THE ECONOMICS AND METHODS OF BRICK MANUFACTURE: A COMPARISON OF USA TO SE ASIAN PRACTICES

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ABSTRACT
Brick manufacture in some parts of the world still uses a traditional firing technique, rather than the continuous burn kilns used in more advanced countries. In Indonesia, the preferred fuel for the manufacture of brick is rice husks, within the setting of a cottage style industry using techniques that predate the Industrial Revolution by millennia. The purpose of this paper is to compare and contrast the manufacture of brick in three distinct regional settings, Indonesia, Thailand, and the United States. The problems of each of the manufacturing types are placed within the context of a resource scarce world that is seeking a sustainable culture.

KEYWORDS: fired brick, SE Asian practices, firing methods.

INTRODUCTION
Masonry has developed in manufacturing sophistication in the last two millennia, since the Romans moved to fired over unfired brick. The significant technological changes occurred in the last century with movement from simple kilns to continuous tunnel kilns, able to produce millions of brick to a consistent standard in a short time. It is interesting to visit Indonesia and observe the development of modern cities of masonry structures using what is essentially technology equivalent to the systems used by the Romans at the beginning of the modern era. The purpose of this paper is to compare and contrast the methods of manufacture and the economics of manufacture in three countries, Indonesia, Thailand and the USA. This paper is not an exhaustive investigation. The paper outlines the issues and identifies the problems for study by future Masters Students at TAMU as part of their research program.

LITERATURE REVIEW AND PLANTS
This research work develops from a study by the second author into the causes of fatalities in a major Indonesian earthquake in 2006 [1-3]. Extensive published research exists on the problems of masonry in earthquakes and the potential for fatalities [4-7]. The natural objective of reducing earthquake fatalities has been a driving force in the development of improved masonry standards in the last century [8, 9], as the economics of brick manufacture have driven the manufacturers to develop highly efficient tunnel kilns, to replace the older style of bee hive kilns. This dual objective meets the requirement of governments of improved life safety [10, 11].

Brick produced in beehive kilns were discussed extensively by Baker in terms of measured properties in the early nineteenth century [4, 12]. Hausler [13] documented the damage to masonry structures in several of the major fatal earthquakes in Indonesia in the last few years. In a recent field trip with the second author, she arranged a tour of two typical Indonesian brick plants. This paper documents the results of the field trip and compares the Indonesian practices to Thai and US practices. This paper uses three brick plants to compare the practical difference in manufacturing bricks in the three countries. The first plant is located about 50 kilometres NE of Padang on Sumatra, Indonesia. This limited operation uses manual and animal labour to produce brick, fired with rice hulls. Figure 1 shows a small-scale Indonesian brick plant.

Figure 1: Indonesian Brick Plant in West Sumatra in 2008

The second plant is located in Thailand. Figure 2 shows the brick plant in Thailand. Thailand has both types of plant, both handmade and modern tunnel kiln, in one way highlighting the economic development differences between the two countries.

Figure 2: Wood Fired Thai Brick Plant in 2009

The third plant is located in the USA. Figure 3 shows a typical kiln in a US Brick plant.

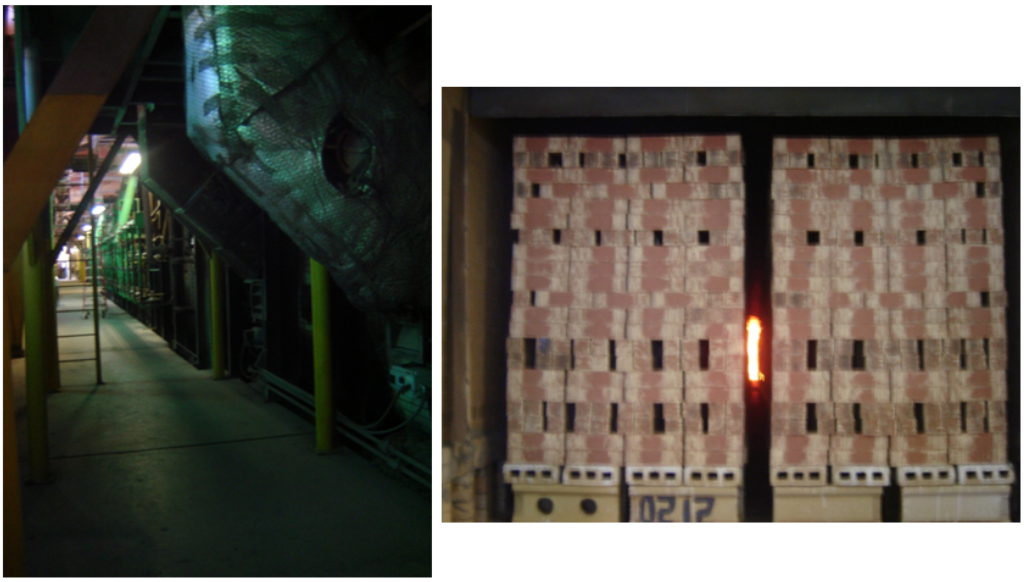

Figure 3: US Brick Plant Kiln in 2009

Bricks are common construction materials for many countries including, Indonesia, Thailand and the USA. In Thailand, brick is the structural element for many archaeological monuments, sacred architecture, historic temples and some residential buildings in the last few hundred years. In the past hundred years, brick were used to build temples or palaces only, while common houses or buildings were built from timber. In Indonesia, bamboo was the common building material for housing and some evidence still exists with old bamboo houses, although the majority of houses are now made of masonry, usually handmade and usually red, really following the Dutch practices, as shown in Figure 4. However the real problem is one of safety for masonry in earthquakes [14] for all masonry, but particularly for soft poorly fired brick.

Figure 4: Handmade Indonesian Brick in 2008

COMPARE AND CONTRAST THE METHODS AND RESULTING OUTPUT
Table 1 lists the characteristics of the different plants.

Table 1: Brick Plant Methods

Location / Description	Indonesia	Thailand	USA
Unit Brick Cost (2008 US cents)	5	Varies	55
Method of manufacture	Rice Hull	Timber and Rice Hulls	Natural Gas
Type of firing	Open Kiln	Open Kiln and Modern	Modern Tunnel Kiln
Typical Plant Production Capacity per day	700	Varies	100,000+
Forming Method	Hand moulds	Hand moulds and machine moulded	Machine moulded
Number of employees	5	5 to 50	50
Clay Source	Road Cuts	Small Pits to Quarry Operations	Quarry Operation
Delivery	Hand Stacked on Trucks	Both	Palletized

In terms of early twentieth century economics, there were limited reasons to compare the operation of a modern brick plant to a handmade operation. Figure 5 contrasts the two operational methods, between Indonesia and the USA.

Figure 5: Handmade versus Machine Made

The real difference between the two methods is the water content required to form the brick. The handmade brick have higher moisture content and are formed at very low pressures. Three mechanical methods are used in different international plants; these are pressed brick with a frog,

extruded bricks typically with holes and repressed extruded bricks. The stiffness and strength of the brick generally increases as the method moves from pressed to repressed brick [12]. However, the significant changes in the perception of the environmental impact of greenhouse gas emissions means that an economic trend is to consider the complete economic cost to the world for a unit's production irrespective of the type of the unit. Three critical aspects highlight the economic and manufacturing differences in the plants. The first aspect is the moulding of the bricks. In terms of moulding methods, the environmental issue is the non-renewable energy used in the modern plant for moulding. The second aspect is the difference in the handling techniques. Figure 6 shows the differences in the labour, between SE Asia and the US.

Figure 6: Hand versus Machine Handling

There are still issues of hand handling of bricks in the older US brick plants, although this is usually limited to stacking the pallets for the kilns and then restacking the pallets for delivery. The first is a loose stack for heating control and the second is a tight small stack for delivery.

The third aspect is the firing method. Modern kiln technology developed in China and then spread to the rest of the world, now as in some early development stages the key element is to reuse as much of the waste heat as possible to reduce the overall cost of energy. A modern kiln uses a gas-fired system in place of the wood and other materials used prior to the 1940's. The handmade process however makes use of renewable energy sources because the manufacturers cannot afford a modern gas system and the local farming communities supply ready power with timber or rice hulls. Rice hulls are the predominant energy source in the West Sumatra region of Indonesia. In Indonesia, the continuous stacking process kiln uses rice husks, in Sumatra where

there is a large rice crop. Indonesia kilns are typically open on at least one side, and form a stack that extends over time.

In Thailand, the common handmade process of making bricks begins from preparing clay, then mixing with other materials dependent on each factories available source materials. Clay is milled in some version of a pug or animal mill. After the clay reaches an acceptable consistency with a high moisture content, it is placed by hand in the moulds, which vary in size depending on the demand in local market. Indonesian practice has essentially standardized on one size from the observations made in Java and Sumatra, which makes it easy to design houses around the standard brick (Refer to figure 4). Thai moulds are made from hard wood. After that the raw bricks are left to dry naturally by sunlight for days in Thailand, whilst in Indonesia is common to develop a set of covered open sided sheds to allow the bricks to dry naturally, but be protected from direct rain. Finally, the dried brick are burned in brick kilns usually for more than 10 days. The materials used to burn the brick are firewood and rice husk. Firewood is used at the early stage of burning, when the brick makers want to heat up the temperature rapidly. After burning for a while, the rice husk can maintain the temperature. This process takes approximately 20 days. Most of these brick kilns only have a permanent steel roof. The walls are temporary made from corrugated metal sheets. After the burning process is complete, these temporary walls are removed. Most of the brick kilns do not have chimneys, with smoke vented out of the kilns through the temporary walls [15, 16]. The brick kilns used in most local factories are easy built, as shown in Figure 7.

Figure 7: Simple Kilns in SE Asia in Thailand

The systems all take a wet clay-shale mix and develop a rectilinear brick that is easily handled. The differences are in the handling systems within the factories and the method of firing, which results in US plants that can produce 100,000 bricks per day and a small Indonesian plant that can produce 700 bricks per day. Baker and others [4, 8, 12, 17] present details of the differences in strengths and stiffness of the various types of bricks from the soft to the hard fired bricks. The

difference in strength between a rice fired brick and a gas fired brick is statistically significant, and of concern for earthquake safety. The contrasting features are in the cities developed from the different brick manufacturing processes. Padang in Western Sumatra and Yogyakarta in Java have a very high percentage of masonry dwellings of a very similar design, such as shown in Figure 8, but mainly with low rise structures housing a single family.

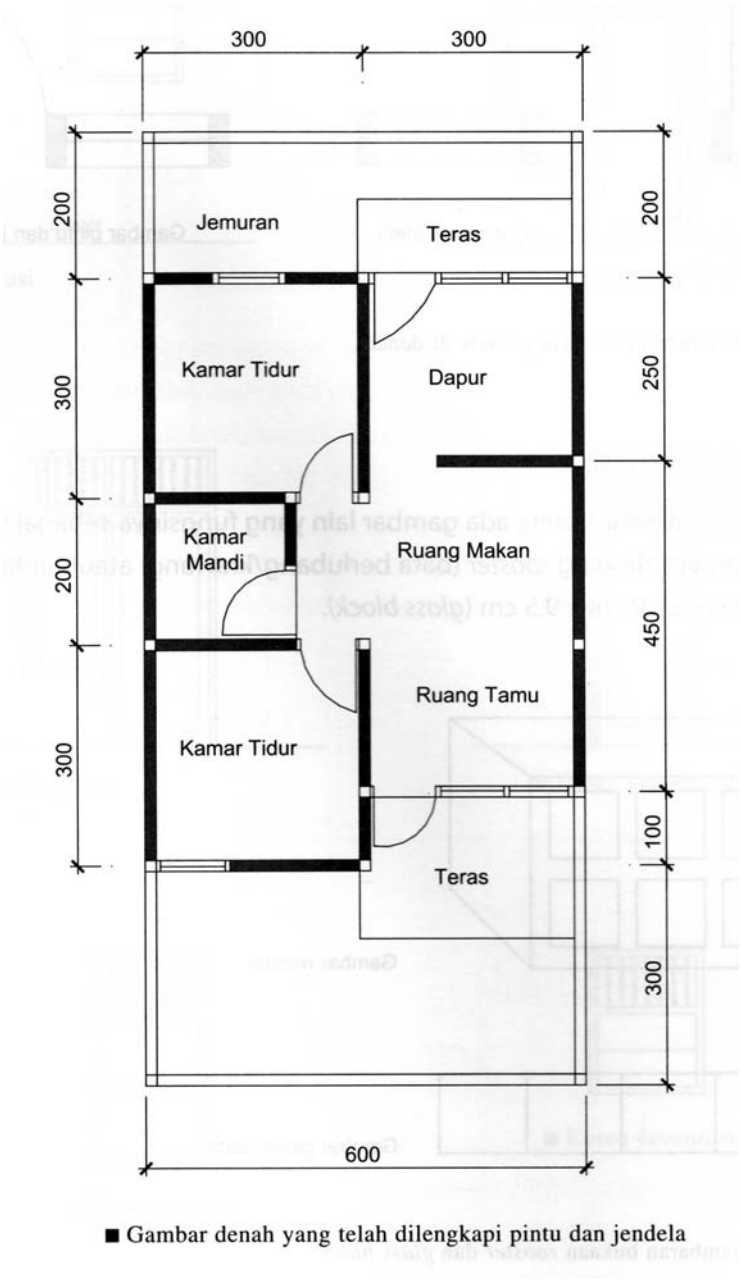

Figure 8: Typical Small Home in SE Asia in the Countryside (After Praktis, C. and D. Mudah) [18]

The second contrasting feature in SE Asia and other world areas of regular seismicity is the thin concrete frame used to reinforce the masonry as shown in Figure 9. The purpose of the frame is

to act as a bond beam and columns for the brittle masonry, providing adequate time for evacuation of the residents in an earthquake. This method appears to be effective and economic.

Figure 9: 100 mm RC Framing System in Indonesia

ECONOMICS OF THE PLANTS

There is no doubt that the manufacturing method that produces brick of a high quality and in consistently high quantities is the modern gas fired tunnel kiln. Of course this truth does not mean that the world masonry community cannot learn or relearn lessons from simpler methods of manufacturing masonry that has lasted somewhere in the world for the last two millennia. The structural engineering communities in these regions, such as Java, provide advanced design methods and applications to use the materials at hand to improve life safety in earthquakes, within the constraints of the local economy. The significant ethical question is: Can the world continue to afford to increase the number of tunnel kilns to produce a high quality brick for the current and perceived world demand? One of the reviewers asked the converse question: Can the world afford to continue to produce marginal quality bricks in open kilns that are unsafe for workers, waste energy and pollute the environment? If the US penetration rate for masonry was on par with places like Java and Sumatra, the demand for bricks and roof tiles in the USA would be a significant multiple of the current production. In some ways from a sustainability perspective one could argue that the US use of siding materials has some environmental advantages, although it does require a higher replacement rate for some forms of roofing and walls. It is not the intent of this short paper to look in detail at the economics and sustainability of the existing SE Asian practices to US modern practices, but a simple review of the economics is instructive as to the relative costs of the masonry production. Table 2 presents a review of the economics of the two systems from the perspective of input and output, rather than a strict dollar comparison.

Table 2: Brick Plant Economics

Country / Description of the Component	Indonesia	Thailand	United States
Population (million)	237	63	303
Land Area (km^2)	1,919,440	513,115	9,826,320
Density (per/km^2)	134	122	31
Observed Typical Home Size (m^2)	20-50	??	100-500
Gross Domestic Product per capita (Purchasing Power Parity) USD	3,728	7,906	47,025
Typical Number of bricks required for a full masonry home (thousands)	6	??	10-20
Typical Factory Output per day	700-1400	Varies	100,000
Number of Workers	5-7	5-50	50
Output per worker per day	140	140-2000	2000
Heat Source	Rice Hulls	Timber and Rice Hulls and Gas	Gas
Type	Open Kiln	Open Kiln, Beehive, Gas Fired Tunnel	Gas Fired Tunnel

CONCLUSIONS

Why is there an interest in the manufacture of bricks in Indonesia, Thailand and the United States? A number of important observations can be made from this data. The first observation is the change in Gross Domestic Product (Purchasing Power Parity) is a tolerable indicator of the slow transfer of manufacturing bricks using an open kiln to a modern gas fired kiln process, with the beehive kiln as an intermediate step. The process has not started at 3,800 USD per capita, but is complete by 47,000 USD per capita. The second observation is the cost of the unit brick, allowing for Purchasing Power Parity, the consumer in Indonesia, Thailand and in the USA are paying about the same cost per brick as a percentage of their annual income. There are economic implications in this observation that are beyond the limited scope of this paper to discuss, but must await a future paper. The third observation is the incredible penetration rate of masonry in the areas inspected in Java and Sumatra, coupled with the ability of the local craft manufacturers to produce a very high brick output from very limited resources sufficient to see the development of modern cityscapes. The fourth observation is the ability of the local engineering communities in Indonesia and Thailand to take the characteristics of the soft brick and develop a design that improves life safety. There is no doubt that these buildings are prone to earthquake damage and destruction, but serious efforts are underway to reduce the death toll. The fifth observation is the ability of the craft manufacturers in Indonesia and Thailand to produce bricks using very crude techniques more suited to the second century and not the 21st century. Has the masonry industry reached a further stage of a required transition, where there is a need to produce a masonry unit using less non-renewable energy and more renewable energy? Does the concept of Purchasing Power Parity suggest that the average human is willing to pay about one hundred thousandth of

their annual income per brick? Do these observations set a limit on the resources available to develop a brick unit using less non-renewable energy and more renewable sources?

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