Clay and Concrete brick

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Introduction

Brick is one of the most used and versatile building materials in use today. Bricks can be defined as modular units connected by mortar in the formation of a building system or product. Commonly the word brick is used to refer to clay bricks, which are manufactured from raw clay as their primary ingredient. However concrete brick has also become a favoured material in recent times. This review will adumbrate the impact of these building materials on energy use and the environment.

Clay brick

Clay bricks are arguably the most common brick type used in construction today. The same can be said for antiquity, since clay bricks are found in numerous old and ancient structures. Though numerous theories exist, it is not known when man first discovered that through heating moulded plastic clay to a high temperature, a hard and durable product could be formed.

The key to clay bricks and their success over the ages is in the simple process used to manufacture them. Clays (e.g. Kaolinite) are an abundant raw material which can be extracted relatively cheaply from the earth. With the addition of water clays become plastic and are easily extruded and moulded into any desired shape. This ability to be worked and shaped is an ideal property for producing uniform identical units such as brick, as moulds could be reused quickly. Over time the use of moulds has diminished as modern brick manufacturing techniques have focused on extrusion which is more efficient. Traditionally clays are fired in a kiln with temperatures ranging from $1000^{o}C$ to $1200^{o}C$ depending on the clay (Clay Brick Association, 2002).

Figure 1: Clay brick processing can be highly mechanised as seen in the first image (left), the image on the right shows the simplicity of the process, with bricks being processed in a rudimentary kiln.

The sequence in the manufacturing of modern clay brick may be generalised into the following stages.

1. Mining
2. Size reduction
3. Screening
4. Forming and Cutting (Extrusion)

5. Coating or glazing (surface treatment)
6. Drying
7. Firing and cooling

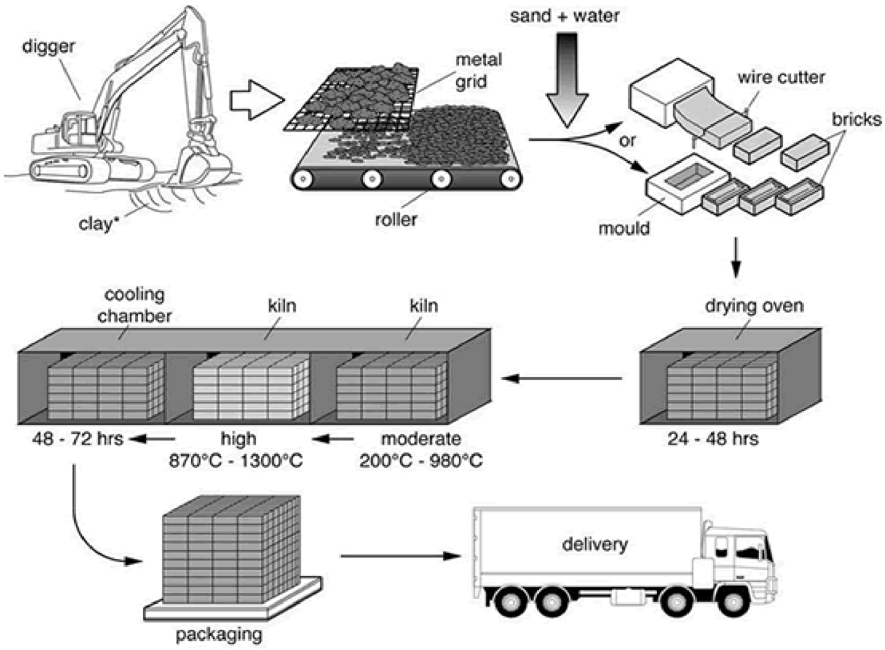

Figure 2: Modern brick manufacturing schematic (www.construction-machine.org)

The stage in which the most energy is consumed is the firing stage. This stage is the most contentious because it calls into question the amount and type of energy sources used. In South Africa common fuels used in the kilns are coal, gas or oil (Clay Brick Association, 2002). The use of hydrocarbons has the undesirable result of releasing greenhouse gas such as carbon dioxide into the atmosphere. This invariably has a negative impact on clay brick as a green building material.

Energy use and environmental impact of clay brick

Concerns about the environmental impact of various construction materials, including clay brick, have prompted manufacturers to undertake detailed analysis on the environmental impacts of their products. Think brick Australia (2010) commissioned a life cycle assessment on clay brick. The study which was based on assessing the environmental impact and energy consumption linked to clay brick over a 50 year period, found that the dominant cause of energy and associated emission of greenhouse gases was related to the long term operation of the structure built with the clay brick. The specific structure used by Energetics in their model was a brick house with varying floor, wall and orientation configurations. The study presented the following key findings:

- The embodied impacts (of clay brick) over the life time of a house (50 years) can be around half (45%-49%) of the total greenhouse gas emissions when compared to the energy consumption for heating, ventilation and cooling. When other energy requirements during the use of a house are taken into account the contribution of embodied impacts falls to 10%.
- When energy consumption for HVAC (during 50 years) is taken into account, the maximum effect of wall construction type on total GHG impacts is between 7% and 12%.

This study asserts that “when other energy requirements during the use of a house are taken into account the contribution of embodied impacts falls to 10%”(Think Brick Australia, 2010) . This statement should be read with cognisance of the numerous assumptions made in determining the environmental impact during the entire lifecycle. These assumptions include; the design and layout of a house built using brick, the house’s orientation and the climatic region in which the house is built. The quantities arising from these assumptions can be wide ranging and highly variable, which brings into question rationale in measuring the environmental impact of brick after the manufacturing stage.

Currently a study has been commissioned by the Clay Brick Association in South Africa to conduct a full lifecycle assessment on clay brick. While energy consumption and greenhouse emission are critical parameters for measuring the greenness of a technology, other important effects of brick manufacture are also considered by a case study undertaken to measure the sustainability of clay brick.

Figure 3: A brick kiln in Kabul Afghanistan: The type of fuel has a significant effect on the environmental impact of the brick product (source: www. nature.com).

Moedinger (2013) proposes that the degree of sustainability be measured by criteria such as, total energy content, consumption of the environment, emissions (including GHG’s), raw materials depilation, waste generation, recyclability, capital costs and durability. The energy embodied in clay brick compared to other construction materials studied by Moedinger [3] are shown in the table.

Table 1: Embodied energy for selected construction materials (Adapted from Fritz Moedinger)

	Bulk density kg/m^3	Energy content MJ/m^3
Brick fired with fossil fuels	700	2524.2
Reinforced concrete	2400	5264.9
EPS	20	1928
Rockwool	80	1399.4

Table 2: Embodied energy of clay brick fired with fossil and renewable fuels

	Bulk density kg/m^3	Energy content MJ/m^3
Brick fired with fossil fuels	700	2524.2
Brick fired with renewable fuels	700	910

Data from the case study shows that brick performs favourably when compared to reinforced concrete EPS and rock wool in so far as embodied energy is concerned. Table 2 adapted from Moedinger's (2005) case study shows that by using renewable fuels the embodied energy in clay brick is reduced by more than half, meaning that once fuels and cleaner energy sources are developed, there is potential for clay brick to be even greener. The renewable fuel used in the study was biogas.

Other criteria specifically relating to the manufacture of clay brick include land for mining, emissions of the production process and the consumption of raw materials. Since the production of building materials varies significantly, no direct comparisons to other competing construction materials were presented in the study.

Concrete brick and blocks

Concrete bricks are brick sized concrete prisms used for building purposes. They are an attractive alternative to clay for brick manufacturers because their production does not require high temperature kilns and the associated infrastructure and operating costs that accompany them. In essence concrete bricks and blocks are a mixture of a binder (usually Portland cement), sand, aggregate and water.

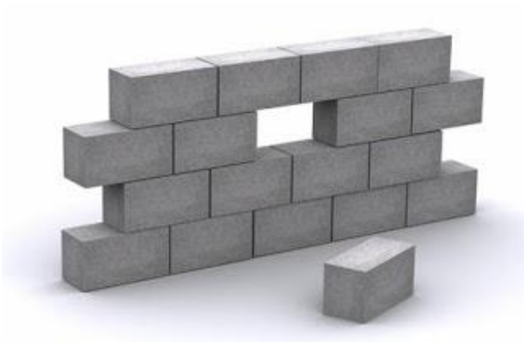

Figure4: Concrete brick

The nature of concrete brick and block manufacture can range from being highly labour intensive to being highly mechanised. The manufacturing process can be summarised into the following stages. Raw materials are first purchased, sand, stone and aggregate are sieved and separated into their desired size fraction. The appropriate type of cement for cement blocks and other conditions is procured. From there on, the cement, aggregate and sand are mixed with water together with any suitable admixture. The mixing may be done by workers using shovels, or in more mechanised production large pan mixers could be used. Once the concrete has been mixed and it is suitably plastic, it can be moulded. Again the type of moulding can be simple human powered moulds or mechanised brick making machines, which use electricity or diesel to mould and compact the bricks.

Figure 5: Concrete provides flexibility for manufacturing; the figure shows two manufacturing scenarios, one that is highly mechanised and one that is labour intensive.

Energy use and environmental impact of concrete brick

Portland cement, being the most critical component in conventional concrete blocks and bricks is also the component which has undergone the most amount of processing. The processing of cement involves heating clinker to a temperature approaching 1450^{o}C in a rotary kiln, this high temperature coupled with carbon dioxide released during the decarbonisation reaction in the production of cement, produces a material with high embodied energy and high emissions of greenhouse gas. Approximately 1 tonne of CO_2 is released into the environment for every tonne of Portland cement produced (Davidovits, 2011).

Table 3: LCA result is for cement and concrete [4]

Building product	Density (kg/m^3)	Thermal conductivity (W/mK)	Primary energy demand (MJeEq/kg)	Global Warming Potential (kg CO2-Eq/kg)	Water demand (l/kg)
Cement	3150	1.4	4.235	0.819	3.937
Cement mortar	1525	0.7	2.171	0.241	3.329
Reinforced Concrete	2546	2.3	1.802	0.179	2.768
Concrete	2380	1.65	1.105	0.137	2.045

Table 3 shows life cycle assessment results for cement and concrete materials. Cement is shown to be the most energy demanding and carbon emitting material in the list. Concrete brick may be comparable to cement mortar and concrete as the density of concrete blocks may fall within that their range.

Concrete brick produced in an efficient block yard will typically have cement contents less than 16% by mass (Cement and Concrete Institute, 2010). Aggregate takes up the majority of the volume in concrete block which helps to reduce the embodied energy generated by Portland cement usage. Aggregate is a naturally occurring material, however in places such as South Africa, aggregate crushing is required in many cases. The energy consumed in crushing will increase the embodied energy of the final concrete block product.

Figure 6: Aggregate being crushed

Conclusions

Clay brick and concrete brick are in wide use in construction. Both materials have distinct advantages over each other. Clay brick production is a simple and continuous process from raw clay to finished brick. Clay brick provides the benefit of having its environmental impact being linked primarily to the energy inputs required for production. Therefore as technology advances and clear sources of fuel are developed clay bricks can only become more sustainable. Concrete bricks are simple to produce when all the ingredients are at hand. Concrete bricks can be manufactured on the site of construction thereby saving energy and cots related to transportation. Portland cement is the most environmentally contentious ingredient in concrete brick and blocks. However cement technology has moved successfully towards the replacement of cement clinker with waste materials such as fly ash and ground granulated slag. This replacement has the double advantage of replacing a material with high CO_2 emissions with a material, which would under ordinary circumstances end up as waste.

References

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