Introduction

Brick is one of the most commonly used building materials in Nepal with about 3.2 billion bricks produced and consumed annually[1]. There are 800-850 brick kilns in operation throughout the country[1], according to the Federation of Nepal Brick Industries (FNBI). The brick production sector is a huge part of the economy in Nepal with investment in the sector estimated at USD 36 million[1]. Brick kilns are predominantly found in the Kathmandu Valley and in the flat land of the Terai. There are approximately 110 brick kilns operating within the Kathmandu Valley alone[2].

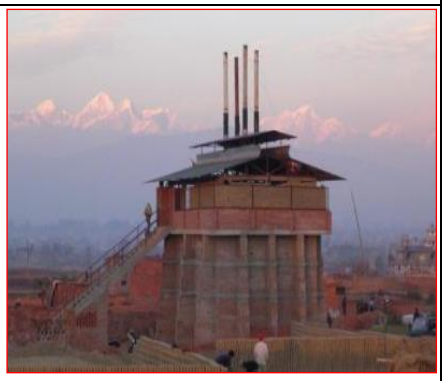
Brick production is a seasonal industry that generally runs in dry season from December to May. Despite improvements in recent years, brick production continues to have serious inherent environmental and social issues. Brick kilns have very high energy consumption and remain one of Nepal's biggest polluters. A study conducted by World Bank in 2007 identified brick kilns as one of the main sources of air pollution in the Kathmandu Valley's atmosphere[4]. Suspended Particulate Matter (SPM), Sulfur Oxide (SOx), Black Carbon (BC) and PM10 are major pollutants from brick kilns[5]. Brick kilns in the valley emit 11% of total PM_{10} emission within Kathmandu Valley[4]. Coal is major fuel for brick firing in Nepal while other fuel such as firewood, agricultural residue, rice husk, saw dust are also used. The study shows that brick industries consume 449,358 tons of coal annually[2]. The monetary value for buying coal would be 10 billion rupees annually. The Energy Synopsis Report of Water and Energy Commission Secretariat (WECS) reported that in the year 2008/09, Nepal imported about 293 thousand ton of coal from India, 40% of which is consumed in Kathmandu. This coal is mainly used in industrial sector like cement, lime and brick kilns[1].

The social issues surrounding the brick production industry include child labour and bonded labour and the people employed in the brick industry tend to be from the most marginalised groups of society[3].Despite the poor working conditions, the brick industry in Nepal is one of the largest employment generating sectors employing more than 175,000 workers seasonally.

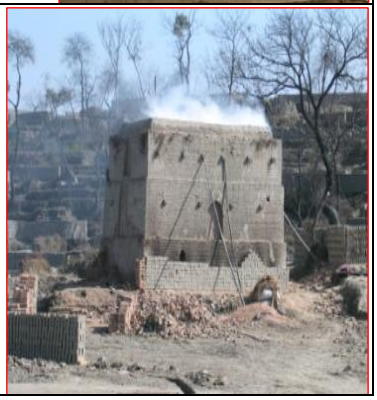
[1] http://www.minergynepal.com/publications/SEC%20Report_MinErgy.pdf
[2]FNBI, 2015 Informal Interview with Mahendra Bahadur Chitrakar
[3]http://www.wecs.gov.np/pdf/snyopsis.pdf
[4]http://siteresources.worldbank.org/INTRANETENVIRONMENT/3635842-1175696087492/21643874/NepalCEAReport.pdf
[5]http://brickclean.net/reports/Report%20Joshi%20-20Environmental_health_effects_of_brick_kilns_in_Kathmandu_valley.pdf[6]http://www.goodweave.org/uploads/Better-Bricks-Nepal_Two-Page_Overview_March-25.pdf
[1] http://www.newbusinessage.com/MagazineArticles/view/1251
[2] http://www.minergynepal.com/publications/SEC%20Report_MinErgy.pdf
[3]http://www.theguardian.com/global-development/2015/feb/12/how-nepal-is-trying-to-solve-its-blood-brick-problem

Brick Firing Technology

There are four types of brick firing technology used in Nepal:

Brick Firing Technology	Description
Fixed Chimney Bull's Trench Kiln (FC BTK)	This is the most widely used brick firing technology in Nepal, and the rest of South Asia. The FC BTK is a "continuous, moving fire kiln in which the fire is always burning and moving forward in the direction of air flow due to the draught provided by a chimney"[4]. This means that the "bricks are being warmed, fired and cooled simultaneously in different parts of the kiln"[5].  (Photo: Chhampi Mai Brick Kiln, Chhampi Lalitpur)
Vertical Shaft Brick Kiln (VSBK)	Vertical Shaft Brick Kilns use a "continuous, updraft, moving ware kiln in which the fire remains stationary while there is counter current heat exchange between air (moving upward) and bricks (moving downward)"[6]. The uptake of this brick firing technology has been relatively low in Nepal in comparison to other South Asian countries, and it is used in only eight brick production factories in Nepal, including two in the valley.  (Photo: RK VSBK, Imadol Lalitpur)

[4] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/1%20Fixed%20Chimney%20Bulls%20Trench%20Kiln%20(FCBTK).pdf
[5] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/1%20Fixed%20Chimney%20Bulls%20Trench%20Kiln%20(FCBTK).pdf
[6] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/4%20Vertical%20Shaft%20Brick%20Kiln%20(VSBK).pdf

Brick Firing Technology	Description
Hoffman Kiln	Hoffman kilns are "continuous, moving fire kilns in which the fire is always burning and moving forward through the bricks stacked in the circular, elliptical or rectangular shaped closed circuit with arched roof. The fire movement is caused by the draught provided by a chimney or a fan"[7].There is very little use of Hoffman Kilns in Nepal. (Photo : Bhaktapur Itta tatha Tile Udhyog: Jagati Bhaktapur) 
Clamp Kiln	Clamp kilns are the most basic type of kiln and no permanent kiln structure is built. Clamp kilns consist "essentially of a pile of green bricks interspersed with combustible material"[8]. The bricks to be fired can be either" piled up on a thin bed of fuel (usually in case of coal fired clamps)"or "tunnels are made through the base of the pile in order to feed the fuel (usually in the case of firewood fired clamps)"[9]. (Photo: Clamp Kiln, Chaling, Bhaktapur) 

Brick Quality and Size

According to Nepal National Building Code (NBC 109: 1994), the *standard brick* must be *240 mm long, 115 mm wide and 57mm thick* with a tolerance of +/-10 mm on length, +/-5 mm on width, and +/-3 mm on thickness. But in actual practice the size of bricks produced varies widely across the country. Bricks produced in the Terai region are generally bigger in size than those produced in the Kathmandu valley. The size of bricks available on the market varies as follows:

- Length 230 -250mm,
- Breadth 110-120mm, and
- Thickness 50-75mm.

The *Crushing Strength* standard of brick, required under the Nepal Building Code (NBC), is *35 kg/cm^2*. But in actual practice the crushing strength is generally higher[7]. According to the Nepal Building Code the *water absorbance* of bricks should be *15% for machine made bricks* however it could be *up to 25% for the hand moulded bricks*.

Impact of 2015 Earthquake on Brick Production

The 7.8 magnitude earthquake which struck Nepal on April 25, 2015, and the subsequent aftershocks, severely affected the brick industry. At the High Level Assembly organized by the Climate and Clean Air Coalition (CCAC) in May 2015, ICIMOD's Senior Air Quality Specialist, Dr. Prakash Bhave, talked about the aftermath of the Nepal Earthquake 2015 and informed that approximately 110 kiln chimneys in the Kathmandu Valley were partially or fully damaged by the

[7] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/5%20Hoffman%20Kiln.pdf
[8] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/8%20Clamps.pdf
[9] http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/8%20Clamps.pdf

earthquake. Four people lost their life as a result of this damage, many others were injured, and the estimated cost of this damage is 1.12 billion NPRs.

From L to R: FCBTK kiln in Lalitpur, Hoffman kiln in Bhaktapur, and FCBTK in Bhaktapur. All were damaged by the April 25th 2015 earthquake.

Future Outlook

The demand for bricks is projected to increase over the coming months and years as the reconstruction following the earthquake adds to demand from an already booming construction industry. According to the Government of Nepal, the demand for bricks will increase to 12 billion bricks annually, almost four times higher than current annual production.[8] However, the brick production in the current season was lower than normal because of erratic rainfall and the impact of the earthquake. Kilns are also facing labour shortages. Workers at the brick kilns, who come mostly from outside Kathmandu, have left the valley due to the fear of subsequent earthquakes. Even before the earthquake, the Federation of Nepal Brick Industries Association said that brick production had dropped by 40%, due partly to erratic rainfall (ICIMOD). As a result, the price of bricks is expected to increase because of higher demand. Already the price of bricks has substantially increased compare to pre earthquake rates. Before the earthquake, the price ranged between 11 NPRs / brick to 15 NPRs / brick. Currently, bricks are being sold at 17 NPRs / brick or more.

To cater increase demand, many brick kiln entrepreneurs will like to rebuild their faster. They would like to build bigger kiln with higher production capacity. Increase brick production will most likely increase pressure on environment and energy demand. This colossal demand and resultant rise in the price of bricks might even lead kiln owners to overlook environmental standards in kiln design, like the height of the chimney. The safety of workers may also be compromised in the rush to produce bricks, as some of the affected kilns are operating with broken chimneys.

On a positive note, the construction of new kilns and repair of damaged ones can be viewed as an opportunity to encourage kiln owners to take up new environmentally sound technologies. With funding from CHeRN, USA and CCAC/ICIMOD, improved version of FCBTKs has been designed. New design and drawings have been distributed to brick entrepreneurs within Kathmandu Valley. In addition, the scarcity of bricks has raised public interest in alternative construction materials. With these problems and opportunities in mind, there is a clear opportunity to rebuild the damaged brick industry in Nepal is such a way as to increase kiln efficiency and reduce black carbon pollution.

Possible Future Interventions in brick sector

Despite all the losses, this earthquake has also provided a unique opportunity to reshape the Nepalese brick industry to make it earthquake resistant, energy efficient, more environmentally friendly, improve labour conditions, and produce better bricks[10][11].

Some potential interventions are:

- Follow improved design of FCBTKs while rebuilding and reconstruction
- Adopt mechanised or semi-mechanised green brick production to enhance product quality as well as productivity
- Promote hollow bricks instead of solid bricks as hollow bricks offer higher environmental and social benefits
- Elongate the brick production season by adopting compact and closed structured design
- Promote small scale cleaner technologies to cater to local demand in rural areas

[10] http://www.poverty.ch/documents/brick.pdf
[11] http://www.npc.gov.np/web/new/uploadedFiles/allFiles/PDNA-vol-B.pdf