ENVIRONMENTAL IMPACT OF MASONRY INDUSTRY

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ABSTRACT

The construction industry in Canada consumes more than 50% of natural resources, including energy and accounts for 17% of total water consumption. These figures relate only to the production of materials. During their lifespan, buildings continue to consume energy and pollute the environment. At the end of their useful life, buildings create waste through the demolition process. It is estimated that in Canada 35-40% of energy is spent during a building's operational life.

This paper looks at the impact of the masonry industry with a focus on clay brick in particular. It evaluates how this industry approaches "the three R's," namely, reduce, reuse, and recycle. All stages of clay brick from the manufacturing stage, through construction, to demolition are included in this study.

It is important to preserve and encourage the use of clay brick as it is part of our history. Brick plays an important role in the vernacular architecture of Canada. Its presence in our cities and rural areas reminds us that brick is a significant contributor to our architectural and cultural heritage. In order to promote the use of masonry, it is important that the construction industry evaluate all the benefits of its products from an environmental point of view, and that designers, contractors and the general public are educated about these benefits. This paper attempts to identify areas where the industry could improve its environmental record and demonstrates how the appropriate use of masonry can maximize benefits in the environmental assessment method.

KEYWORDS: clay brick, sustainability, life cycle assessment, LEED, thermal mass

INTRODUCTION

The gross economic output of the Canadian construction industry reached \$163 billion in 2004 [1]. Residential construction shared 40% of this market. In 2004, the industry contributed over \$67 billion (just over 12%) [1] to the Gross Domestic Product. It is predicted that the GDP, and the contribution of the construction industry to it will increase over the next five years, showing sharper growth at the beginning of the five-year period and levelling towards its end.

The construction industry is an important employer of Canadians, providing one of every sixteen jobs. The economic success of the industry is accompanied by its significant impact on the environment. Manufacture and supply of materials consumes 50% of natural resources, including energy. The industry is also responsible for 17% of total water consumption. The industry produced 11 million tonnes of waste (including waste from road construction) in 1998, a

staggering 375 kg of waste per Canadian. The operation and maintenance of each project results in further demands on resources and create waste. At the end of a building's design life, major rehabilitation or demolition takes place, creating further waste. Thus, each construction project has a significant environmental impact over an extended period of time. In order to decrease the impact of the construction industry on the environment, a number of issues have to be considered during the design-stage of a project. These issues include: 1) material and site selection (where applicable); 2) the impact of the construction process (pollution and waste); 3) the operation and maintenance of a project, which for buildings includes energy consumption, material replacement; 4) indoor environment quality; and 5) end of the life of the project when further waste is generated.

Canada's commitment to Kyoto (a 6% reduction in CO₂ emissions below 1990 levels by 2008) and rising public awareness are forcing each sector of the construction industry to evaluate their own practices and to look for the potentials which would result in both a better, "greener" product, and a better, "greener" practice, and which, perhaps, would at the same time give a company an economically competitive edge. This paper focuses on building construction, both residential and non-residential, which shares more than 50% of the construction industry's gross output. In particular, the paper looks at the masonry industry.

ENVIRONMENTAL IMPACT OF A BUILDING PROJECT

A Life Cycle Assessment is the complete evaluation of a building project. The environmental impact of such a project is assessed over the entire lifespan of the building, from the time the materials are selected, through construction, to occupancy, and finally, to the end of the building's life. Environmental impact is most commonly assessed by means of the concepts of "embodied" energy and "embodied" CO₂. The term "embodied" means "consumed" or "locked-in." Embodied energy over the lifespan of a building project can be divided into the following categories: 1) materials (all energy associated with a product); 2) construction (energy associated with entire construction process); 3) operation (energy required over the life of a project to support its function); 4) maintenance (periodical maintenance and refurbishment); and 5) end of life (demolition and disposal). The total embodied energy is split into four categories: 1) initial (materials and construction process); 2) operational; 3) maintenance; and 4) demolition.

In order to identify where the environmental impact of the construction industry can be minimized, a study was conducted by the author to find the embodied energy associated with each of the latter four categories for a single-family detached house in the Toronto area. Athena software was used to evaluate the embodied energy for different stages of the lifespan of this building. The objective of this investigation was to study the impact of the material selection for structure and cladding on the total embodied energy. The hypothesis was that in spite of building envelope assembly compliance with the R2000 for all investigated systems, the preferred material selection (the one with the lowest embodied energy) for structure and cladding would be identified.

The house used for this study was a two-story with a gross floor area of 265 square meters (excluding the basement) and a full basement. The expected lifespan was set at 35 years. Table 1 summarizes the combinations of structural and cladding systems investigated. The embodied energy in megajoules associated with all materials, delivery, and construction of different wall systems is shown in Figure 1. There is not much of a difference between the different wall

systems. The lowest embodied energy is for System 4 (wood construction with stucco finish). The total embodied energy split into the initial (materials and construction), was the highest for System 6 (steel construction with steel siding), which is only 11.6 % higher than System 4 (the lowest embodied energy). The two systems with masonry veneer are System 2 and System 5, with 5.5% and 7.8%, respectively, above the lowest energy system, System 4. The energy consumption over the life cycle of the house for various wall/ cladding systems is shown in Figure 2.

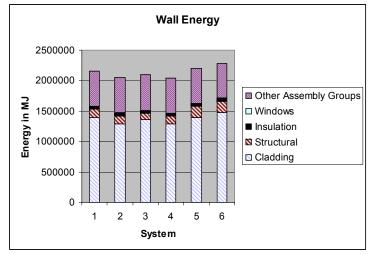


Figure 1 – Embodied energy of materials and construction

Tuble 1 Description of structural and chauding systems									
System	1	2	3	4	5	6			
Description	Wood stud (38x140- R20) with brick veneer	Wood stud (38x140- R20) with hor. wood siding	Wood stud (38x140- R20) with metal siding	Wood stud (38x140- R20) with fibreboard sheathing and stucco	Steel stud (150 deep- R20) with rigid insulation & brick veneer	Steel stud (150 deep- R20) with rigid insulation & metal siding			

Table 1 – Descri	ption	of structural	and	cladding	systems

The literature review identified two total embodied energy studies conducted for office buildings in Canada [3, 4] and in the United Kingdom [5, 6]. These studies investigated the impact of various structural systems on total embodied energy. The designs were carried out in compliance with local energy codes. The studies indicated that the selection of the materials for the structural and cladding system shows very little variation in embodied energy [7]. However, in comparison with the study of the house in the Toronto area, both maintenance and operational energy are higher. The embodied energy associated with demolition is insignificant (below 0.05%) in all cases. A summary of all three studies is presented in Figure 3. The Figure shows the percentages of total embodied energy consumed by materials and construction (initial), maintenance, and operation during the design lives of the buildings. The embodied energy for a 60-year lifespan per square meter of the three different studies was compared.

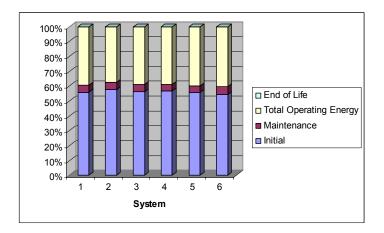


Figure 2 – Total embodied energy for various systems applicable to housing in Toronto

Several conclusions can be drawn from Figure 3. First, the operational energy of an office building is dependent on climate (more severe climate requires more energy). Second, the operational energy as a percentage of total embodied energy ranges from 74% for the UK to 89% for Toronto. Third, operational energy for a detached home is significantly less than for an office. Finally, the initial cost as a percentage of total of embodied energy is higher for a house, because it has a much smaller ratio of floor area to surface, has more finishes, and has a 35-year design life.

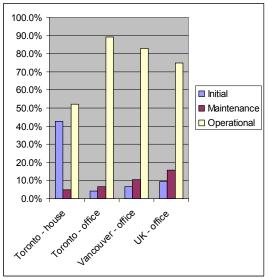


Figure 3 - Total Embodied Energy Breakdown For A Steel System. Life Span 60 Years.

The above discussion highlights the fact that the energy consumed during the operational life of a building is very significant and the selection of a structural and cladding system from among the conventional systems does not significantly impact embodied energy. When assessing the impact of a particular material, these findings are significant. It should be noted that the Life Cycle Assessments quoted above do not include a sophisticated energy modelling or the impact of thermal mass.

HISTORY OF THE CANADIAN MASONRY INDUSTRY

There is no question of the great significance of masonry construction in the history of humankind. Masonry is one of the oldest construction methods known to humans. It is those old buildings constructed using this method, buildings which have survived the forces of nature, and man, which are the storytellers of our history.

In Canada, brickwork was developed toward the end of the nineteenth century. It was established first in the areas where the natural materials for producing brick were available. Stone was scarce and the population had started to increase. Transportation during this period was expensive and unreliable and this further supported the idea of local brick manufacturing. Local incentives were often available to brickwork entrepreneurs. Capital investment was low, resulting in many small, often family-based operations all over the country.

The post-World-War II years witnessed the rebuilding of industries damaged during the war. This rebuilding, in turn, stimulated the economy, increased spending power, and led to economic growth. The booming economy resulted in increased demands on the masonry industry, and therefore, led to its expansion. Old brick plants either went out of business or were forced to modernize. Modernization led to increases in production. Associated with these changes was a drastic decrease in the number of plants. Advances in wall systems and the adoption of the rain screen principle led to a further decrease in demand for clay brick as well as for concrete block products as back up walls of masonry units were replaced by steel and wood studs. This transformation impacted the industry and further decreased the number of brick manufacturing plants. Currently, there are only eight brick manufacturing companies in Canada, with five of them located in southern Ontario. As a result, masonry is no longer a true local material. Fortunately, however, the location of the existing manufacturing plants is in the vicinity of the most densely populated areas.

CLAY BRICK AND LEED

The Life Cycle Assessment (LCA) study was described earlier. As noted, LCA is a very complex method, which evaluates embodied energy according to the different stages of the lifespan of a building. An alternative environmental assessment can be performed using the Leadership in Energy and Environmental Design or LEED method. LEED [8] does not provide an absolute measure of "embodied" (locked-in) energy and "embodied" CO_2 , but assigns buildings a credit score between 0 and 70, ranging from minimum environmental performance to absolutely environmental issues related to site, water, energy, materials and resources, and indoor air quality. However, it does not measure environmental impact in terms of energy or associated CO_2 emissions. Nevertheless, LEED is an important rating tool for the certification of "environmentally friendly" buildings.

A summary of LEED credits, which can be obtained by a project if clay brick is used, are discussed below. The credits, which can be directly obtained, are related to the category "materials and resources." There are five areas where the use of brick masonry can be directly applied to for LEED credits: 1) building reuse; 2) construction waste management; 3) reuse of materials from a demolition; 4) use of local materials; and 5) durability.

One to two credits can be obtained when the structure and building envelope are reused (75% for 1 credit, 95% for 2) when renovating an existing building. The advantage of brick masonry is in its durability, proven over centuries of exposure resulting in satisfactory performance; therefore there is less resistance to its reuse. Another credit point can be achieved when rehabilitating an existing building if there are masonry partition walls which can remain in place.

The goal of construction waste management is to divert construction materials from landfill disposal. There are two credit points in total available in this subgroup. They are not strictly related to masonry but to the total percentage of materials (by volume or weight) diverted from landfill (50% for 1 point, 75% for 2). It should be pointed out that currently in Ontario, brick is a material identified for separation independently of LEED. Ontario Regulation 103/94 deals with Industrial, Commercial and Institutional Source Separation Programs. It requires that waste be separated for reuse and recycling, and it requires the implementation of separated waste collection, handling, storage and removal. The regulation requires that the program is communicated to the program users, with the results of its performance and encouragement to reinforce it.

Large new construction projects and demolition projects are defined as those with a total floor area in excess of 2000 square metres and they are the only ones targeted by the Regulation as having to implement a waste separation program. The contractor is responsible for the separation of each category of recyclable waste from general waste. The categories of waste which ought to be separated are brick and Portland cement concrete, corrugated cardboard, unpainted gypsum board, steel, and unpainted, untreated and non-laminated wood.

The resource reuse credit encourages reusing of materials and products either as they are or as they are refurbished in new construction or renovation. If 5% of the total material cost comes from salvaged, refurbished, and reused products, then the project receives one point. Two points are awarded for 10%. Again, durability and the attractive, antique look of reclaimed brick may help it to be reused as a construction material, rather than converted into other products.

As explained in the previous section, brick is no longer a local material, but the fact that the concentration of brick production is in the most populated area of Canada can result in one point credit for its use under the regional material category. Masonry on the project could represent 10% of building materials, which have at least 80% of the mass extracted, processed and manufactured within 800 km (2400 km if transported by rail or waterway) of the site.

A building envelope of masonry can secure another point under the durability credit as material with a proven track record as a durable material.

Another potential benefit of masonry in the LEED rating system and a scoring possibility is in the energy and atmosphere category. Thermal mass can be utilized in optimization of energy performance of buildings. There is evidence [9, 10] that thermal mass is important in mediating peak loads both for heating and cooling and can produce small savings in energy cost. The issue of thermal mass is a controversial one. Although benefits have been extensively reported, there are known problems with acoustic performance [10, 11]. Consequently, masonry is often insulated by at least a gypsum board, which decreases its impact as thermal storage. The heating and cooling system of a building as well as the location of walls play important roles in their effectiveness as thermal storage. Also, it should be noted that any benefit from thermal storage is not directly related to the achievement of a LEED credit point but it can assist in obtaining one. This paper is concerned with clay brick and not with concrete block/ brick mainly because the latter is similar to concrete while the former has a completely different manufacturing process. However, it is important to point out that concrete bricks and blocks, besides qualifying for LEED credit as described above, could also achieve rating in the sustainable site category. There are credits for storm water management if open grid and permeable pavers are used, and for heat island effect, if light coloured concrete pavers are used. Additional credit can be achieved in the material and resources category for recycled content. Concrete block can utilize the waste products produced by the industry, such as blast-furnace slag, fly ash, silica fumes, and sawdust. There are also possibilities for credit from using post-consumer waste.

ENVIRONMENTAL IMPACT OF THE MASONRY INDUSTRY

Both the Life Cycle Assessment and LEED approaches were investigated in order to identify their relationship to masonry, specifically clay brick masonry. Neither method revealed that the use of clay brick as a construction material impacts a building's environmental assessment significantly or guarantees the building as "green." Therefore, in this section the environmental impact of the masonry industry will be assessed according to other factors. Here extraction/ processing, manufacturing, and construction will be looked at, as well as the design life and end of life of a building in order to determine the areas where there is potential for improvement.

Extraction/ Processing:

The natural source material for the manufacturing of clay brick is a variety of different clays and/or shales. The mining of these materials has a significant environmental impact. If practiced without due consideration for the environment, clay extraction can destroy the local landscape and ecosystem and affect water runoff, and the natural habitat for both plants and animals. However, it is possible to manage the extraction impact with conscious management of the local environment, planting of vegetation, and control of water runoff. Extraction sites whose use is discontinued are free of any contaminants and can be developed. They can, for example, be turned into landfills, recreational facilities, and commercial and/or housing developments. The mining of clay and shale is very efficient. Chemical and mineral analysis is carried out in

The mining of clay and shale is very efficient. Chemical and mineral analysis is carried out in detail and materials are selected for production accordingly. The stock pile of materials for manufacturing consists of different ingredients of known mineral content and consistency which are carefully proportioned before they enter the manufacturing process. Most of the material extracted is used.

The industry needs to focus on the research into the use of alternative materials, which are byproducts of other industries or collected through waste diversion programmes. Sewage sludge [14] has been successfully added to clay in clay brick production. Another experimental brick production includes use of petroleum contaminated soils in combination with clay [15]. When this mixture is fired at very high temperatures, the resulting brick is free from hydrocarbon contamination. This is an important process, because it is related to a clean up of contaminated sites.

Manufacturing:

The goals of the manufacturing process are to minimize raw material waste, and reduce water and energy consumption. Today, the stiff-mud process uses very little water, and is fully automated. The ground ingredients are proportioned. Added water is mixed in a two-stage process, including passage through a vacuum chamber. Small chunks of mixture are collected in a drum, pushed through a die and cut to a desired size. There is very little waste of raw materials. Off cuts and wasted extruded clay is returned back into the process. Green bricks are stacked onto carts and enter the drying tunnel. Here, they are cured and preheated by heat recovered from the cooling of fired bricks and exhaust from the kiln. When the moisture content reaches around 1% (in approximately 48 hours), bricks enter the kiln where the temperature reaches around 1100° C for a 24 to 48 hour period. Then they are cooled, inspected, and packed for shipment.

The manufacturing process consumes a lot of energy. The application of new technologies can lead to a significant improvement in energy consumption. The automation of the process results in increased productivity due to more efficient operation and round-the-clock production. New low thermal mass kilns which use ceramic fibre insulation instead of conventionally used refractory bricks are more responsive to start ups and shut downs. These kilns provide better hot air circulation around the bricks and thus cut down the firing time. Switching from the conventional manufacturing process to a modern and technologically sophisticated process can result in a 100% increase in production, a 35% reduction in natural gas consumption, and around a 20% reduction in NO_x emissions for brick production. However, there is a 5% increase in electricity consumption [12]. Another type of a kiln which emerged recently is a roller kiln [13]. This kiln is suitable for certain clays (it uses 6-8% less water) and for perforated bricks. Its rapid firing technology decreases the firing time to 8-9 hours. Kiln cars were replaced by rollers. It is even more efficient than the new generation of tunnel kilns. The expenditure in new technology and large volume production is only possible with the centralization of manufacturing.

The manufacturing process is responsible for the emission of carbons, hydrogen fluoride, and particulate. The industry has been trying to use innovative technologies as applied to filters and scrubbers in order to limit emissions to comply with regulations or to do better than current legislations and international standards.

There is very little waste during this stage as the imperfect and substandard fired bricks are crushed and are sold. The most common use of these products is in landscaping.

Construction:

In spite of the centralization of production, clay brick for most of Canada can still be considered as a regional material. The process of construction is labour intensive and usually not limited to simply the laying of bricks, but also to connecting to the support structure, and applying the vapour barrier and insulation. Workmanship can impact the durability of masonry.

As far as construction waste is concerned, masonry waste should be separated (Ontario Regulation 103/94) and reused or at least recycled. In Canada, there is a lack of interest in prefabrications [16, 17, 18]. This is unfortunate, because prefabrications can eliminate some of the construction problems outlined above. In many countries, including the United States, the United Kingdom, the European Union Countries, and Australia, brick panels are prefabricated in factories and used on construction sites in larger panels. Typical on-site bricklaying work can be characterized by poor efficiency, and difficult management, and is subjected to weather conditions. Prefabrication can transfer this process into the relative safety of factories, where efficiency and control can be better managed. This can also lead to social benefits, including improvements in health and safety, increased diversity in the workforce, more stable employment, increased investment in machinery and the development of worker skills. Greater

stability in the construction process also generates potential economic benefits. All of these contribute to environmental, economic, and social sustainability. Prefabrication can address a lot of current issues in the construction industry related to the quality and current shortage of the labour force.

Life of a building:

Regular maintenance of exterior masonry leads to a durable and problem-free building envelope. The most important part of maintenance is the replacement of caulking around the openings in masonry walls. History provides reliable proof of the satisfactory performance of masonry.

A lot of emphasis is placed on the role of masonry as a thermal mass storage media. If a material is chosen for its potential for creating thermal mass storage, it should be used on the interior of the building. The problem is that most interior walls become insulated either for the sake of aesthetics or to improve acoustic performance. The importance of thermal mass is related to passive approaches to heating and cooling in combination with understanding of the world's biggest heat source, the sun [9, 10, 11]. This relationship requires an understanding by the owner or manager of a building in order that the maximum benefit of masonry is achieved. The work currently in progress by the author indicates that the issue of thermal mass is intricate and complex and requires further study if the full benefit is to be achieved.

End of life/ Demolition:

Buildings which perform well during their design life are often excellent candidates for rehabilitation and adaptive reuse. Masonry certainly has the potential for surpassing the design life of the project itself. If demolition occurs, masonry materials are among those materials which should be separated and diverted (102/94 Ontario Regulation – Part IV) from landfills.

The potential for reuse of masonry materials has been demonstrated by a number of projects, which have adopted reclaimed masonry products into buildings rather than using new construction materials (e.g., C.K.Choi at UBC, Mountain Co-op in Winnipeg and Montreal, and the Distillery District in Toronto). There are two problems with the reuse of masonry materials. The first one is a psychological one--a general perception exists that reused material is inferior. The second problem is related to the available supply of masonry products, which originated from the same source for reuse. Reuse is possible, but it is laborious as it requires separation of bricks from mortar. If reuse is not possible, then masonry is recycled. Again, the bricks are crushed and used in landscaping or as a sub-base.

CONCLUSIONS AND RECOMMENDATIONS

In order for the masonry industry to stay competitive and continue to respect the significance of brick in the heritage of vernacular architecture in Canada, it is important that those who shape the industry become cognisant of construction trends, that they take public opinion into consideration, and that they play an active part in the education of designers, contractors, and the general public. The following recommendations are intended to serve these aims:

1. The industry must embrace strategies for sustainability that combine the application of technological advancement together with forecasts for the nation's economy. New technologies are important in the reduction of energy consumed during the manufacturing process leading to reduction in environmental impact. Research into the use of waste materials from other industries or recycling should be supported.

- 2. It is important for the industry to explore the use of prefabrication of components. Attention to prefabrications will address many issues, such as dependable quality, durability, the shortage of the skilled labour force, cost, reuse, and performance.
- 3. More research is needed to determine the benefits of thermal mass in relation to the HVAC system adopted and location of elements which have the potential for thermal storage.
- 4. There is a need for ongoing education of designers, contractors, and the general public about the role of passive heating and cooling systems in relation to considerations of thermal mass.
- 5. Methods for ease of separation of units from mortar need to be developed.
- 6. Masonry units should carry a standard identification code, which would allow for their identification and thus make their reuse easier.
- 7. The industry should take full responsibility for their products and initiate the processes of reuse and recycling at the end of a building's design life. Currently, third parties are dealing with "second hand" units. This means that the there is a limited supply of identical units which makes reuse difficult.
- 8. All possibilities for the recycling of masonry materials and potentials for their reuse should be investigated.

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