Status report on VSBKs in India

By

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Section 1
Indian brick industry

India is the second largest producer of bricks after China. The estimated brick production during 2000-01 was close to 140 billion bricks. The Indian brick industry is unorganised with small production units clustered in rural and peri-urban areas. There are more than 100,000 brick kilns operating in the country. Brick making consumes about 24 million tonnes of coal and several million tonnes of biomass fuels per year. Coal consumption by the brick industry is approximately 8% of the total coal consumption in the country. The share of energy in total costs of brick production is 35 to 50%. Several types of brick kilns are used for firing bricks. The choice of technology depends generally on factors such as scale of production, soil and fuel availability, market conditions and skills available. Table 1.1 shows brick kiln technologies used in the country.

Table 1.1 Brick kilns in India (2001)

Kiln type	*Typical production capacity range (lakh bricks per year)#*	*Approximate Number of kilns*
BTK–Fixed chimney §	30 - 100	20000
BTK–Moving chimney	20 – 80	13000
High draft/zig-zag firing	30 - 50	200
Clamps	0.5 – 10	> 60000
Vertical shaft brick kiln (VSBK)	5 – 40	27

§ About 40% of the fixed chimney BTKs are estimated to have gravity settling chamber

The brick making season in the country is generally 150–200 days in a year

The brick-producing regions in India can be categorized into two major zones based on nature of soil availability.

- Indo-Gangetic Plains, consisting of the north and north east part of India. Good quality alluvial soil is available for brick making in this region and large capacity BTKs are found in this region. This region caters to about 65% of the total production.
- Peninsular and coastal India, consisting of the west, central and southern parts of India accounts for the rest 35% of total production. This region has shortage of good quality soil for brick making. At present clamps and moving chimney BTKs are used for brick production. VSBK technology has higher potential in this region.

The brick kilns in general can be classified into (1) intermittent kilns and (2) continuous kilns (figure 1.1). An Intermittent kiln without permanent kiln structure is commonly called as clamp. Clamps are generally used when the volume of production is small. The production capacity of clamps generally ranges from 5,000 to 5,00,000 bricks per firing. A variety of fuels such as coal, firewood, various types of agricultural residues, dungcakes etc. are used in clamps. The arrangement of bricks in a clamp generally depends on the type of fuel used. Intermittent kilns have low energy efficiencies as most of the heat in the flue gases, fired bricks and kiln structure remains unutilized.

BRICK KILNS

Intermittent

1. Clamp
2. Scove
3. Scotch
4. Downdraught

Continuous

1. Moving firing (annular kiln)
    - Hoffmann
    - Bull's trench kiln (BTK)
    - Zig-zag
        - Habla
        - High draught
2. Moving ware
    - Tunnel
    - Vertical shaft brick kiln (VSBK)

Figure 1.1 Classification of brick kilns

Continuous kilns incorporates heat recovery features to utilise heat in fired bricks as well as heat available in hot flue gases. These kilns are superior to intermittent kilns in terms of energy efficiency as well as the quality of bricks. Continuous kilns include bull's trench kilns (BTKs) with moving chimney and fixed chimney, Hoffmann kiln, high draught kilns and vertical shaft brick kiln (VSBK). Brick kilns can also be classified according to the production capacity. The Gazette Notification on "emission standards" for brick kilns classifies brick kilns into three categories:

(1) Small (production capacity less than 15000 bricks per day);
(2) Medium (15000 to 30000 bricks per day); and
(3) Large (more than 30000 bricks per day)

Section 2
Introduction to vertical shaft brick kiln (VSBK) technology

Historical development

Vertical Shaft Brick Kiln (VSBK) technology is an energy efficient technology for firing clay bricks. It is particularly suited to the needs of brick production in developing countries – which is small scale and decentralized type. The evolution and initial development of VSBK technology took place in rural China. The first version of VSBK in China originated from traditional updraft intermittent kiln during 1960's. During 70's, the kiln became popular in several provinces of China. In 1985, Chinese government commissioned the Energy Research Institute of the Henan Academy of Sciences at Zhengzhou (Henan province), to study the kiln to improve the energy efficiency. Several thousand VSBKs were reported to be operating in China in 1997. Attempts to disseminate VSBK technology outside China started in early 1990's. Apart from India, the VSBK technology was demonstrated in several Asian countries such as Nepal, Afganistan, Pakistan, Vietnam and Bangladesh.

VSBK technology in India

Under an 'Action Research Project' supported by the Swiss Agency for Development and Cooperation (SDC), four VSBK pilot plants were field-tested during the period 1996-99. The locations for the four pilot plants were selected so as to test VSBK technology under different 'soil-fuel-climate-market' conditions.

Presently there are about 27 VSBKs are in operation in Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, Karnataka and Tamil Nadu. A list of places where VSBKs have been installed under the SDC sponsored India Brick Project (IBP) is given as table 2.1.

Table 2.1 VSBKs in India (as on January 2003)

Category	Madhya Pradesh	Uttar Pradesh	Maharahstra	Orissa/ Karnataka/ Tamil Nadu
Privately owned and managed	8	2	7	1
IBP-funded	–	–	–	3
Self-replicated and privately owned	2	–	–	4
	10	2	7	8

Technology adaptation under local conditions

Several design modifications have been incorporated under the IBP in the original Chinese VSBK design to improve its performance in energy, environment and product quality aspects. These include:

- Increasing cross-sectional area of shaft to increase production capacity;
- Increasing the height of the shaft to improve energy efficiency;
- Increasing the height and the area of the chimney and use of a single chimney per shaft instead of two chimneys per shaft;
- Incorporation of shaft lids to reduce air pollution at the working platform;
- Use of cooling chambers for controlled cooling of the unloaded bricks; and
- Instrumentation (thermocouples to measure brick and flue gas temperature) for kiln operation and control.

India Brick Project (IBP)

The IBP programme is supported by the Swiss Agency For Development and Cooperation (SDC) since 1995. Promotion of VSBK and empowering of small brick producers through sustainable methods are the twin objectives of IBP.

IBP has a partner network consisting of Tata Energy Research Institute (New Delhi), Development Alternatives (New Delhi), Gram Vikas (Orissa), Damle Clay Structurals Pvt Ltd (Pune) and Fourth Vision (Ahmedabad).

The project partners provide assistance in the construction, operation and troubleshooting of VSBKs. Training of manpower for VSBK construction and operation is also provided by the project.

Further efforts are being made to reduce the cost of the kiln, simplify its operation and demonstration in new regions. Several new VSBKs are under planning and construction stage, which will soon become operational. The main advantages claimed for VSBK technology are:

a) Highest energy efficiency among all types of kilns
b) Lower emissions
c) Small area requirement
d) Uniformity in the quality of the fired bricks

Figure 2.1 shows VSBKs operating in India.

Figure 2.1 View of some of the VSBKs in India

Section 3
Working principle and design considerations of VSBK

3.1 Working principle

The VSBK is a vertical kiln with stationary fire and moving brick arrangement. Figure 3.1 shows the cross-section of a two-shaft VSBK kiln. The kiln shaft has rectangular/ square cross section. The kiln operates like a counter current heat exchanger, with heat transfer taking place between the air (moving upwards) and the bricks (moving downwards). The kiln can be divided into three distinct sections. The top section is the brick-preheating zone, the middle section is the firing & heat soaking zone and the lower section is the cooling zone for bricks. The shaft wall (inner surface of the kiln) is usually lined with refractory bricks and the outer kiln wall is made up of red brick. The gap between the shaft wall and outer kiln wall is filled with materials such as clay, fly ash etc.

VSBK is a natural draft kiln, requiring no electricity for supply of combustion air. The air required for combustion enters from the bottom of the kiln. It extracts the heat from the cooling bricks before reaching the firing zone. The flue gases leaving the firing zone exchange heat with dry bricks loaded thereby preheating them. The flue gases finally enter the chimney through the flue duct at a temperature of 60 to 150°C. Each shaft is provided with two

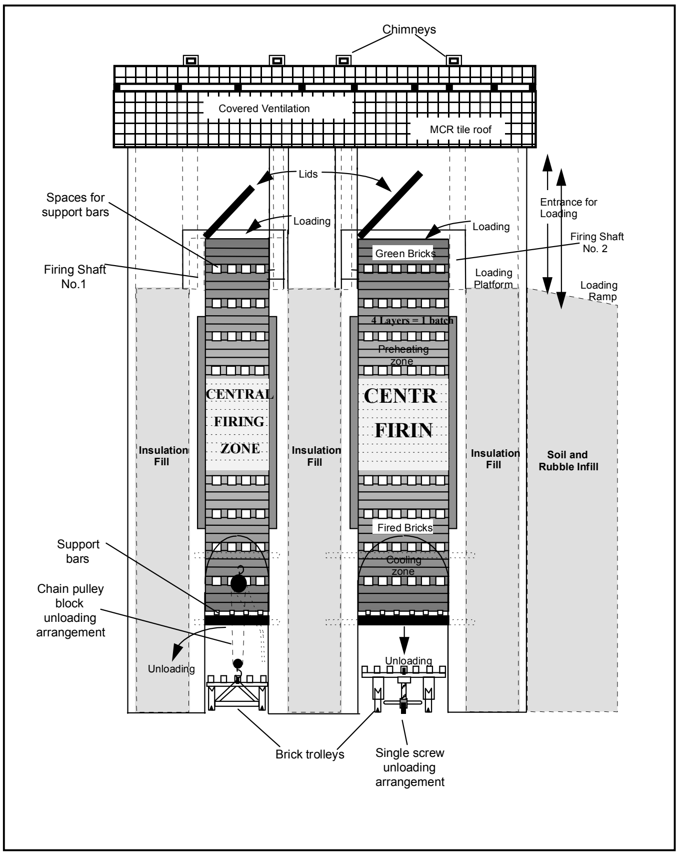

Figure 3.1 A two-shaft VSBK

chimneys placed diagonally opposite to each other. These Lids are provided at the shaft top which direct the gases to pass through chimney. A single screw jack system is used for unloading of the fired bricks.

High unloading temperatures can lead to formation of cooling cracks[a] in the fired bricks. To reduce the formation of cooling cracks, cooling chambers are provided at the end of the unloading tunnel. The unloaded bricks can be kept in these chambers for controlled cooling of bricks. These chambers are particularly useful for high vitrification temperature soils (vitrification temperatures > 1000°C).

3.2 Operation

Dry bricks are loaded from kiln top in batches. Each batch has four layers of bricks in a predetermined pattern (figure 3.2). A predetermined quantity of crushed coal is also fed along with dry bricks. The number of bricks per batch depends on the cross-section of the shaft. Larger the area of cross-section, higher will be number of bricks produced in a batch. However it can't be increased beyond 1.25 m X 2.0 m because of screw jack limitations. Table 2.1 shows the production capacity of bricks per shaft per day in VSBKs.

Table 3.1 Production capacity in VSBKs

Shaft size (metre X metre)	Production capacity (bricks per day)
1 X 1	2000
1 X 1.5	3000
1 X 1.75	3500
1 X 2	4000
1.25 X 2	5000

Note: (1) For brick size of 230 mm X 110 mm X 70 mm, And
(2) Number of unloading assumed as 11 batches per day

Unloading of fired bricks is carried out at an interval of 2–3 hours. The total time for firing bricks on batch wise in VSBK varies between 20 to 40 hours. Duration of loading and unloading varies between 15 to 20 minutes. A trolley mounted on a screw jack is the main equipment used for unloading the bricks. The unloading of bricks creates space at the top of the shaft in which a new batch of bricks is loaded. The procedure of unloading and loading is now described in following sections.

[a] Cracks formed due to sudden cooling of fired bricks. This problem has been observed is some VSBKs where the unloading temperature of bricks exceeds 200 °C.

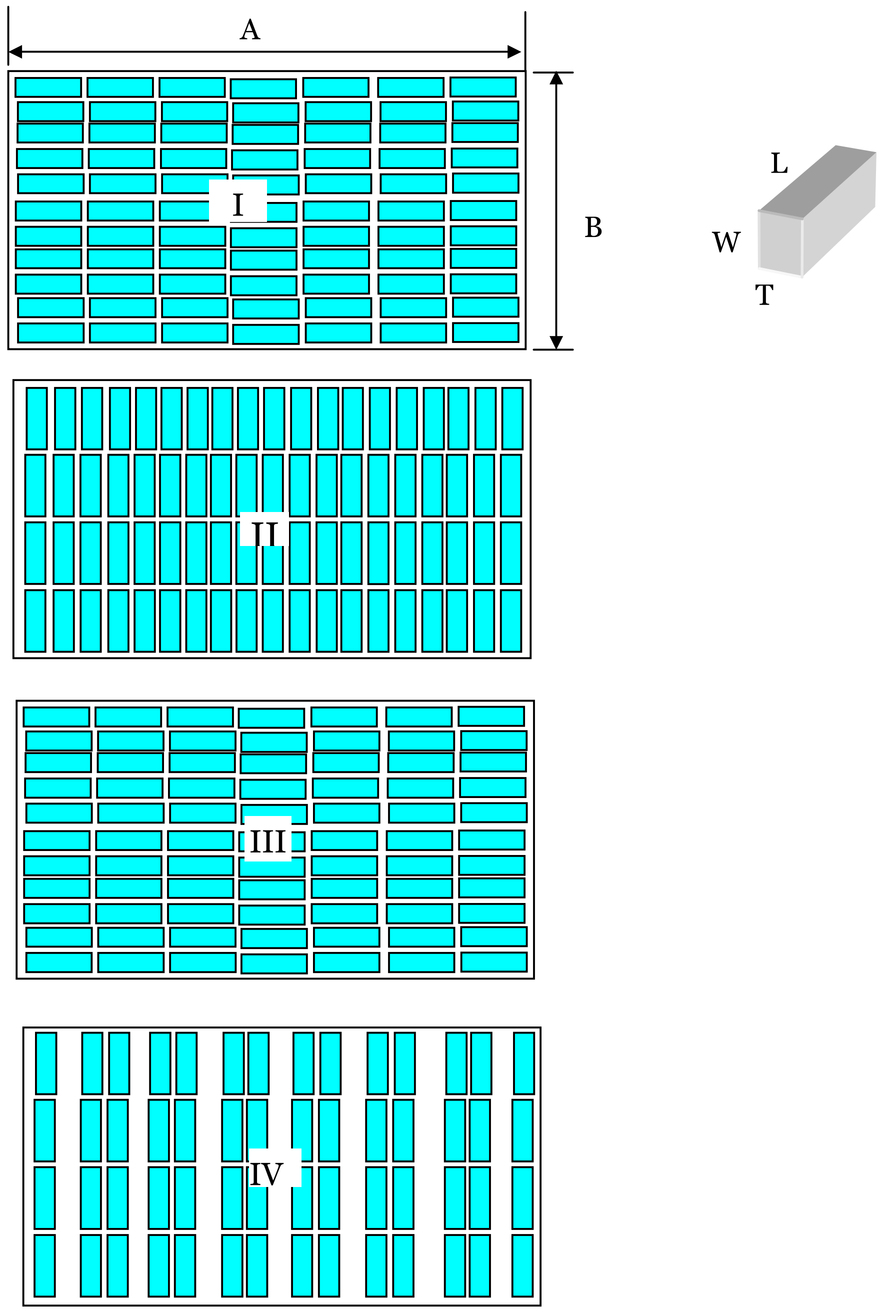

Figure 3.2 Layer by layer brick arrangement in a batch

W = Width; L = Length; T = Thickness

The sequence of operations for unloading a batch is shown in figure 3.3. Figure 3.3 (a) shows the normal operating condition:

- The column of bricks in the shaft is resting on support bars (solid or hollow rectangular steel bars).

- Empty trolley is resting on the ground.
- The screw jack is in fully retracted position.

For unloading, the trolley is lifted up using the screw jack. On lifting, the wooden planks kept on the trolley, go in the gap between the support bars and touches the bottom surface of the brick setting. On further tightening of the screw, the weight of the brick column is transferred on to the trolley and the support bars become free and are pulled out. This position is shown in figure 3.3 (b), in which:

- The screw jack is in fully extended position.
- The support bars have been withdrawn and the brick column in the shaft is now resting on the trolley.

After removal of the support bars, the brick column resting on the trolley is lowered using the screw jack. The lowering is continued till the row of gaps in the brick setting are just above the top level of the support beam. This position is shown in figure 3.3 (c). Now the support bars are inserted in the gaps. After inserting the support bars, the lowering is continued till the support bars rests on the support beams and the weight of brick column is again transferred back on to the support bars. Further lowering of the trolley results in detachment of one batch of fired brick from the main brick column. The batch resting on the trolley is lowered to the ground this is shown in figure 3.3 (d), in which:

- The screw jack is in fully retracted position.
- The main brick column is now resting on the support bars and the trolley with a batch of fired bricks is resting on the ground.

The completion of unloading operation creates space for loading a new batch of green bricks at the top of the shaft. The bricks are arranged in the shaft in layers as per the arrangement shown earlier in figure 3.2**.** Three densely packed layers are followed by a fourth layer having gaps for support bars. Crushed coal (particle size 0-15 mm) is weighed and spread over each layer of bricks.

The fuel added along with bricks is referred to as “external fuel”. Crushed coal is generally used as external fuel in VSBKs. Recently, lignite, charcoal and firewood has also been successfully used as external fuel in VSBKs. Apart from the external fuel, generally some powdery fuel is also added in soil during soil-mix preparation stage, this fuel is referred to as “internal fuel”. A number of fuels such as coal powder, fly ash, bagasse, rice husk etc. are used as internal

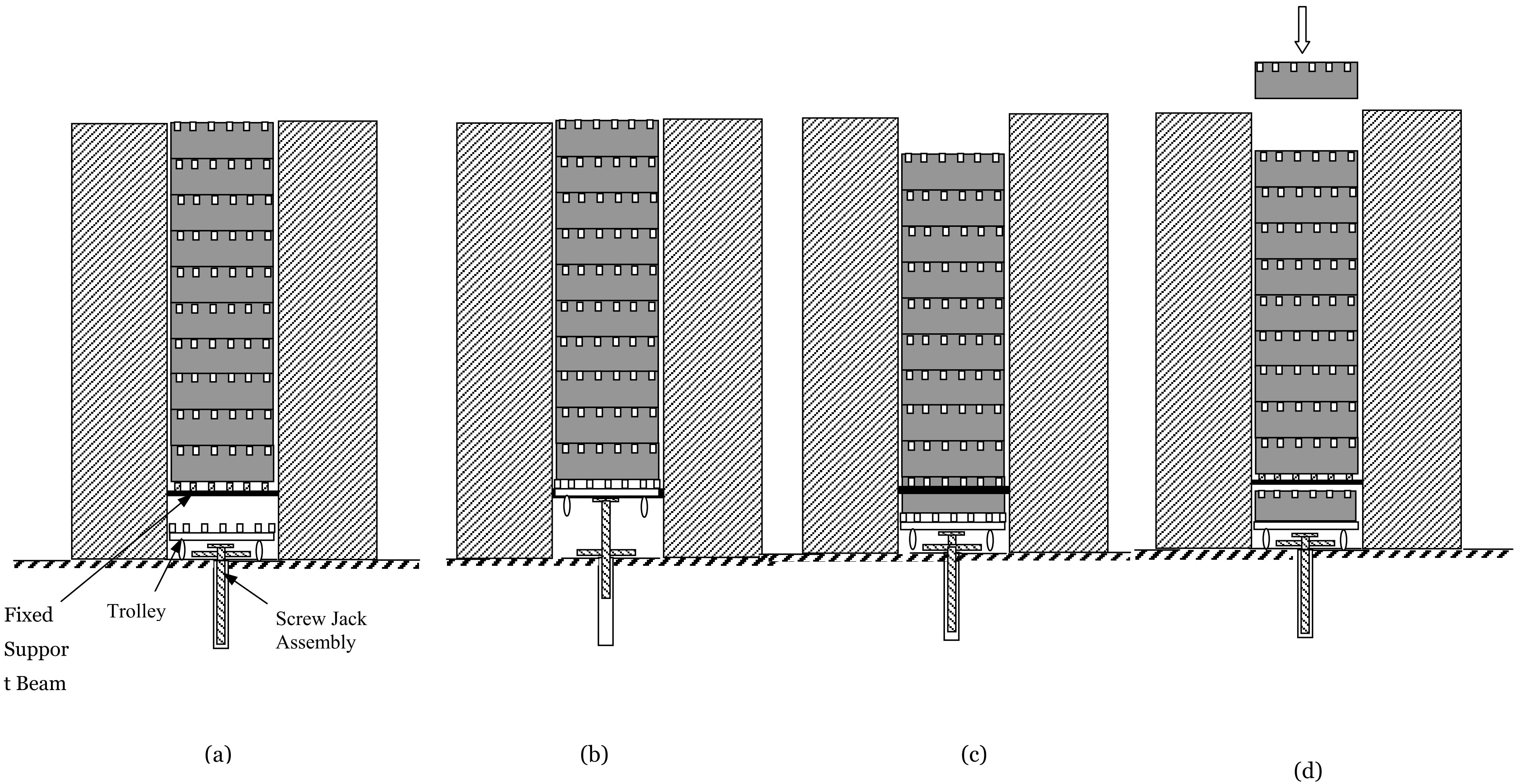

Figure 3.3 Operation Sequence of VSBK

fuels. The extent to which internal fuels can be used is dictated by soil quality and desired brick quality.

3.3 Design

VSBK is modular in construction. The most important component in VSBK design is the determination of the dimensions of the shaft (cross-section and height).

(i) Cross-section of the shaft

The nominal shaft cross-section is chosen based on the desired production capacity as per table 2.1. The exact shaft cross-section is calculated based on the size of dry green bricks. The internal shaft cross-section dimensions A and B (refer figure 2.2) are calculated using formulae as given below.

$A = (L + G) X N_L$

$B = (L + G) X N_w$

Where,

L = Length of dry green brick

G = Gap between bricks (of about 10 mm) required to ensure air/gas flow and for accommodating fuel between the bricks

N_L = Number of bricks accommodated along dimension A (e.g. $N_L = 7$ for brick arrangement shown in figure 2.2)

N_w = Number of bricks accommodated along dimension (e.g. $N_w = 4$ for brick arrangement shown in figure 2.2)

(ii) Height of the shaft

The height of the shaft varies between 3.6 to 6.0 m (i.e. number of batches of bricks that can be accommodated in the shaft varies between 8 to 13). The height of the shaft depends on the strength of dry green bricks available for brick production. The regions where good quality green bricks are available e.g. Indo-Gangetic plains, shaft height of 5.5–6.0 m is used. For areas having poor dry green brick quality e.g. Maharashtra, shaft height of 4.0–5.0 m is used. The height of the shaft is calculated as below:

H = [(W + 4) X 4 X N] + W + 50

where

H = Height of shaft in mm

N = Number of batches in the shaft

W = Width of brick mm

The thickness of the walls of the kiln is determined depending on the storage and working area requirement at the kiln top. Figure 2.4 shows an example of major dimensions of the VSBK kiln.

3.4 Construction

The typical construction cost of single VSBK shaft ranges from Rs 2.5 to 3.5 lakh. The bill of quantity for a 2 shaft VSBK are provided in table 3.2**.** The construction period of a VSBK ranges from 30 to 45 days. VSBK construction requires supervision from a trained construction supervisor/ engineer. Special care is required during following stages of construction:

- Layout marking
- Arch construction
- Shaft construction particularly for the refractory brick masonry work and ensuring verticality of the shaft
- Flue gas outlet construction

Table 3.2 Construction materials required for a two-shaft VSBK (8000 bricks day capacity)

S.No	Item material	*Specification*	*Quantity*
1	Bricks	9”×4”×3”	40,000
2	Refractory bricks	9”×4”×3”	3,100
3	Refractory clay	50 kg/bag	10 bags
4	Cement	50 kg/bag	70 bags
5	River sand	400 cu. ft/truck	4 truck
6	Boulder (Big stone)	400 cu. ft/truck	4 truck
7	I section for screw support	150×80, L=2520 mm	4 Nos
8	I section for Rail beam for support bar	200×100, L=2480 mm	4 Nos
9	Channel beam for shaft support	L=2420 m, 125×55 mm^2	8 Nos
10	Support plate for screw I beam	350 mm×250 mm×8 mm	4 Nos
11	Support plate for brick support I beam	250 mm×250 mm×8 mm	8 Nos
12	Support plate for channel steel	280 mm×250 mm×8 mm	8 Nos
13	Trolley guide	50 mm×100 mm, L=1100 mm	8 Nos
14	Angle iron for trolley track	50 mm×50 mm×5 mm=6000 mm	4 Nos
15	Steel iron rod	Dia 6 mm	90 kg
16	Screw jack assembly		2 no.
17	Trolley		2 no.
18	Roofing material	According to local requirement	

Note: The above table does not include the requirements for ramp/lifting arrangements, cooling chambers.

Section 4
Performance measurements of VSBKs

4.1 Energy performance

The energy performance of brick kilns is calculated as the thermal energy consumed per kg of bricks fired (MJ/kg brick fired). Coal[a] is generally used as the external fuel in VSBKs and fuels such as coal powder, boiler ash, biomass fuels such as rice husk are added as internal fuel. While internal fuels are added during moulding process, the external fuel i.e. coal is added during each loading operation.

The specific energy consumption of VSBK technology was observed to be the lowest (0.74 to 1.1 MJ/kg fired brick). Table 4.1 shows the specific energy consumption of few VSBKs monitored by TERI.

Table 4.1 Specific energy consumption of other VSBKs

VSBK	*State*	*Specific energy consumption (MJ/kg fired brick)*
VSBK –Datia	Madhya Pradesh	0.84
VSBK –Kankia	Orissa	1.06
VSBK –Pune	Maharashtra	0.85
VSBK – Varanasi	Uttar Pradesh	0.83
VSBK – Amravari	Maharashtra	0.78

Source: TERI report

A comparison of specific energy consumption of different brick making technologies are shown in figure 4.1, which clearly shows that specific energy consumption for VSBK is much lower as compared to other brick firing technologies.

[a] Experiments are in one of the VSBKs in Tamil Nadu to use charcoal as the fuel as the state is dependant mostly on biomass fuels for brick kiln firing

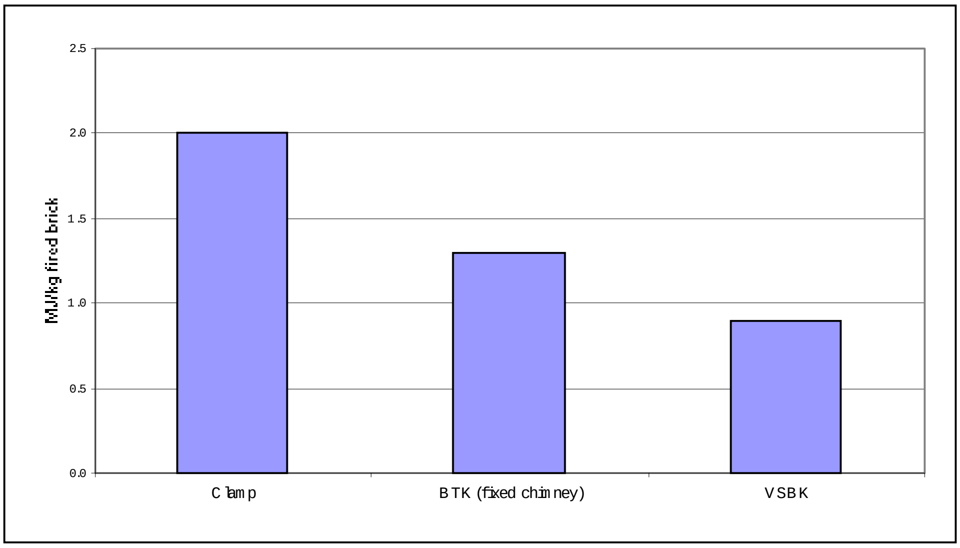

Figure 4.1 Specific energy consumption of brick kiln technologies

The heat input in a brick kiln is in the form of fuel. Different heat output components are free-moisture removal, heat for chemical reactions, flue gas loss, surface heat loss, residual heat in unloaded bricks and unburnt carbon losses. A typical energy balance of VSBK is given in table 4.2.

Table 4.2 Heat balance of VSBK

Component	Share (%)
Heat for free moisture removal	10%
Heat for chemical reactions	37%
Flue gas loss	18%
Surface heat loss	6%
Heat loss from exposed bricks	14%
Residual heat loss	8%
Heat loss due to "CO" formation	3%
Unaccounted losses	4%
Total heat input = 0.84 MJ/kg fired brick	

Note: Data of VSBK–Datia
Source: Action Research project on brick kilns (October 1997 to June 1999), TERI

4.2 Stack emissions

In BTKs, the SPM (suspended particulate matter) emissions generally follow a cycle. SPM emissions are higher during fuel feeding and will be lower during non-feeding. IN VSBK, fuel is fed along with brick setting, which means the SPM emissions are fairly constant during entire operation of VSBK. The SPM emissions from VSBK were found to vary between 77–250 mg/Nm^3. Table 1 shows SPM emissions from different brick kilns. As can be seen, the SPM emissions from VSBKs are much lower than the stringent standards of 750 mg/Nm^3.

Table 4.2 Typical SPM emissions from brick kilns (mg/Nm^3)

Kiln	Fuel feeding	Non-feeding	Weighted average
Fixed chimney	550	220	350
High draught	850	350	550
VSBK	N.A.	N.A.	170

N.A. – Not Applicable

Source: Draft report on "Development of emission standards and stack height regulations for the vertical shaft brick kilns (VSBK) vis-à-vis pollution control measures" submitted by TERI to CPCB

Section 5
Conclusions

A comparison covering both technical and economic aspects of VSBK and BTK kilns of similar capacities for Gwalior is presented in table 5.1.

Table 5.1 Comparison of VSBK and BTK at Gwalior

S No	Data/ information	VSBK	BTK
1	System description	6-shaft VSBK with each shaft of 1 m x 2m	Fixed chimney system
2	Production capacity (bricks per day)	30,000 to 36,000	25,000 to 40,000
3	Investments for kiln construction (materials, wages, consultancy)	Rs 15 lakh	Rs 10 lakh
4	Coal consumption (per lakh bricks) (GCV of coal = 5000 kcal/kg)	10 to 11 tonne *	14 to 18 tonne
5	Quality of bricks		
	▪ Class-1	80–84%	65–70%
	▪ Class-2	8–10%	20–30%
	▪ Class-3	–	3–5%
	▪ Broken bricks	8–10%	2–5%
6	▪ Manpower requirements for firing	24	6
	▪ Wages (per month)		
		Rs 60,000	Rs 12,000
7	Land requirements for kiln construction	400 to 500 sq. m	2000 sq.m

* In practice 5–6 tons of coal (external fuel) and 8% by weight boiler ash (internal fuel) is used. These have been converted into equivalent coal for direct comparison with BTK.

The data presented in table 5.1 is region specific and pertain only to Gwalior. Very large diversity is found across different geographical regions in terms of quality of raw material used for brick making (soil and fuel), skills, labour cost, market price of bricks and the quality of bricks produced. Hence similar comparative statements comparing VSBK technology with other firing technologies would have to be prepared separately for different geographical regions.

The experience so far indicates that the data related to fuel consumption, manpower and area requirement for VSBK technology show little variations across different geographical regions. Other parameters (particularly those related with quality of fired bricks, production capacity, wages) show significant variations. In an overall analysis it appears that VSBK is one of the viable options for firing of bricks in decentralised small-scale production in India.

While factors such as fuel options, marginally higher costs for construction and mechanism/ arrangement to lift dry brick have to be considered while opting for VSBK, the technology offers several positive features, which are:

1. High fuel efficiency, with average fuel savings of about 20% compared to BTKs and 50–60% compared to clamps
2. Lowest SPM emissions
3. Lower fugitive emissions and cleaner working environment
4. Consistency in fired brick quality
5. Less space requirements for kiln structure (space saving of about 60% compared to BTK)
6. Kiln structure is weather protected and hence VSBK can be operated even during rainy season hence extending the brick firing season.
7. Provides flexibility in production. The kiln can be easily started and stabilizes within a very short time and hence, depending on market demands and raw material availability and the production can be varied