Use of Charcoal as Internal Fuel in Vertical Shaft Brick Kiln
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Abstract—A large number of brick kilns are operating in the Kathmandu Valley. These brick kilns are major sources of air pollution of Valley. For the better energy performance and less pollution emission from the industries a new type of brick kiln, Vertical Shaft Brick Kiln (VSBK) was introduced in Nepal since 2003. The energy and environmental benefits from the operation of VSBK are more than other existing brick firing technologies. For further betterment on energy, environment and economic performance, the internal fuelling for brick firing can be done by using renewable solid biomass, charcoal, produced by community forests within the country. Three ratios of internal fuelling by charcoal viz 40%, 50% and 60% for the brick firing were prepared on the basis of existing energy consumption pattern in kiln. For each of ratios 20,000 bricks were prepared and its energy performance, emission monitoring and brick qualities were monitored. The specific energy consumption on 60% internal fuelling ratio was found to be 0.59 MJ/Kg of fired bricks. The figure was least among three ratios and also less in comparison with only coal as external fuel. The emission monitoring on suspended particulate matter, SO$_2$, NO$_x$, CO and CO$_2$ revealed that there were no significant pollutant emissions with increasing internal fuel ratios. No significant increase in breakage was also monitored with increasing internal fuel ratios. Hence, 60% internal fuelling by charcoal was recommended for the commercial firing which not only reduces the consumption of coal also decreases the pollution emission with increasing brick quality.

Index Terms—VSBK, coal, charcoal, emission, internal fuel

I. INTRODUCTION

The brick production in Nepal has begun since more than three thousand years ago. The evidences found like bricks pieces, ceramics products, artefacts, potteries, etc from the excavation and exploration of old heritages like Lumbini and Tilaurakot proves that brick production in Nepal is a very old phenomenon [1]. But the commercial brick manufacturing technology was introduced in Nepal since 1950 [2]. Brick industry a seasonal industry [3] generally runs from December to May. Among all brick industries in the country, a large numbers are present within the Kathmandu Valley. According to All Nepal Brick Kiln Association, there are about 104 brick kilns operating in the Kathmandu valley alone [4]. There are various types of brick kilns like Fixed Chimney Bull's Trench Kiln (FC BTK), Movable Chimney Bull's Trench Kiln (MC BTK), Fixed Chimney Force Draught Bull' Trench Kiln (FC FD BTK), Fixed Chimney Natural Draught Bull's Trench Kiln (FC ND BTK), Vertical Shaft Brick Kiln (VSBK) etc. Among them, VSBK is found that it is more environment friendly than others. These brick kilns are one of the main contributors of air pollutants in the valley’s atmosphere specially the Suspended Particulate Matter (SPM) and Sulphur Dioxide (SO$_2$) [3]. According to a study conducted by the World Bank and ENPHO in 2007 [5], brick kilns are one of the main contributing sources for particulate matter, PM$_{10}$ in the valley with 11% contribution on total pollution emission. In another study, the contribution of brick kilns was found to be 28% which is more than other sources like domestic fuel combustion (25%), cement factory (17%), vehicle exhaust (12%) and road re-suspension (9%) [6].

The main source of pollution from the brick kiln is none other than the coal used for burning the green bricks. The rate and amount of emission also depends on the types of kilns used and quality of coal. In the year 2008/09, Nepal imported about 293 thousand tons of coal from India. Kathmandu alone consumed about 40% of it and is mainly used in the industrial sector mainly in the brick kilns and cement factory [7]. Within the valley, this sector has become the single largest consumer of coal. The share of energy in the total cost of brick production is 40% to 50%. Generally medium grade bitumen coal is used for the firing process of the bricks [8]. The low quality of coal likes low grade bitumen and lignite emits high pollution than the high quality coal.

Vertical Shaft Brick Kiln (VSBK)

The environmental and economic benefits of the VSBK over other technology are identified by several research works. The air pollution was reduced in Dhaka with providing faster benefits for public health by introducing VSBK technology [9]. The study of Ministry of Population and Environment (MOPE) and Environmental Sector Program Support (ESPS) showed that the total suspended particulate matter has been decreasing since 2001 introducing the advance and cleaner brick firing technologies like fixed chimney, VSBK etc and banning the operation of moving chimney [10]. From a research study it was concluded that VSBK significantly reduces the energy consumption and pollution emission hence Promotion of VSBK in Kathmandu valley can provide a good example for co-benefit of local air pollution and global GHG emission [11]. The VSBK technology greatly reduces the stack emission of the brick kilns including total mass emission load, total CO$_2$ as well as coal consumption. The black carbon emission of the VSBK technology is 10 and 20 times less than FCBTK and MCBTK [12]. It was also mentioned that VSBK is one of the best option for reducing air pollution and for reducing energy consumption along with fixed chimney, zigzag kiln in India [13].

Use of charcoal in VSBK

Biomass considered as forest waste which is a by-product of annual cutting and pruning activities are used to produce charcoal [14][15]. This activity is carried out mainly by the poorest households in the Community Forests. The current demand of char is low and limited. Charcoal is mostly being used by the rural households and low income level households in urban area. Besides these, it is found to be used as fuel in different cottage industries like bread baking, metal smelting operation, briquette making and furnaces, while it also has great potential to used in the brick
kilns as well replacing the current fueling system i.e. from coal and fire wood. The powder of charcoal can be used as the internal fuel in VSBK which will substitute the coal consumption.

**Objectives**

The broad objective of this research project is to use the charcoal as internal fuel with optimum ratio in VSBK. The specific objectives of this study are as follows:

- To identify the specific energy consumption pattern in three different internal fuel ratios of 40%, 50% and 60% bricks (internal fuelling is on energy consumption basis)
- To evaluate the stack emission based on SPM, CO, CO$_2$, NO$_x$, and SO$_2$ emission
- To identify the optimum internal fuel ratio for firing the bricks.

**II. MATERIALS AND METHODS**

Shree Satya Narayan Itta Bhatta (brick kiln) is the study site of this research study. This brick kiln is commonly known as W-bricks, name after its logo of the brick. It is located in Imadol VDC ward number 09 of Lalitpur District. This VSBK was established in 2003 as a pilot VSBK project by closing the existing MC-BTK. This industry was established with two shafts but now there are six shafts, in which all shafts have been operating in peak production season.

The specific energy consumption was determined with the amount of coal requirements for firing of green bricks under ideal temperature conditions with three different internal fuel ratios bricks viz 40%, 50% and 60% on the basis of energy consumption. For this determination the calorific value of both coal and charcoal were determined by digital bomb calorimeter and the weight of both dried green bricks and fired bricks were determined gravimetrically.

In the case of stack emission monitoring, different parameters like velocity of plume, SPM, SO$_2$, NO$_x$, CO and CO$_2$ were determined. Velocity was determined with S-type Pitot tube. SPM, SO$_2$ and NO$_x$ were determined with APM 620 handy stack sampler and CO, CO$_2$ and O$_2$ were determined with Orsat gas measurement equipments. All methods were performed by following standard procedures for stack emission monitoring.

**Experimentation**

After the determination of specific energy consumptions with only coal as external fuel, three ratios for internal fueling were selected as 40%, 50% and 60% for internal fueling by charcoal. Then 20,000 green bricks were made by mixing the energy equivalent charcoal amount to the soil in each ratio by determining the calorific value of charcoal. Then after drying the green brick the firing were performed in ideal temperature condition of the shaft. Emissions were monitored and coal consumptions were also noted during firing. At last energy consumption pattern and emissions were compared in all three ratios. The optimum char ratio was then finally identified for commercial firing.

**III. RESULTS AND DISCUSSIONS**

**3.1 Specific energy consumptions (SEC)**

The firing of various ratios of char mixed bricks was done in two different seasons. The green bricks with 40% and 50% char ratio were fired in July 2012 where as the green brick with 60% char ratio was fired in July 2013.

![Fig. 1: SEC with different internal fuel ratio](image)

The SEC on 60% internal fueling bricks was found to be least among three internal fuel ratios. The specific energy consumption on 0% internal fueling was found least among other ratios. It was because, the organic matter content of soil was higher (3.45%) than those soil used in internal fueling by charcoal (0.5% to 2%). But the average SEC of VSBKs from different literatures VSBK monitoring by IEM from 2003 to 2008 showed that the range from 0.8MJ/Kg of fired bricks to 1MJ/Kg of fired bricks. Hence it can be concluded that the SEC is found lesser with increase in internal fueling by charcoal.

**3.2 Suspended particulate matter**

![Fig 2: Comparison of SPM emissions with different internal fuel ratios](image)

In comparison with different internal fuel ratios the emission of SPM is also less than the non internal fuel bricks firing monitored in 2005 [16] and 2009 [17] in same shaft of
the brick industry and also less than the non internal fuel in same year of monitoring. SPM emissions with different internal fuel ratios were below the national recommended standard of 400 mg/Nm³ for VSBK. With comparison to non internal fuel ratio the SPM emission was 38% less up to 50% internal fuel ratio and obviously more less in 60% internal fueling. As the coal consumption reduces with increase in internal fuel ratio there will be less SPM in increasing internal fuel. During 60% internal fuel ratios bricks firing the SPM emission could not be measured due to lack of instruments. Therefore, only RSPM and NRSPM were measured. The corresponding values for RSPM and NRSP were 8.3mg/Nm³ and 2.9mg/Nm³. The total dust hence becomes 11.1 mg/Nm³.

### 3.3 SO₂

![Graph of SO₂ emission on different fuel ratios](image)

**Fig 3:** Comparison of SO₂ emission on different internal fuel ratios

The average SO₂ emission for different internal fuel ratios showed that the emission concentration had been decreasing with the increasing in the internal fuel ratio as shown in fig 3. These values were also comparable to IEM 2005 and Prajapati 2009. No standards with regards to SO₂ emissions are recommended as it is directly related to the kind/type of coal available. But from the above data obtained it was clear that the SO₂ emission was least in high internal fuel ratios.

### 3.4 CO and CO₂

![Graph of CO% in different fuel ratios](image)

**Fig 4:** Emission of CO% in different fuel ratios

Basically CO and CO₂ emission are used in the energy auditing of the shaft but these emission have very crucial role for the bad atmospheric condition. The decreasing percentage of CO emission with increasing internal fuel ratios clarified that the total internal combustion of the fuel and green bricks. The similar types of results were also obtained in the emission of carbon dioxide gas with different internal fuel ratios bricks. 11.25% and 11% CO₂ were measured for 40% and 50% in internal fuel ratios respectively. These results are quite higher than the results obtained by Prajapati 2009, with both internal fuel and non internal fuel and are also higher than IEM 2003 and IEM 2005 monitoring. But before drawing conclusion about CO₂ and CO emission, detailed analysis should be done on the basis of only these emissions.

### 3.5 NOx emission

Petroleum products like gasoline are the main sources of NOx. Coal contributes very less to the NOx emission. The emission of NOx was found to be very less in all internal fuel ratios green bricks firing. Its value was less than 0.28% and less than 0.028µg/Nm³ during 40% and 50% internal fuel bricks firing. But during 60% internal fuel firing its value was in undetectable range.

### 3.6 Physical quality of bricks

The quality of brick is identified by its physical properties like breakage, sound, color and compressive strength. Practically it was found that the quality of internal fuelled bricks was better in quality than without internal fuel. The breakage rate was reduced with various ratios of char mixed bricks where as the breakage percentage was least in the 60% char mixed bricks. The other properties like sound and color which are the qualitative properties were also found best with 60% of char ratio.

![Graph of Breakage percentage with different internal fuel ratio](image)

**Fig 5:** Breakage percentage with different internal fuel ratio

### IV. CONCLUSION

The average specific energy consumption in the 60% internal fueling of charcoal is found to be less in comparison with other three ratios of 40%, 50% and with non internal fuel ratios. The emissions of SPM were also found to be decreasing with increasing internal fueling. It was monitored that up to 42% less emission of SPM was found in 60% internal fueling than in non internal fueling. The sulfur dioxide emission particularly depends on the nature of coal used. The decrease in SO₂ emission with increasing internal fuel ratios also observed like as in the case of SPM emission. The decrease in coal consumption in each successive internal fueling leads to this type of results. NOx emission is not the serious problem from the VSBK as its primary source is gasoline. Hence, very low NOx emissions were observed in all internal fueling as it less than 0.154 µg/m³ in 40% internal fuel ratio. Carbon monoxide and CO₂ emission were also less in higher internal fueling ratios and than non internal fueling ratios. The Breakage percentage
was also found to be less in 60% internal fueling and other physical qualities like sound, color was also better in 60% internal fueling by charcoal (quality of bricks). From the assessment, on the basis of energy, environmental and brick quality performance of internal fueling by charcoal on three different ratios, 60% internal fueling is identified for the commercialization. The application of charcoal as an internal fuel not only substitute the coal consumption, it also reduces the pollution emission and enhances the brick quality.

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