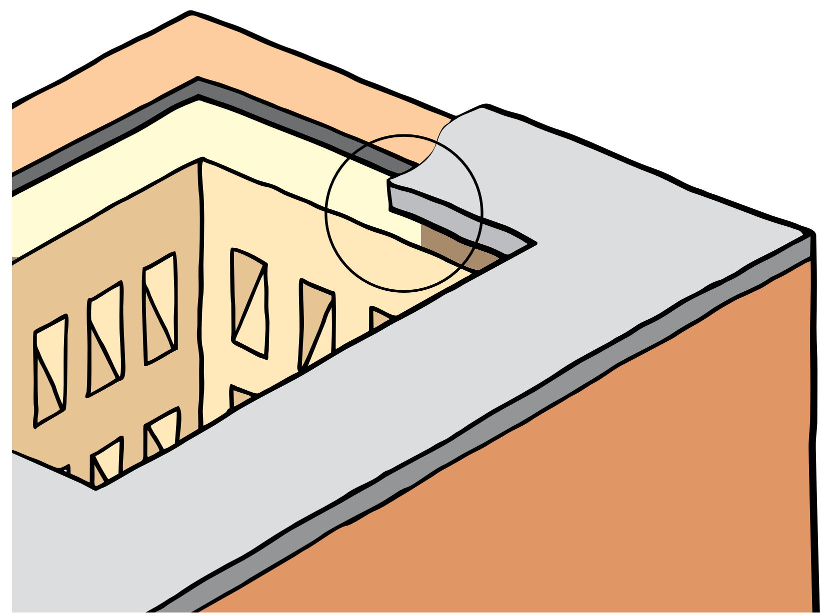
Design principles

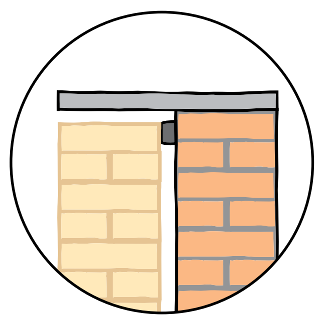
The shaft top structure should not disturb a vertical expansion of the refractory shaft.

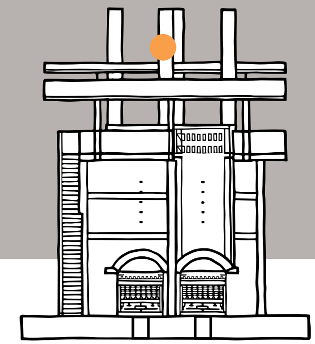
It should be designed in such a way that additional features like flue duct guides, lid-cover base and chimneys can be securely fixed.

The expansion gap must be sealed with flexible material to avoid heat loss after the kiln is fully dried out.

OPTION 1 : R.C.C. shaft top anchored on the shaft supporting wall	
Advantages • Allows vertical expansion movement of the refractory shaft • Reduced shaft bulging probability	**Disadvantages & Limits** • None







17 EMISSION EXHAUST SYSTEM

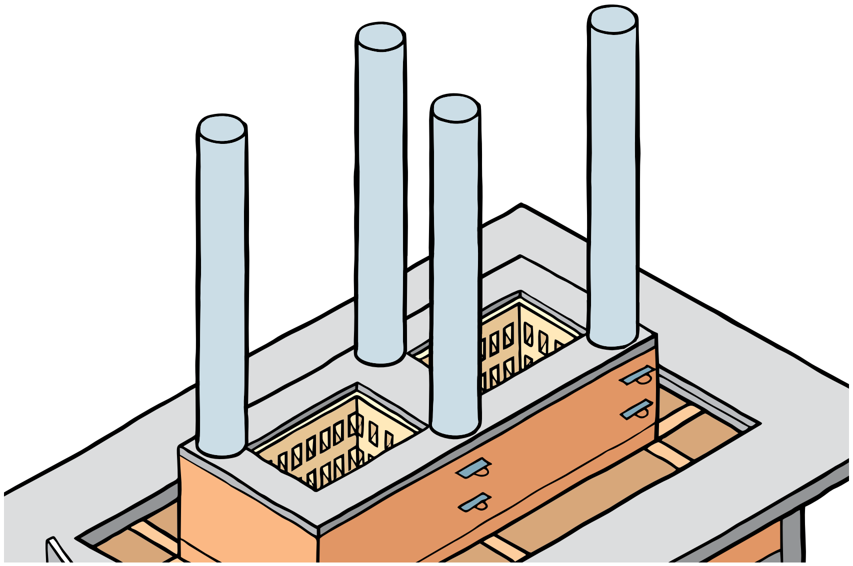
Function

The Emission exhaust system is to provide the draft for proper fire positioning as well as to discharge exhaust gases at a safe height.

Design principles

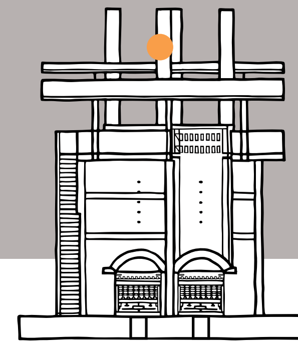
The emission exhaust system must be designed by respective experts.

OPTION 1 : Natural draught with flue ducts	
Advantages • No electricity required, hence an economical option • Can be constructed with material other than metal, i.e. fired bricks	**Disadvantages & Limits** • Draught can vary with weather conditions • Difficult to erect and tie up the chimneys, especially in high wind prone areas • High wear and tear of metal parts due to corrosion from acidic emissions



DESIGN FUNCTIONALLY BUILD ECONOMICALLY!

17 EMISSION EXHAUST SYSTEM



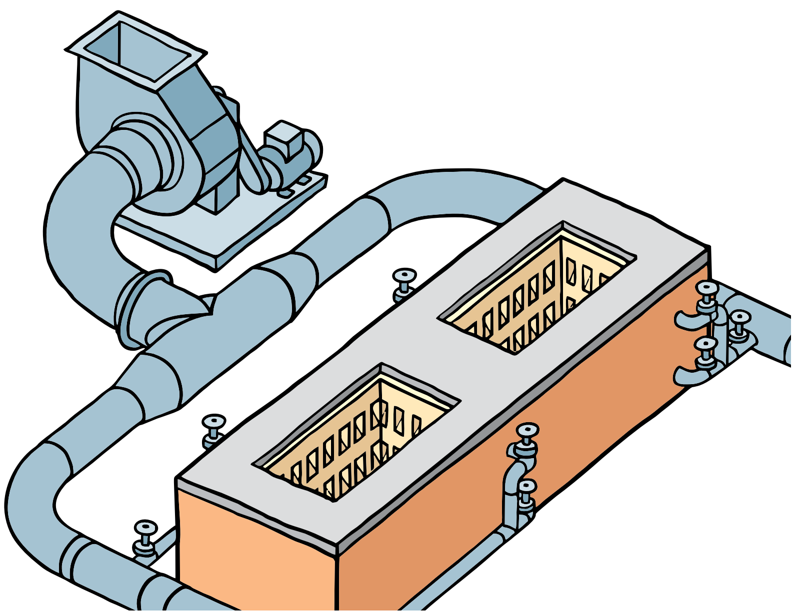
OPTION 2 : Forced draught with flue ducts

Advantages

- Uniform draught, hence better fire position control
- One chimney can be used for multiple shafts
- Brick quality is likely to be more uniform

Disadvantages & Limits

- Requires electricity, including a back-up system
- Exhaust gas temperatures must be maintained to avoid corrosion of metal parts
- Increased maintenance costs



FUTURE OPTION 1 : Natural draught without flue ducts

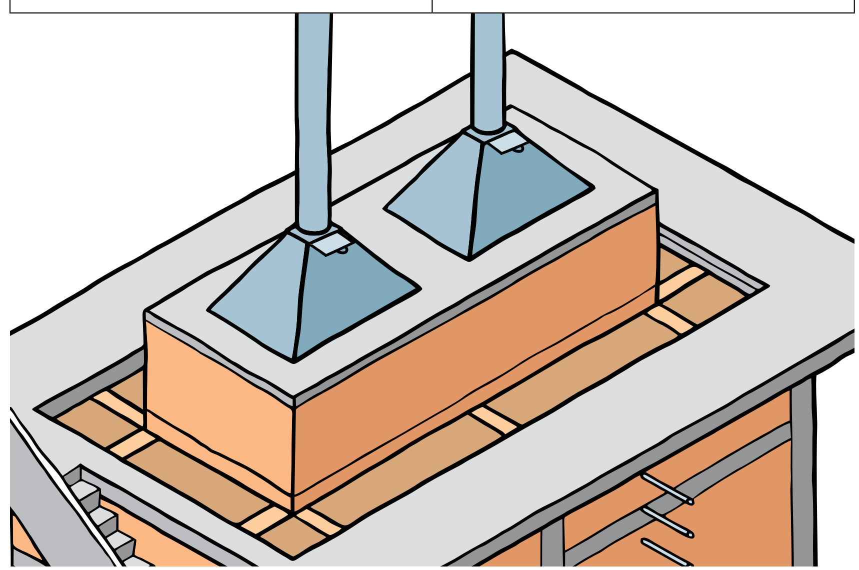
Note : This system is preferred for multiple shafts.

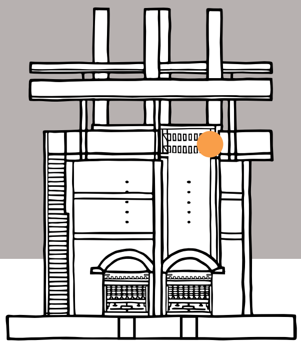
Advantages

- Elongated firing curve
- Uniform draught
- User friendly draught control
- One Shaft - one chimney
- During loading, emissions can be extracted separately
- Inbuilt shaft lid, hence reduced health hazard

Disadvantages & Limits

- Anti corrosive material required for the hood
- Potential of increased hood system maintenance





18 FLUE GAS DAMPERS/VALVES

Function

Flue gas dampers/valves regulate the air flow within the system, therefore steering the appropriate fire schedule and ensuring a clean working environment while loading the bricks.

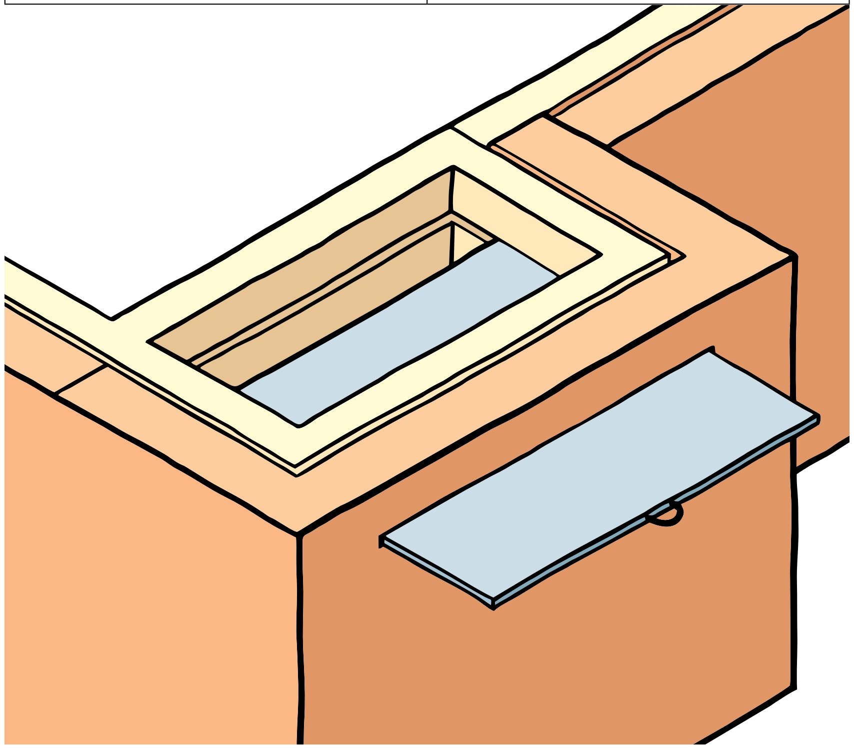
Design principles

The upper and lower flue duct system requires two independent valves/dampers each, hence 4 valves/dampers are required per shaft.

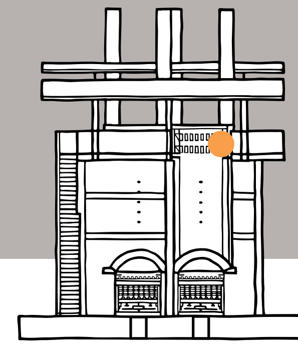
Valves and dampers should be designed so that least amount of flue-gasses can pass when they are completely shut.

Damper slots must be constructed so that no excess air can enter into the emission exhaust system.

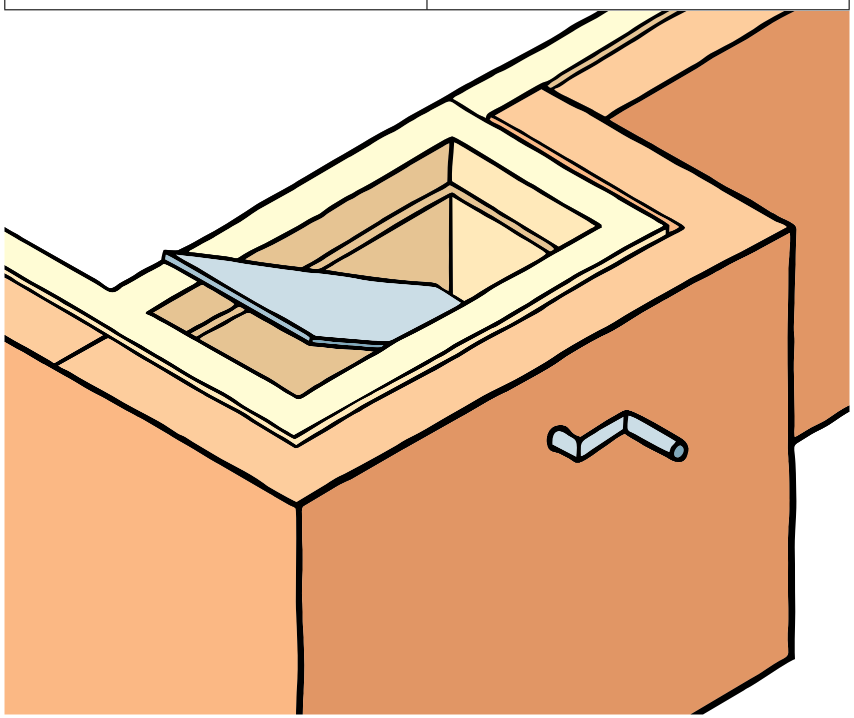
OPTION 1 : M.S. sheet flat dampers	
Advantages • Are an economical option • User friendly to operate and repair	**Disadvantages & Limits** • Probability of excess air entering • High corrosion potential



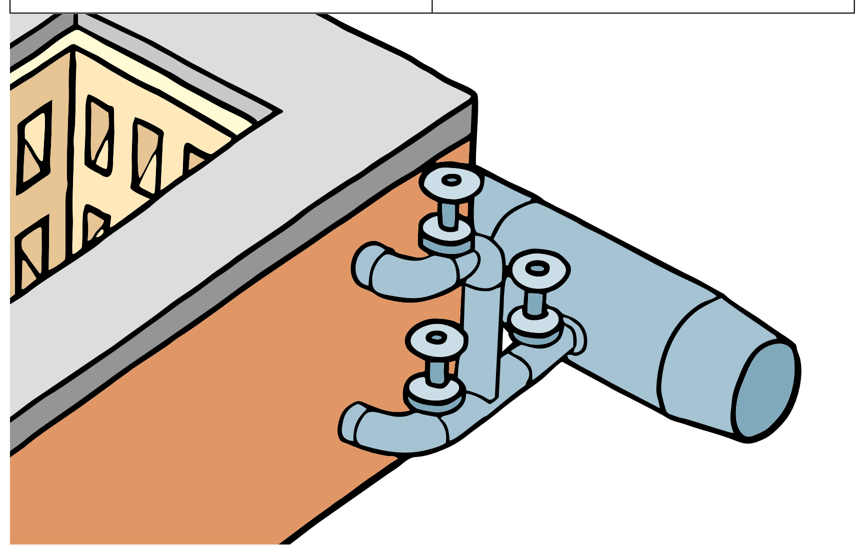
18 FLUE GAS DAMPERS/VALVES



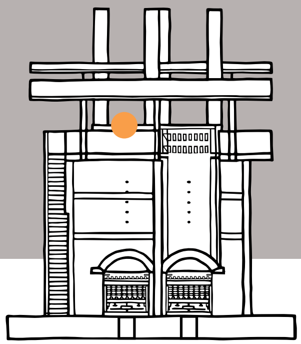
OPTION 2 : M.S. sheet butterfly dampers	
Advantages • Are an economical option • User friendly to operate • Reduced probability of excess air	**Disadvantages & Limits** • High corrosion potential • Replacement only possible during shaft closure, hence expensive



OPTION 3 : Valves for forced draught system	
Advantages • Easier to control the airflow • Air flow meter gauge can be installed	**Disadvantages & Limits** • Expensive air flow management system • High corrosion potential if green bricks with >1% moisture content are loaded • Potential excess air problems if gap between refractory shaft (flue duct channel opening) and valve mouth is not sealed



19 SHAFT LID



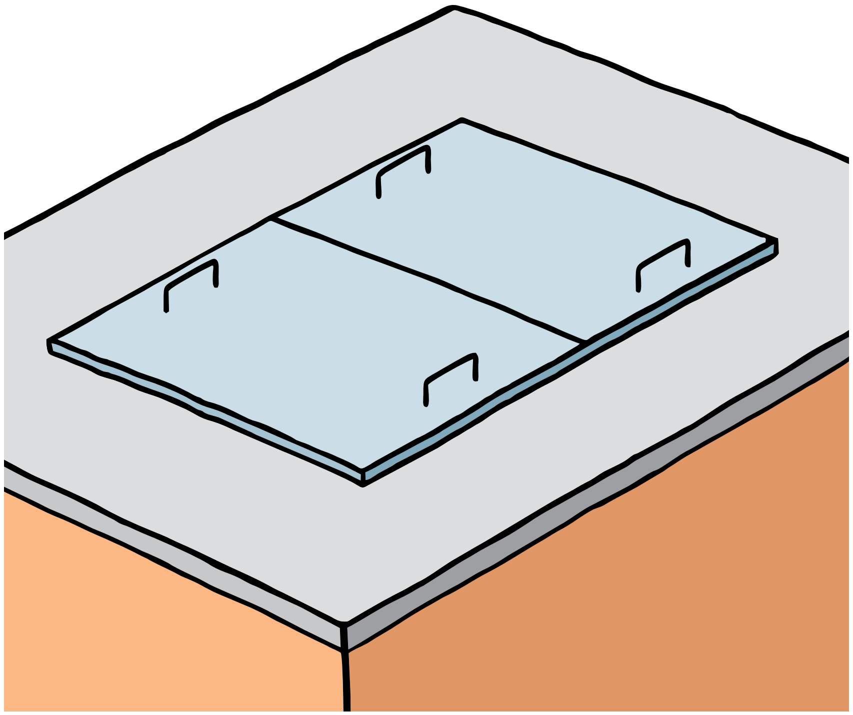
Function

The shaft lid supports the efficiency of the counter current air flow principle (energy efficiency) and ensures a clean working and general environment on a VSBK.

Design principles

Shaft lid should be designed user-friendly as well as light weight, fire and preferably corrosion resistant materials.

OPTION 1 : M.S. sheet lid/elements	
Advantages	**Disadvantages & Limits**
• Is an economical option	• High corrosion potential



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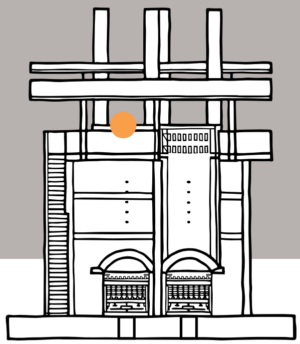
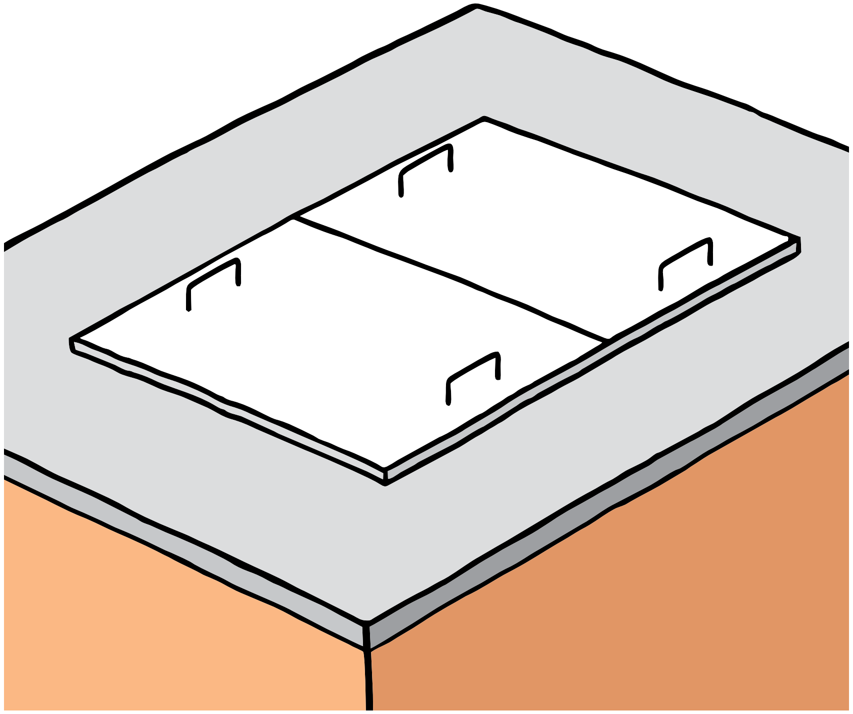
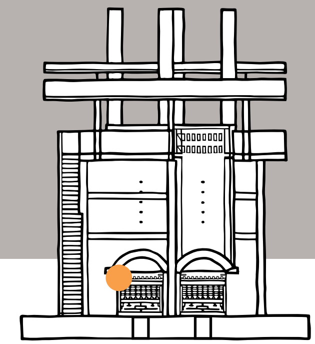


OPTION 2 : Stainless steel sheet	
Advantages	**Disadvantages & Limits**
• Lower corrosion potential	• Expensive option



20 UNLOADING BARS



Function

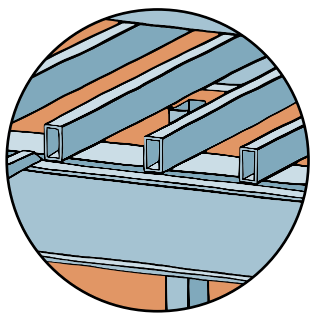
The unloading bars support the brick setting inside the shaft during regular operation and transfer the brick setting load to the brick support I-beams.

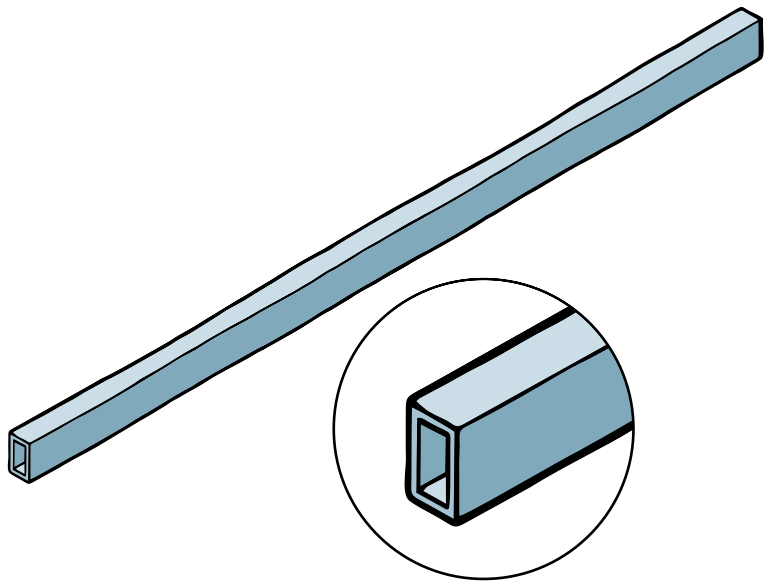
Design principles

An unloading bar should be designed light weight, small in cross section and must be able to resist high heat stresses under constant load of approx. 4 tons.

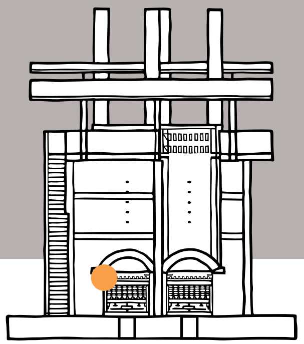
Note : Unloading bars are to be considered operation wear-and-tear material.

OPTION 1 : M.S. square bars	
Advantages	**Disadvantages & Limits**
• Lighter than M.S. I-bars	• High chance of brick breakages due to reduced flange width



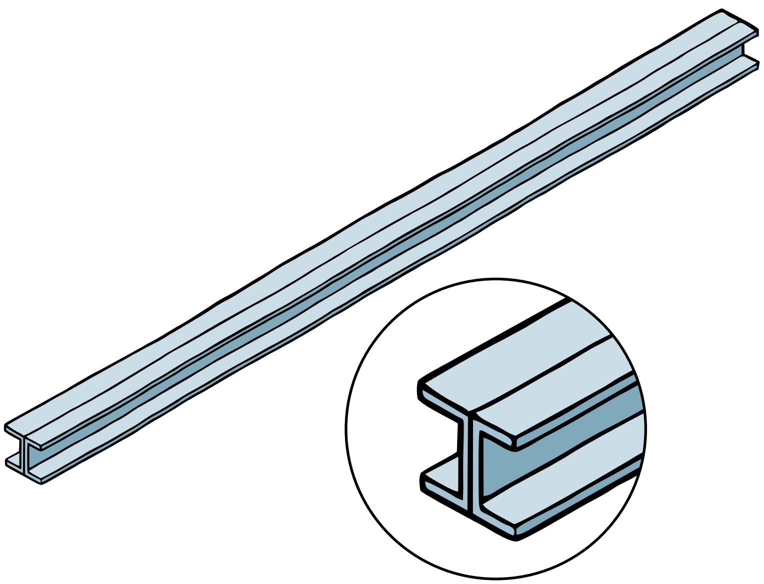


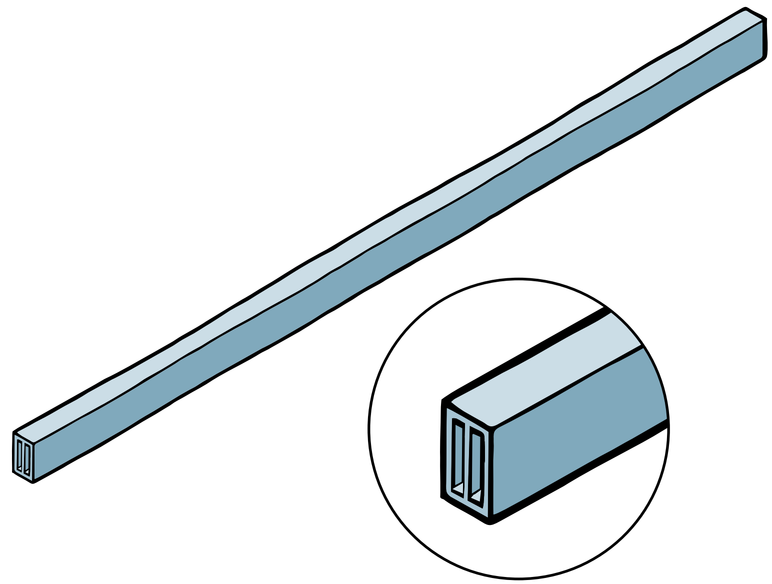
UNLOADING BARS

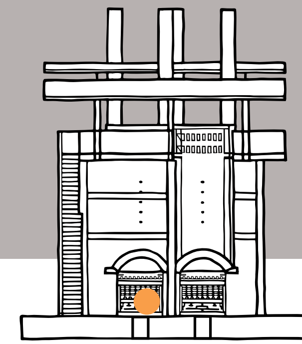


OPTION 2 : M.S. I-bars	
Advantages	**Disadvantages & Limits**
• Stronger than M.S. square bars • Less chance of brick breakages due to bigger flange width	• Heavier than M.S. square bars and therefore rarely used for larger shaft dimension

OPTION 3 : Reinforced M.S. square bars	
Advantages	**Disadvantages & Limits**
• Can be used for larger shaft dimension	• High chance of brick breakages due to reduced flange width







21 UNLOADING TROLLEY

Function

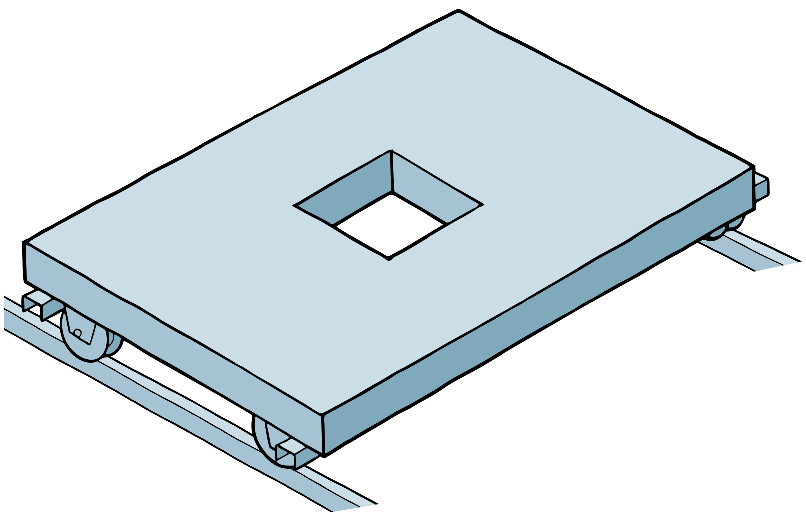
The unloading trolley is used to unload the fired bricks and to transport them to the unloading stations.

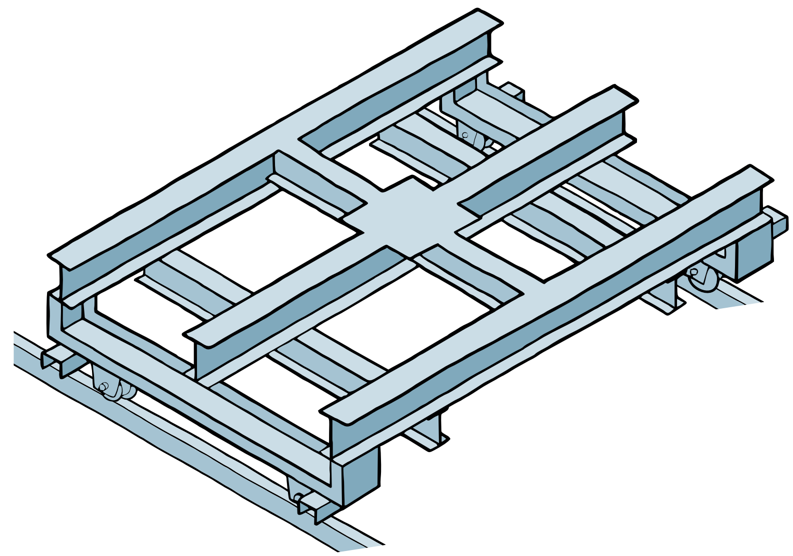
Design principles

The unloading trolley should be designed in such a way that it can bear the brick setting load without warping or bending.

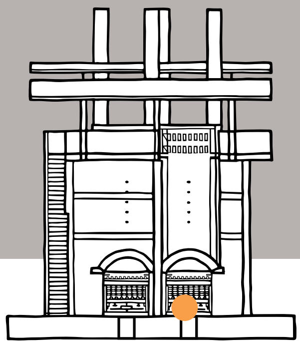
It must be as light as possible but strong enough to handle emergency situations .

OPTION 1 : M.S. trolleys	
Advantages • Locally available and economical fabrication • Light weight trolleys can be designed when using a hydraulic unloading mechanism	**Disadvantages & Limits** • Trolley weight increases with larger shaft size





22 BRICK UNLOADING SYSTEM



Function

The brick unloading system raises and lowers the trolley and the brick settings inside the shaft.

Design principles

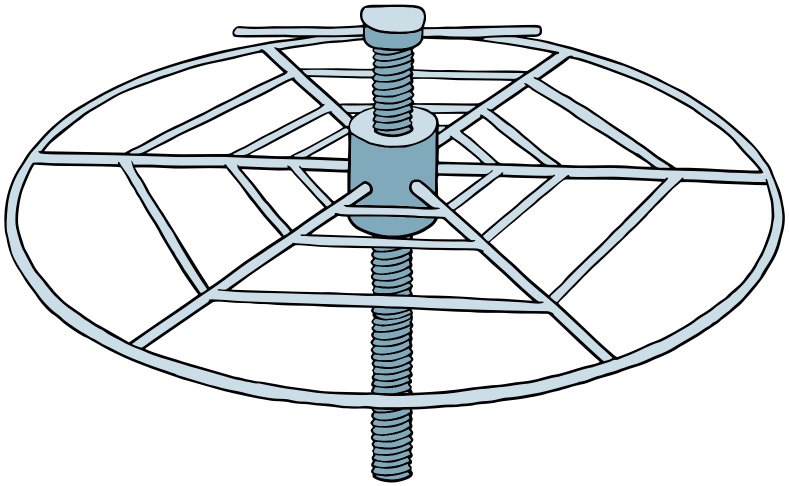
The unloading mechanism must be capable of bearing the entire brick setting load inside the shaft and to lift it to the point where the support bars can be retracted during the unloading of the bricks without the threat of sudden failure.

Both screw jack and hydraulic unloading system are in general designed to carry and lift up to 30 tons of weight (bricks and trolley).

OPTION 1 : Screw jack mechanism

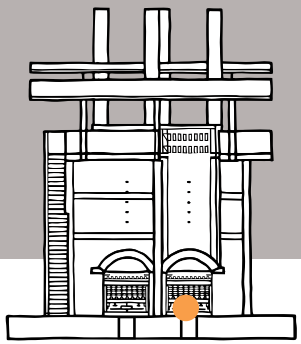
Note : Screw must be fabricated with high carbon steel.

Advantages	Disadvantages & Limits
• No electricity required • An electro motor can be (retro) fitted to mechanically operate the screw jack mechanism	• Complex and time consuming fabrication process • Maintenance of nut is high as it is made of cast-iron • Accident prone system and hard work for personnel

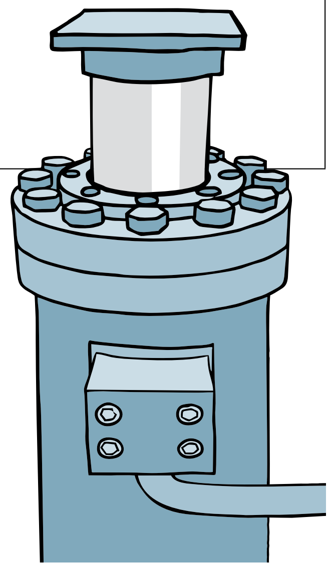


DESIGN FUNCTIONALLY BUILD ECONOMICALLY!

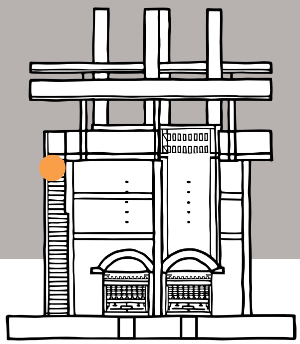
22 BRICK UNLOADING SYSTEM



OPTION 2 : Hydraulic mechanism	
Advantages • Easy to handle, working personnel are not exposed to hard work and falling coal • No girder system required, hence construction time and cost saving • Fewer workers required • Manual power pack can be applied in case of power failure • Trolley track can be narrowed and therefore trolley movement is easier	**Disadvantages & Limits** • Requires electricity, including a back-up system • Expensive lubricants required • Requires special dust protection



23 ACCESS TO THE WORKING PLATFORM



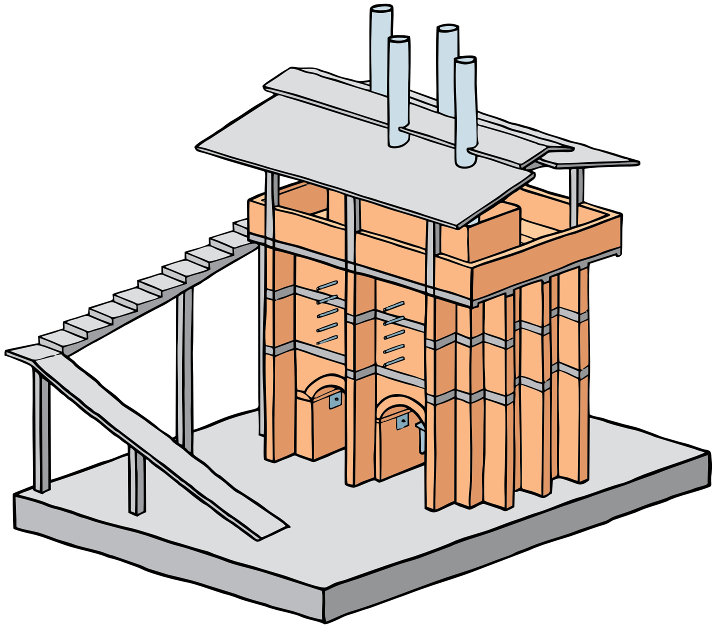
Function

Is the means to transport green bricks and coal up to the working platform level for an uninterrupted firing process.

Design principles

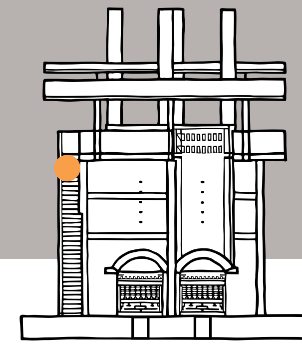
The main design parameter is to transport dry green bricks from the ground level to the working platform level in the most economical way, ensuring that the green brick quality is not compromised.

OPTION 1 : Ramp/staircase	
Advantages • Possibly the most economical construction option • Requires no electricity • Depending on gradient angle, mechanical equipment can be used to carry bricks	**Disadvantages & Limits** • Drudgery work for employed personnel • High green brick handling damage potential



DESIGN FUNCTIONALLY
BUILD ECONOMICALLY!

23 ACCESS TO THE WORKING PLATFORM



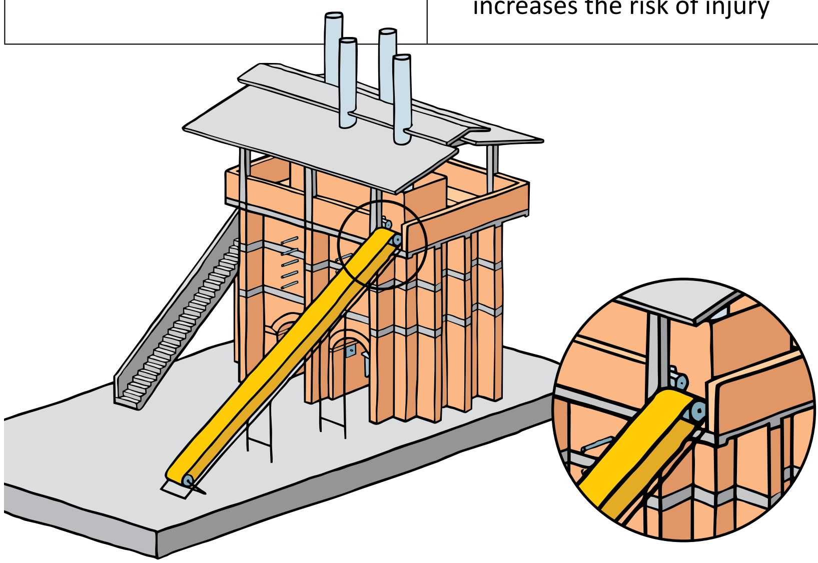
OPTION 2 : Conveyor belt

Advantages

- Reduces drudgery
- Less workforce required when compared to manual transportation system
- Very efficient and swift transportation system

Disadvantages & Limits

- High dry green brick handling damage potential
- High wear and tear, hence high maintenance and repair cost potential
- Requires power (electricity or fuel generator) to operate
- Potential of falling green bricks increases the risk of injury



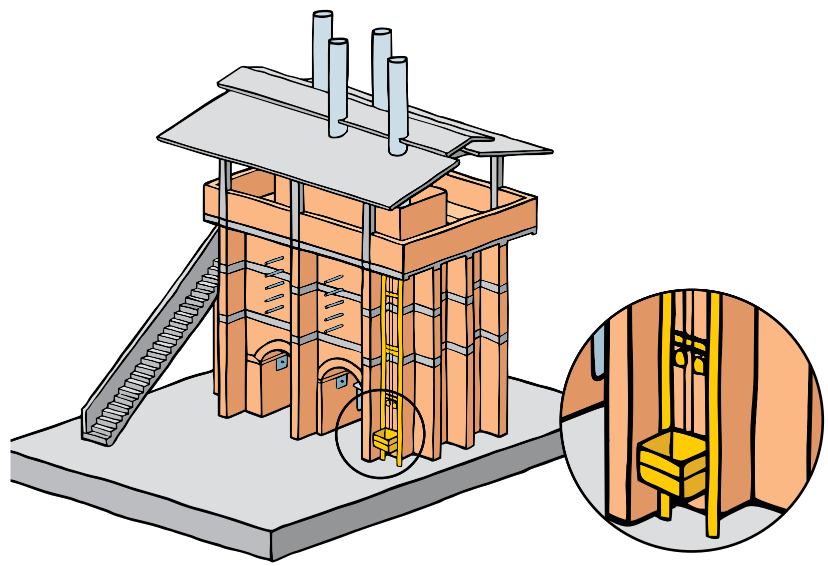
OPTION 3 : Lift

Advantages

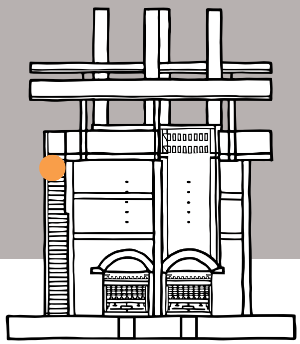
- Reduced drudgery
- Less workforce required when compared to manual transportation system
- Low green brick damage potential

Disadvantages & Limits

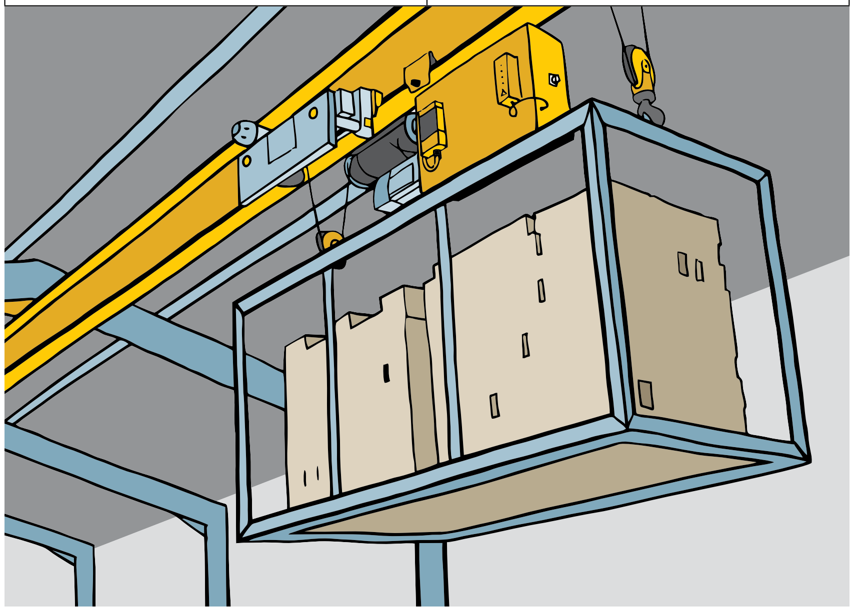
- Requires power (electricity or fuel generator) to operate



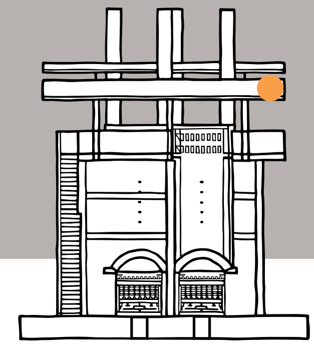
23 ACCESS TO THE WORKING PLATFORM



OPTION 4 : Gantry	
Advantages • Reduced drudgery • Less workforce required compared to any other system • Low green brick damage potential • Mechanized loading of green bricks into gantry cage possible	**Disadvantages & Limits** • High initial investment • Only economical for large numbers of shafts • Requires power (electricity or fuel generator) to operate • Requires considerable platform space



DESIGN FUNCTIONALLY BUILD ECONOMICALLY!



24 ROOF

Function

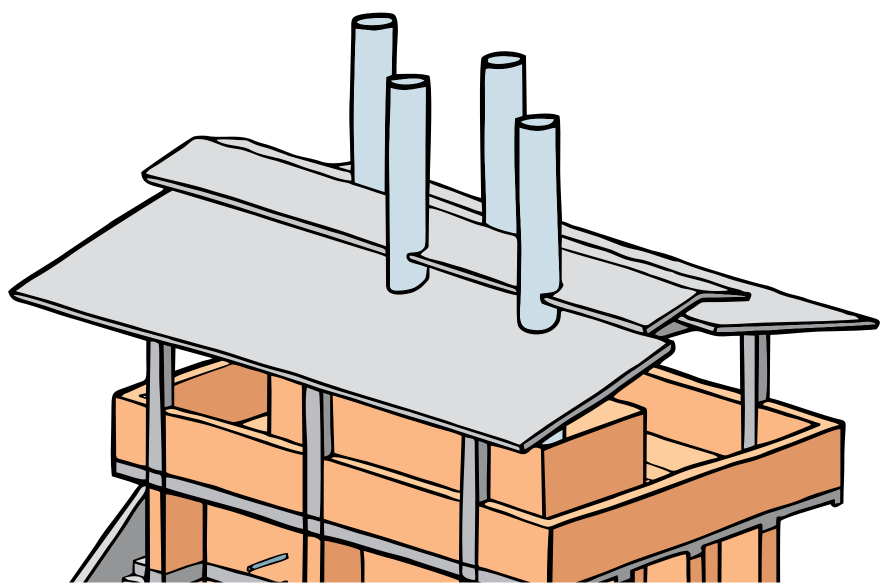
The roof protects the kiln structure and working personnel from the elements such as rain, sun and wind.

Design principles

Roof should be designed as economically as possible while at the same time ensuring that the kiln remains dry, green bricks and working personnel are protected.

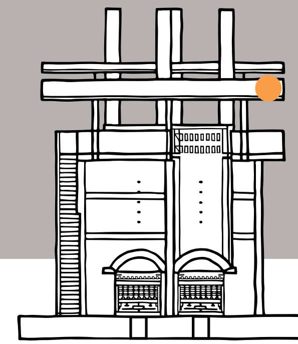
A roof monitor is essential to ensure proper ventilation that reduces the accumulation of harmful emissions. The height of the roof should be enough for the fire master to work efficiently above the shaft top for loading bricks.

OPTION 1 : High-end level (Corrugated/plain plastic roofing sheets or P.V.C. corrugated/plain sheets on sloped M.S. pipe trusses and purlins) (Sloped concrete or ferro-cement roof)	
Advantages	**Disadvantages & Limits**
• Is resistant to damaging emissions	• Is an expensive roof



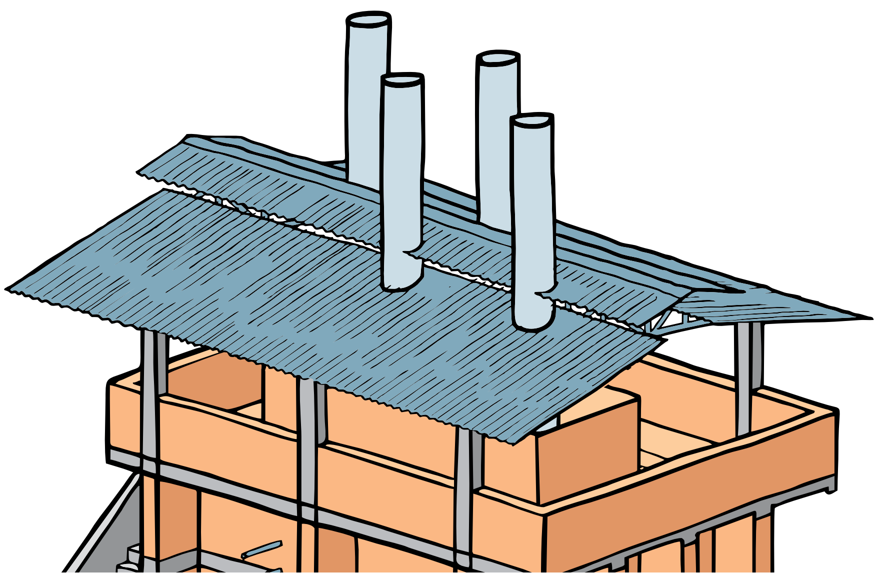
DESIGN FUNCTIONALLY BUILD ECONOMICALLY!

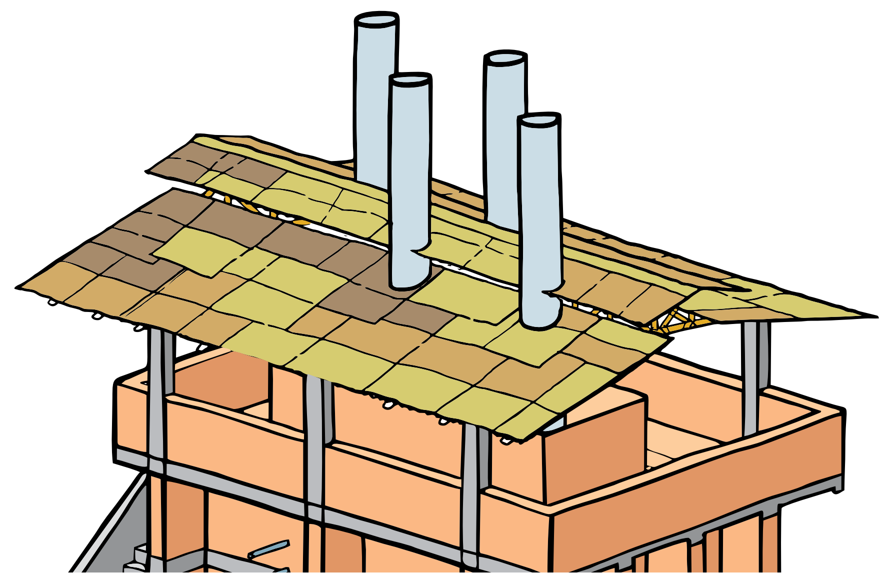
24 ROOF



OPTION 2 : Normal range level (Colour coated roof sheets/corrugated/plain, galvanized iron sheets on sloped M.S. pipe trusses and purlins)	
Advantages	**Disadvantages & Limits**
• Is an economical solution	• Requires frequent maintenance due to corrosion problems

OPTION 3 : Budget level (Biodegradable materials: Bamboo mats or clay roofing tiles on timber or bamboo trusses and purlins)	
Advantages	**Disadvantages & Limits**
• Is a low cost and functional roofing option	• Requires regular replacement/ repair due to relative short lifespan of material • Potential of rain leaking exists





Note

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