

CLEAN BRICK TECHNOLOGY – From Design To Development

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Abstract:

This paper is a first attempt at understanding and describing the needs for design methods that have arisen in response to worldwide interests for the energy-efficient and environment-friendly brick firing technology, i.e. through the Vertical Shaft Brick Kiln (VSBK) Technology. Generally, it is understood that designing is done in order to produce drawings needed by clients and construction experts. However, in recent times with the proliferation of the need of VSBK in various countries, there has been a need to write down a standard method or recipe that can be relied upon for designing a VSBK. These design aspects are also country specific, since they depend on technical, social and geographical conditions particular to that country. Thus, the need to develop a design report, specific to Kashmir conditions was necessary. This design paper specific to Kashmir conditions is based on more than a decade long practical working experiences, researches, reports and various other technical parameters from the ground specific to Kashmir. This design paper is expected to serve as a basic tool for construction engineers and supervisors to delineate the essential parameters for the construction of a VSBK. This design paper does not claim to be complete or perfect. It is in the hands of the users to utilize it fully by using it as a reference guide for further improvement.

Keywords — Brick supporting I-beam, Flue ducts, Green brick, Ground level, Girder, Loading platform, Support Bars/ I-bar, Shaft, Shaft size, Screw supporting I-beam, Trolley track, Trolley guide, Unloading trolley

I. INTRODUCTION

The design of VSBK is the result of various hit and trial designs created in the past and the practical experiences of VSBK's performances in different countries in the region. The design of the shaft size is the most important part of VSBK because it determines the dimensions of the entire VSBK structure. The shaft design also plays an important and a crucial role in VSBK's performance. Any fault in the design can lead to VSBK's failure. Also the shaft size cannot be changed, once it is designed and constructed. Thus serious considerations on all

aspects are necessary while designing the shaft size.[1]

II. DESIGN PRINCIPLES

An engineering design is created by using scientific principles, technical information and imagination in the definition of a mechanical/civil structure, machine or system to perform pre specified functions with the maximum economy and efficiency. The traditional objective of any designer is to produce criteria's for drawings for the approval of a client and for instructions of the manufacturers or engineers. During the development of design criteria, the product life and

its efficacy has to be taken into account. This is generally true when any particular design is being developed, since all sponsors will be financially affected at every stage of the product life. However, the effects in the long term has also to be considered during the design stages since there are also performance and life cycle issues associated with the same. The act of designing is difficult to carry out and hard to describe. One of the fundamental problems is that the designers are obliged to use the current information to predict a future state that will not come about unless their predictions are correct.[2] The final outcome of the design has to be assumed before the means of achieving it is explored. Thus, the designers have to work backwards from a fixed set of boundary conditions with an assumption that the defined set of conditions are sacrosanct and cannot be changed in the entire lifecycle of the designed product. In case of developing a design of a well-defined final product, often the dilemma faced by the designers is the incorporation of their creativity. This must be treated with extreme caution since there are in some cases nonnegotiable issues. A designer has to clearly understand the areas of creativity application with an assumption that it will not affect the lifecycle of the final product, but will make the final product more practical.[3]

The following list of criterion are derived from design aims and design errors applicable to the present issue of developing the same for a Vertical Shaft Brick Kiln system and limited not only to the final civil superstructure.[4]

A. Identification and review of critical decisions

Every decision which carries a high penalty must be identified as early as possible. Such decisions should be taken only tentatively at first and should be reversible if they are later found to be conflicting with reliable evidences or with informed opinions.

B. Relating the cost of research to the penalties for taking wrong decisions

The penalty for not knowing must exceed the cost for finding out if it is worth using expensive design efforts to answer any questions. The first

requirement in evaluating a proposed action is to identify the questions to which the action will provide answers.

C. Matching design activities to the implementation team

The actions expected from the design team members must be those that they are confident of. They should have the capabilities and the motivation to carry out these actions. This must also match the capability of the implementation team and therefore be within their reach and understanding.

D. Identifying usable sources of information

Information should be sought from all the major sources of stability or instability to ensure their compatibility with the designs. The reliability of alternative sources of information should be assessed independently before undertaking the design exercise.

Thus the following outlines may be used for evaluating the design criteria and parameters:

1. Identify the uncertainties that are critical to the success or failure of a range of design options under considerations.
2. Identify the degree to which critical uncertainties need to be reduced.
3. Identify the time and resources available for reducing critical uncertainties.
4. Review the available data provided for accuracy.
5. Check the relevance of partial results to the critical uncertainties and alter the procedures as necessary.

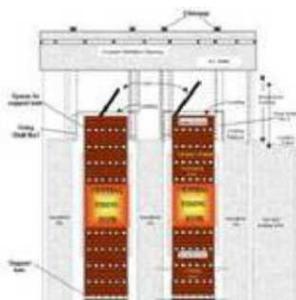
III. INTRODUCTION TO VSBK

The VSBK is an energy-efficient and environment-friendly firing technology for producing burnt red-clay bricks. The VSBK technology was originally developed in China in the

1950's and perfected in India during the 1990's. Thereafter it has been implemented in many countries, based on standardised conditions, by adapting and making required modifications as per the local conditions, but keeping the basic principles similar.[5]

The VSBK has vertical shaft of rectangular or square cross-section. The gap between shaft wall and the outer kiln wall is filled with insulating materials –broken bricks and burnt coal ash. The kiln works as a counter-current heat exchanger, with heat transfer taking place between the air moving up (continuous flow) and bricks moving down (intermittent movement). Green bricks are loaded in batches from the kiln top. Bricks move down the shaft through brick pre-heating, firing and cooling zones and unloaded from the bottom. The combustion of coal (added along with bricks at the top) takes place in the middle of the shaft. Combustion air enters the shaft from the bottom, gets preheated by hot fired bricks in the lower portion of the shaft, before reaching the combustion zone. Hot combustion gases preheat green bricks in the upper portion of the shaft, before exiting from the kiln through a shaft or a chimney. [6]

The brick setting in the kiln is kept on support bars at the bottom of the shaft. The unloading of bricks is done from the bottom of the shaft, using a trolley. The trolley is lifted (using single screw mechanism) till the iron beams placed on the trolley



touches the bottom of the brick setting and the weight of bricks is transferred on to the trolley. The freed support bars are taken out. The trolley is then lowered by one batch (equivalent to four layers of bricks) – the support bars are again put in place through the holes provided in the brick setting for that purpose. With a slight downward movement, the weight of the brick setting is transferred to the support bars. The trolley (with one batch of fired bricks on it) is further lowered till



it touches the ground level and is then pulled out of the kiln on a pair of rails provided for the purpose. In every 2-3 hours, a batch of fired bricks is unloaded at the bottom and a batch of fresh green bricks is loaded at the top simultaneously. At any given time, there are typically 11 to 12 batches in the kiln, depending on the green bricks' quality.

The two chimneys, located diagonally, opposite to each other on top of the shaft, remove the flue gases from the kiln. A lid is also provided on the shaft top, which is kept closed during the normal operation. Flue gases are directed to pass through chimneys so that the working area on the kiln top does not get polluted. The provision of shaft lid, better ventilation of working area on kiln top and higher and bigger chimneys are some of the highlights of the VSBK kiln and its related processes.[7]

The heating cycle for the green bricks is raw material specific (preheating, vitrification and cooling down) and is normally completed within 24-30 hours. A batch of bricks is loaded and unloaded every 2-3 hours; requiring round the clock operations and supervision. This requires special skills and the firing operator needs to maintain a correct balance between:[8]

- *Energy* Controlled by the amount of coal feeding
- *Airflow* Controlled by stacking density and damper position
- *Unloading speed* Controlled by the operator

IV. COMPARISON OF BTK AND VSBK OPERATION

Both types of kilns are continuous updraft kilns with a central chimney for exhaust of flue gases. However the basic differences between both the types of firing are:[9]

- VSBK requires only about 3500 to 4500 bricks to start the firing (depending upon the shaft cross section). In BTK firing can only start after at least 50 to 60 lines are filled up. The above process requires approximately 2 to 3 lakh green bricks. Thus VSBK is a low capital investment firing system.
- In VSBK small fireboxes are made at the bottom for initial firing.. The initial firing from the bottom requires only about 100 kg of dry firewood. Once the fire starts, no additional firewood is required. In BTK the fireboxes are much wider and larger in size. Large quantities of firewood is required along with other flammable materials, like saw dust, rubber tyres etc.
- In VSBK the fire wood burns for an initial period of 3 to 4 hours for firing initialization, whereas in BTK a minimum of 16 to 20 hours are required for the same result.
- In VSBK, stable production is achieved within 3-4 days after the initial firing and saleable bricks are produced. In BTK, for the production of suitable saleable bricks a gestation period of at least 15 to 20 days is required.
- In VSBK, fire is stationary at the centre of the shaft and the bricks move from the top to the bottom of the shaft. Whereas in BTK, bricks are stationary in the duct and as fire moves around the duct.
- VSBK is a rapid firing system. It takes just 24-30 hours to fire bricks in VSBK, hence making the technology more demanding when compared to BTK. The other technology is a slow firing system. It takes 10-15 days to fire bricks in BTK, hence providing higher firing tolerance

V. BASIC ADVANTAGES OF VSBK OVER CONVENTIONAL BTK TECHNOLOGY

- *High energy efficiency*

The VSBK technology economises on fuel costs, with savings of between 30 to 50 per cent when compared to other common brick-firing technologies, such as clamps or Bull's Trench Kiln with movable chimneys.

- *Environment friendly operations*

As a VSBK can only be fired with coal (or with coal dust), the deforestation of rural areas can be controlled. Additionally, if a VSBK is operated, as per the recommended conditions, emissions are reduced by approximately 90 per cent, compared to common traditional brick-firing technologies.

- *Economically viable*

Brick production using the VSBK technology is a profitable business and the overall initial investment is low (considering investment in a permanent land). Since, in a VSBK, energy consumption is 30-50 per cent lesser, the working capital required is also less.

- *Less land requirement*

The construction of a VSBK requires very little land. The building of multiple shaft production units further enhances the ratio of land use to production output.

- *Uniform quality of production*

Unlike the other brick firing technologies, where a uniform quality of fired bricks is not possible due to the heat loss, in VSBK the batches of the fired bricks produced are 95 per cent uniform in quality segregated into a single class. Compared to BTK where the second and the third grade bricks are produced in significant quantities, a VSBK produces mostly the first grade bricks. Breakages and wastage can be limited to even less than 5 per cent through stable operation of the VSBK and quality green brick making.

- *Round the year production*

The VSBK can be operated all the year round and even during the monsoon time, subject to the availability of dried green bricks. Weather factors

have only a minor influence because a roof protects the kiln

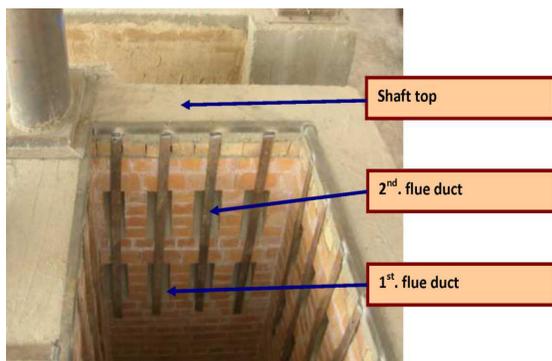
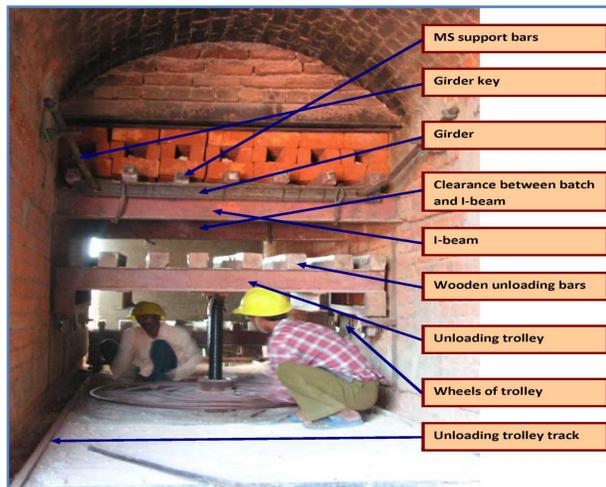
• *Consistent quality*

VSBK produces high quality bricks, albeit proper firing practices are followed. In fact, the products are even superior to those of the existing rural brick production technologies (traditional and BTK firing technologies). The VSBK-fired bricks show a fine, deep red colour and have a good, metallic ring depending upon the quality of the soil. A compressive strength of up to 200 kg/cm² can be achieved using good quality soil.

• *Flexibility in operation*

The firing of each shaft is independent from each other, which means it is not necessary to fire or close all shafts together. A decision on the number of shafts to operate can vary according to the availability of dried green bricks, market demand etc.

VI. TERMINOLOGY USED IN VSBK DESIGN



VSBK	Vertical Shaft Brick kKiln
Brick supporting I-beam	I-beams are fixed along the two sides of the lower portion of the shaft. The total load of the bricks inside the shaft is supported by these I-beams by means of I-bars.
Flue ducts	The flue duct is a specially designed structure at the upper most part of shaft, through which the flue gases passes to the chimney.
Green brick	Green bricks are raw dried bricks, which are ready for firing.
Ground level	The top of screw supporting the I beam is taken as ground level (GL +/- 0.00mm).
Girder	The girders are placed on the top of the I beam, which can be easily removed with the help of a girder key at the time of unloading. The support bars are placed on the top of the girders.
Loading platform	A loading platform is at the upper part of the VSBK, where the green bricks are stacked before loading inside the shaft.
Support Bars/ I-bar	It is an iron bar of I-shape. It bears the total load of the bricks in the shaft.
Shaft	A vertical rectangular or square hollow section, constructed with refractory bricks, where the brick firing takes place. The shaft has notionally designated preheating, firing and cooling zones where different stages of firing take place.
Shaft size	Shaft size is three dimensions of the shaft. It is dependent on the dimensions of dried green bricks.
Shaft height	The shaft height is the total height of a shaft, measured from the ground level (+/- 0.00 mm) to the shaft top.
Screw supporting I-beam	Screw supporting the I-beams are fixed in the two sides of the lower portion of the shaft. The unloading mechanism rests on these I-beams.
Trolley track	Trolley track is fixed in unloading tunnel ground.

VII. VSBK SITE SELECTION CRITERIA

The VSBK's brick quality highly depends upon the quality of the soil used. Hence the design of the VSBK begins with the selection of a suitable kiln construction and soil mining site, as well as designing the layout of the entire brick production system. The soil mining site and the kiln construction site might or might not be the same, but both the sites should be within an economical distance. [10]

There are various essential factors that need to be evaluated during the site selection, which binds the design and operation of the entire VSBK system. These are:[11,12]

1. Soil Quality

The VSBK's brick quality highly depends upon the quality of the soil; hence the site should be selected where suitable soil is available. [13]

2. Soil Quantity

The soil mining site should have sufficient quantity of soil at least for five years to make the VSBK business economically viable.[14]

3. Transportation

The site should be easily accessible and should be as near as possible to the targeted market place to deliver the bricks economically. The location of the soil mining and construction site must be in economical distance to minimise the transportation cost.

4. Drainage

The selected site must be free from any water logging problems. Such areas should be avoided for VSBK, or a well laid drainage system should be designed. Special care should be taken while designing a VSBK in areas where the water table is high.

5. Topography

It is a great advantage to have a hillock, elevated (sloping) land, or some high ground next to the kiln, as created by the topography. The topography can be used to design the vertical transportation mechanism of the green bricks. Therefore, the cost of the ramp construction can be reduced with proper use of topography. [15]

6. Water availability

The site should have access to sufficient quantity of water for green brick making and other sanitary purposes.

7. Future expansion

There should be enough space for future expansion. [16]

8. Electricity

Though VSBK does not require electricity to fire bricks, it is imperative to have a provision for electricity at the site, mainly for the lighting purpose and for using other mechanical devices, like a pug mill, extruder, lifting mechanism etc.

9. Site conditions

The site should not have numerous trees and should be distant from a river bank. The site should also be free from boulders.

10. Bearing capacity

This is especially applicable for the kiln construction area. The load bearing capacity of the soil determines the type of footing; either mat footing or step masonry footing. It should be determined or data should be collected before the designing is initiated.[17]

VIII. LIMITATIONS IN VSBK DESIGNS

The design of a VSBK is bound by certain limitations. The limitations are basically with:[18]

- a. Shaft cross-section
- b. Shaft height
- c. Changing the shaft cross-section

Limitation in shaft cross-section

- The size of the dried green brick determines the shaft size.
- The squareness of a nominal cross section of a shaft should not be less than 50 Per cent.
- Greater shaft width causes large bending in support bars due to additional load, which limits the width of the shaft.
- Greater the shaft size, greater will be the load inside the shaft, influencing the design of the screw and support bars.

Limitation in shaft height

- The shaft height is dependent on the batch number and batch height, which again directly depends on the green brick’s breadth and weight.
- The total brick weight in the shaft must also be considered, while determining the shaft height.
- The load carrying the capacity of bricks also influences the design of a shaft height.

Limitation in changing the shaft cross-section

- The shaft design directly depends upon the green brick dimensions. Once the shaft is constructed, it is not possible to change the cross-section, unless the whole shaft is dismantled and reconstructed.

IX. VSBK DESIGN PARAMETERS

1. Design brick dimension

The “Design green brick” parameter is referred to the green brick, used for designing the VSBK. The green brick dimension plays a vital role in the designing of the shaft and the VSBK. Once the shaft is constructed, its size cannot be adjusted or changed. Thus the dimensions of a “Design Green Brick” during the design process should be carefully assessed and calculated. The “Design Green Brick’s” size is the dimension of the bricks, which is completely dried and ready to be loaded in the shaft during operation. If the loaded brick dimension does not match with the “Design Green Brick”, then there might be cases of shaft damage, shaft jamming or excessive heat loss. Hence this is the most important and fixed parameter[19,20,21]



Calculation of “Design Green Brick” dimensions

- Assess the fired brick dimensions, commonly used in the market or as desired to be produced by the entrepreneur.

Thus

Length = L mm

Breadth = B mm

Depth = D mm

- Evaluate the “design green brick” dimension using total shrinkage

Thus,

Design green brick length (L_d) = $L / (1 - L_f \%)$ mm

Design green brick breadth(B_d) = $B / (1 - B_f \%)$ mm

Design green brick depth(D_d) = $D / (1 - D_f \%)$ mm

OR

If it is an existing brick production unit, then determine the dimensions of green bricks by measuring the dimensions of 30 dried green bricks, which are used in production.[22,23,24]

2. Shaft cross-section

The empirical formula for calculating the shaft size is: [25]

a) Length

$$Length\ of\ shaft = [L_d \times N_{length}] + [10 \times (N_{length} + 1)]$$

Note:

- L_d is the calculated or measured “design green brick” length
- N_{length} represents the total number of bricks accommodated in shaft length.
- The value of 10 (expressed in mm) is added for providing airflow gap from both sides of the brick.
- Value 1 inside the inner bracket is provided to adjust total number of gap between brick.



b) Breadth

$$Breadth\ of\ shaft = [L_d \times N_{breadth}] + [10 \times (N_{breadth} + 1)]$$

Note:

- L_d is the calculated or measured “design green brick” length
- $N_{breadth}$ represents the total number of bricks in shaft breadth.



- The value of 10 (expressed in mm) is added for providing an airflow gap from both the sides of the brick.
- Value 1 inside the inner bracket is provided to adjust total number of gaps between brick.

3. Batch height

The empirical formula for calculating batch height is:[26,27]

$$\text{Single batch height} = [B_d + 4 \text{ mm}] \times 4 \text{ layers}$$

Note:

- B_d is the calculated or measured “design green brick” breadth
- 4 (expressed in mm) is the tolerance for variations in breath.
- 4 (expressed in number) is the number of layers considered in one normal batch.



4. Kiln height from ground level

Shaft height depends on the following given parameters:[28,29,30]

4.1. Height up to the base of the I-beam

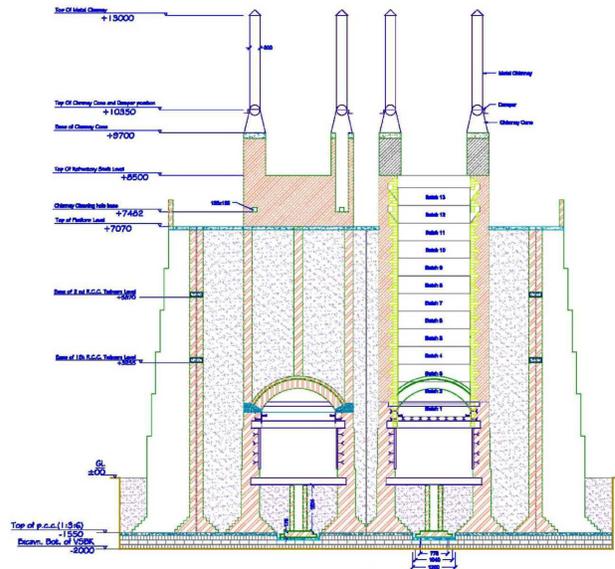
This is based on the addition of the height of:

- 4.1.1. Unloading trolley track
- 4.1.2. Unloading trolley set, including the wheels
- 4.1.3. Wooden bars on the unloading trolley
- 4.1.4. Provision of 6 layers (1.5 batches) unloading
- 4.1.5. Clearance gap between the bricks and the beam

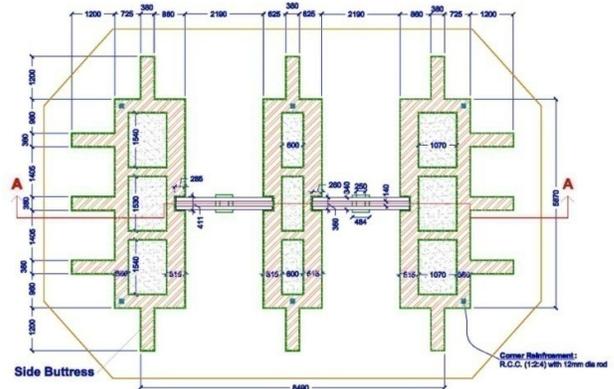
- 4.2. I-beam height
- 4.3. Girder operation clearance
- 4.4. Support bar depth
- 4.5. Height of first flue duct level
- 4.6. One flue duct height
- 4.7. Height from second flue duct top level to shaft Top

$$\text{Total kiln height} = [4.1 + 4.2 + 4.3 + 4.4 + 4.5 + 4.6 + 4.7] \text{ mm}$$

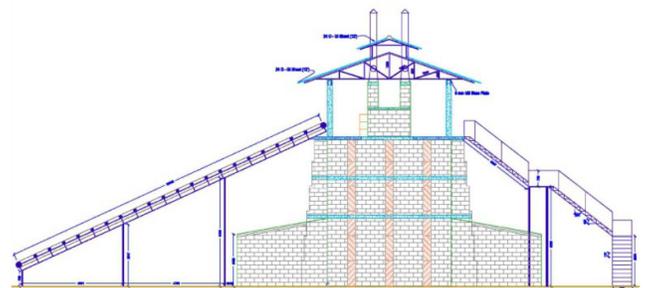
X. TYPICAL CROSS SECTION OF VSBK



XI. PLAN AT GROUND LEVEL



XII. ELEVATION OF VSBK WITH CONVEYER AND STAIRCASE



Acknowledgement

The author is highly thankful to various organisations viz. UNFCC, ICIMOD, WORLD BANK, SKAT CONSULTING, SWISS AGENCY FOR DEVELOPMENT & COOPERATION, STATE POLLUTION CONTROL BOARD, SSM COLLEGE OF ENG & TECH. and various other persons who directly or, indirectly provided the necessary help required for doing this research. Also, I'm very thankful to my Parents for their regular support and guidance. Last but not the least, I am grateful to all my friends for providing critical feedback & support whenever required.

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