UBC Social Ecological Economic Development Studies (SEEDS) Student Report

APSC 261 Sustainability Project An Investigation Into the Use of Cob and/or Straw Bale Construction in Non-residential Buildings

Anthony Kao, Jacky Chou, Rebecca Guo, Zi Zhang

University of British Columbia

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APSC 261 Sustainability Project

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Submitted to Dr. Faizal Karim

By Anthony Kao, Jacky Chou, Rebecca Guo, Zi Zhang

Source: Green Building Elements <http://planetsave.com/files/2008/09/hildecobinsnow.jpg >

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ABSTRACT

The report investigates the use of cob and/or straw bale construction in non-residential buildings. The main purpose of the investigation is to present the possibility of having a building or a section of a building be constructed at the UBC Farm. The new structure will act as a farm centre managed by the Centre for Sustainable Food Systems. At the farm centre, students, professors and the general public will have the opportunity to learn about sustainable technologies.

The investigation begins by identifying what cob and straw bale is and how it is used in the construction of buildings. Additionally, the similarities and differences of cob and straw bale construction are explored. Furthermore, three case studies of non-residential cob buildings are described and summarized. Next, a triple bottom line assessment was used to evaluate the possibility of using cob and/or straw bale construction at the UBC Farm. This assessment consists of three indicators: social, environmental and economic. The social factors include accessibility to local construction resources, safety and comfort of the building as well as the impact of such a building on the local community. The environmental issues involved exploring the carbon footprint of using cob and straw bale as well as how the material will fare in Vancouver's climate. Lastly, the economic factors include assessing the production, labour and maintenance costs as well as the lifetime of a cob and straw bale building.

Finally, after using the triple bottom line assessment to evaluate the possibility of using cob and/or straw bale construction for a new farm centre, the results recommend a section of the new farm centre be constructed using cob and straw bale.

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1.0 Introduction

Straw bales are traditionally used as livestock feed when fresh grass is not available. It contains wheat, oats, barley, flax, and rice and these materials are found readily available at most of the farms internationally. Straw bales are seen as a cheap product which farmers sell as animal bedding or landscape. Furthermore, excess straw bales are burned which causes heavy negative effects on the environment. The techniques of using straw bale within structural buildings have been in existence since late 1800s to early 1900s.

Straw and/or cob bale buildings were not popular in the past 25 years, and this material has been "introduced and popularized later" (Chris Magwood, 2005). People accept this new building material because of its "high energy efficiency, lowered environmental impact, and the simplicity" (Chris Magwood, 2005, P1). There is enough straw material "produced each year in North America to meet all the building needs" (Chris Magwood, 2005, P6) since grain farming is extremely common in most regions. Straw and/or cob bale also has efficiency benefits such that "the insulation is to minimize the amount of energy is used" (Chris Magwood, 2005, P7). "The thickness, the amount of air entrapped, and low conductivity" (Chris Magwood, 2005, P7), which also makes the material energy efficient. By using straw bale or cob, it lowers construction costs and design varieties. Building with this material will have a significant cost advantage than the common building material. Additionally, it takes less knowledge to build with straw bale. Building walls with straw bale does not require skilled labor and the "low cost makes this material economically attractive" (Chris Magwood, 2005). Straw bale material can also alternate building systems, required by the builders, in order to adapt to new or complicated ideas. Straw bale construction is also "easily adaptable to other configurations such as the traditional suburban homes" (Chris Magwood, 2005). Its insulation and cost makes the material appealing to most of the suburban builders. Straw bale walls are also fire resistance. They are naturally "fire resistant since the compact nature of bale does not have enough air to combustion"(Paul Lacinski 2000). However, the loose straw is extremely combustible and many constructions accumulate a serious fire hazard. The most convincing benefit is the cost. Acquiring cob or straw bale is not hard and farms should have this building material readily available.

2.0 Case Studies

2.1 Tipu Sultan Merkez School Building, Jar Maulwi, Pakistan

An extension of the school, Tipu Sultan Merkez (TSM), located in Jar Maulwi, Pakistan was built using local materials of mainly cob and bamboo. This project was awarded Holcim Awards Gold 2011 by Holcim Ltd, a construction company founded in Switzerland in 1912 (Holcim Ltd., 2012). The TSM project began in February 2011 and was completed in June 2012.

The building was split into two compact parts, see Figure 1 below; a 60 cm thick ground floor wall constructed using cob and bamboo with an earthen filling was used in the upper floor. The local residents of Jar Maulwi were educated and trained to assist in the building phase. As a result, the skills of using this building technology, creates an opportunity and promotes future building projects. In June 2012, the project was delayed due to a shortage of lime sealing for the roof and parts of the drainage. This critical moment required instant resolution because the rainy period was closely approaching.

The new school is low-cost and energy efficient compared to the alternative brick and concrete buildings. The TSM project utilized local materials and labor and has gained worldwide recognition as a sustainable earthen building (Eike Roswag, 2012).

Figure 1: Tipu Sultan Merkez School located in Jar Maulwi Pakistan

Source: Holcim Awards Gold 2011 – Asia Pacific <http://www.holcimfoundation.org/T1559/Locally-manufactured_cob_and_bamboo_school_building_Pakistan.htm>

2.2 Emerald Earth Sanctuary Community Center, Mendocino County, California

Emerald Earth Sanctuary (EES) is a non-profit organization located in Mendocino County, California. EES' mission involves practising and promoting "sustainable living skills such as organic gardening, permaculture, herbal medicine, natural building, and home generation" (Emerald Earth Sanctuary, 2012).

In 2010, Emerald Earth Sanctuary started construction on a new community center, shown below in Figure 2, using cob, slip straw and straw bale. Natural building expert, Michael G. Smith, explains the difficulties of obtaining building codes and permits for this project. In a brief interview video, he identifies the problem of building using cob in the state of California. However, there is a workaround by following the building codes for structures made out of adobe, which is similar to cob. Unfortunately, the community center had to be reinforced with other non-natural and semi-natural materials like adobe and steel beams.

A major problem with building using cob, is a lack of research and testing done on this material. Thus, a cob building may be structurally unpredictable. The architects and engineers involved in the EES community center project had to install steel beams in order to further reinforce the walls of the building. A mixture of straw bale and adobe was also used because there is adequate data from research and testing on these materials (Dirksen, 2010).

There is a lack of information on the EES community center project, but the video (Dirksen, 2010) identifies a major issue involving building codes and permits when building using cob. However, the Stanley Park Ecology Society in Vancouver, Canada, built a small cob house and decided to perform earthquake testing at the UBC Earthquake Engineering Research Facility (Stanley Park Ecology Society, 2012). The actual earthquake test (Sider, 2011) showed minimal

Figure 2: Emerald Earth Sanctuary Community Center located in Mendocino County California

Source: Natural building codes: some for straw bale and adobe, little for cob < http://faircompanies.com/videos/view/natural-building-codes-some-straw-bale-but-little-for-cob/>

cracks on the walls when subjected to a simulated 7.2 on the Richter scale earthquake, as shown on the left, below in Figure 3. After a simulated 9.0 earthquake, the structure's walls crumbled but the roof stayed intact. The building remained standing and proved a person would have a high chance of surviving a massive earthquake inside a cob building.

Figure 3: Stanley Park Ecology Society simulates a 7.2 (Left) and 9.0 (Right) earthquake on a cob structure at the UBC Earthquake Engineering Research Facility

Source: A Creative Impact: The Stanley Park Earthen Architecture Project < http://www.youtube.com/watch?feature=player_embedded&v=ChbccUQhpJc#!>

2.3 METI School, Rudrapur Dinajpu, Bangladesh

Austrian architect, Anna Heringer and Eike Roswag from Germany gathered a team of pupils, parent and teachers to build the METI (Modern Education and Training Institute) school in Rudrapur Dinajpu, Bangladesh, see Figure 4. Eike Roswag also led the project in the first case study mentioned in this paper, The Tipu Sultan Merkez School Building.

Using local and inexpensive materials like bamboo, straw, jute rope and cob, the team started construction in September 2005 and the school was completed after four months. On the METI school website, “The ultimate goal is to gain and disseminate knowledge and information for optimising the use of locally available resources. The improvement of the building techniques is as important as the economic aspects and the creation of a regional identity” (School Handmade in Bangladesh, 2005).

Unlike alternative building materials, using cob requires thicker walls in order to provide a strong foundation. Thus, a larger portion of the building area is needed for the walls. The project required exemplary leadership and organization which Heringer and Roswag provided.

Another crucial factor for this project was the onsite training the team provided to the locals. In only four months, Heringer and Roswag's team trained a group of locals and erected the school.

The METI School has won numerous awards and gained international recognition. The project brought unity within the community, promoted sustainability and encouraged the use of local materials (Williams, 2010).

Figure 4: METI School in Rudrawpur Dinajpu, Bangladesh

Source: METI School in Bangladesh, Sustainably Hand-build by Locals <http://www.inhabitots.com/the-meti-hand-built-school-in-bangladesh/>

3.0 Triple Bottom Line Assessment

Overview

The following sections are used to investigate the factors that are needed to be considered when using cob and/or straw bale in the construction of a natural building. The social variables that need to be considered are the accessibility to local construction resources as well as whether or not natural buildings sacrifice comfort for sustainability. The ecological (environmental) factors are exploring the carbon footprint of the material itself and how the material will fare in the drastic North American climate. Lastly the economic factors will include the lifetime of cob/straw bale and assessing production, labour and maintenance costs of the material.

Cob buildings traditionally consist of clay, sand and straw; the combination is mixed extensively using either human labour or a cement mixer. The clay holds everything together, the sand provides strength and mass and the straw gives the building some tensile strength when dried. This mixture provides great flexibility when building and is fireproof, able to resist seismic activity and is cheap to acquire.

Straw bale buildings by definition are the use of bales of straw in structural elements and/or insulation. The use of this material boasts sustainability, cost efficiency, easy accessibility and superb insulation. However straw bale tend to rot under imperfect circumstances and take up a lot of space.

3.1 Social Factors

Natural buildings emphasize the importance of the environmental and social variables during construction. The positive social impacts of a building begins with its construction, from the usage of local and sustainable materials to community engagement during the construction process. Positive social factors also include minimizing waste and environmental damage while promoting vibrant social interactions and healthier lifestyles. The social variables are indicated through the investigation of the effect natural buildings have on local society, the availability of the materials and the safety and comfort factors.

3.1.1 Safety and Comfort

The general public believes that natural buildings have to sacrifice comfort for sustainability and cost efficiency; contrary to popular belief research that has been done in North America "shows that there should be no need to be concerned that straw/cob bale walls will not withstand the test of time and rigours of our (the) climate" (Farm, 53). Straw bale provides superb insulation; the K value(insulation) of straw bale is 0.09W/mk, in combination with walls is two to three times lower than contemporary materials (Farm, 8). Another area of concern is whether natural buildings, straw and/or cob bale buildings specifically poses as a fire risk. However due to the density of the bales there is insufficient air within the bales for them to burn. Furthermore straw and/or cob bale walls have been strenuously tested and have passed "all the fire tests they have been subjected to in the USA and Canada" (Farm, 55). Therefore the occupants in any natural building should feel as safe and as comfortable as they would in any conventional building.

3.1.2 Impact on Local Community

The production of natural houses uses local, untreated materials and is usually a lot smaller than conventional houses; this minimizes the strain on local infrastructure. The downside of the use of cob and/or straw bale is that it trades off material costs with labour costs. Techniques relying greatly on human labour "produce a different social dynamic (compared to) dependency on heavily processed materials, expensive machines, and specialized skills" (Smith, 5). Construction of a natural building uses minimal power tools, which is a safe environment for the community to get involved. Building using straw and/or cob bale is ideal for the incorporation of the organization Friends of the Farm from UBC. Also the majority of the materials if not all of it can be acquired locally and/or at the UBC farm. Anyone can help with the production of straw and/or cob bale ranging on mixing the cob to stomping the mixture in the ground.

3.2 Environmental Factors

The building and housing industry in North America constitutes up to 30% of energy consumption (Swan, 1). Many owners and consumers alike are all searching for a more efficient building system to decrease this energy use. The ideal substitute will have minimal initial production and maintenance carbon footprint. The following section will explore the carbon footprints of material production, adequacy for North American climate as well as possibility of a local source.

3.2.1 Carbon Footprint

Straw and cob bale are a renewable natural product; approximately four million tonnes of extra straw are produced each year and the use of straw bales will mean the reduction of pressure to use more environmentally damaging materials. Four million tonnes of straw is enough to build approximately 400 000 houses a year. The production of straw and/or cob bale can result in a "net decrease in greenhouse gas emissions", this is due to the material converting carbon dioxide to oxygen during its life cycle (Farm, 8). With the net decrease from the production, natural houses can further reduce its carbon footprint from the minimal and efficient heating systems.

3.2.2 Durability

The location of the building in question will be in UBC Vancouver, which exhibits an oceanic climate and is situated along the Pacific Ring of Fire. Vancouver is observed to rain 161 days in a year with an average total of 1199 mm of precipitation in a year (Osborn). According to Environment Canada, Vancouver's temperature ranges from 14.1 to 7.9 degrees Celsius with record highs of 32.8 and record lows of -18.3 degrees Celsius ("Canadian Climate Normals", 2012, n.p). The durability of straw bale and cob buildings is analyzed through its reactions to flood conditions and seismic activity according to its location.

During the flood tests, cob walls reinforced with straw were completely submerged in water to observe any reactions. As shown in Figure 5 below, cob walls reinforced with straw showed signs of deterioration after five days since initially submerged. It was concluded that straw reinforced, cob walls are able to "resist total failure when subjected to initial flood conditions" (Forster, 320). Straw buildings are also found to be excellent thermal insulators, able to moderate any extreme temperature fluctuations three times better than traditional buildings (Farm, 8). The ability for cob buildings to "withstand greater loads than will be imposed on them by floors, roofs and possible snow loading", is not a question of material but the "quality of building" design and construction (Farm, 51).

These results establish that cob walls are more than capable of withstanding Vancouver's weather conditions.

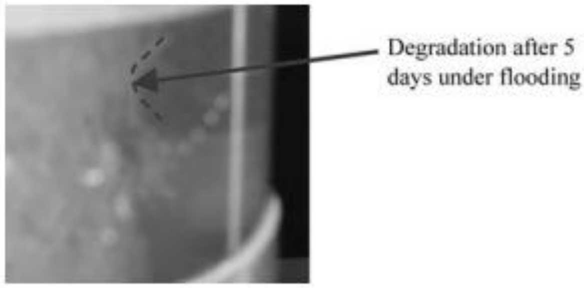

Figure 5: Flood Test Results. Adapted from "Traditional cob wall: response to flooding," by A. M. Forster and G. M. Medero, 2008, *Structural Survey, 26(4)*, 313.
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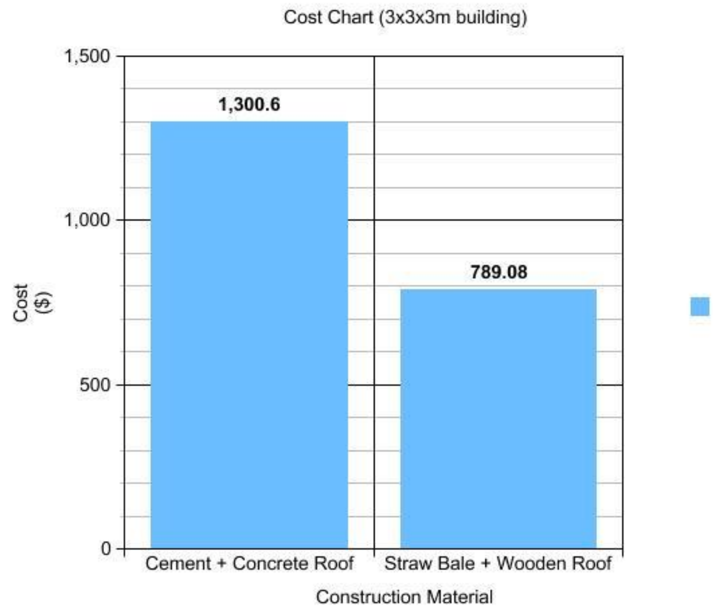
3.3 Economic Factors

There are various economic indicators that determine the viability of using cob and straw bale for the construction of nonresidential buildings. To assess these factors, direct comparisons are made between the production costs of conventional building methods and the prices of cob and straw bale construction. The long term costs of both building methods are assessed through energy costs as well as durability which contribute to maintenance costs and ultimately the life cycle of the building.

3.3.1 Production Costs

Straw bale and cob has been observed to be much less expensive than conventional materials such as cement bricks. More specifically, it has been noted that a "compartment unit of 3 x 3 x 3 m" with a "concrete roof" costs $1300.60, while a straw bale compartment of the same size with a wooden roof costs $789.08 directly, see Table 1 (Garas, 56). This translates into almost a 40% reduction in initial costs if a person were to use straw bale instead of cement as a building material. According to Farm, the use of "400 straw bales" for construction of a "normal 3 bedroomed house" costs approximately $768 whereas the use of bricks for to build the same house would increase costs to $12803 (p. 7). This presents an average reduction on the material costs alone by 94%. Cob and straw bale construction process is very straightforward so "people without previous building experience can participate on design and construction" allowing labour costs to be reduced significantly as well (Farm, p. 7).

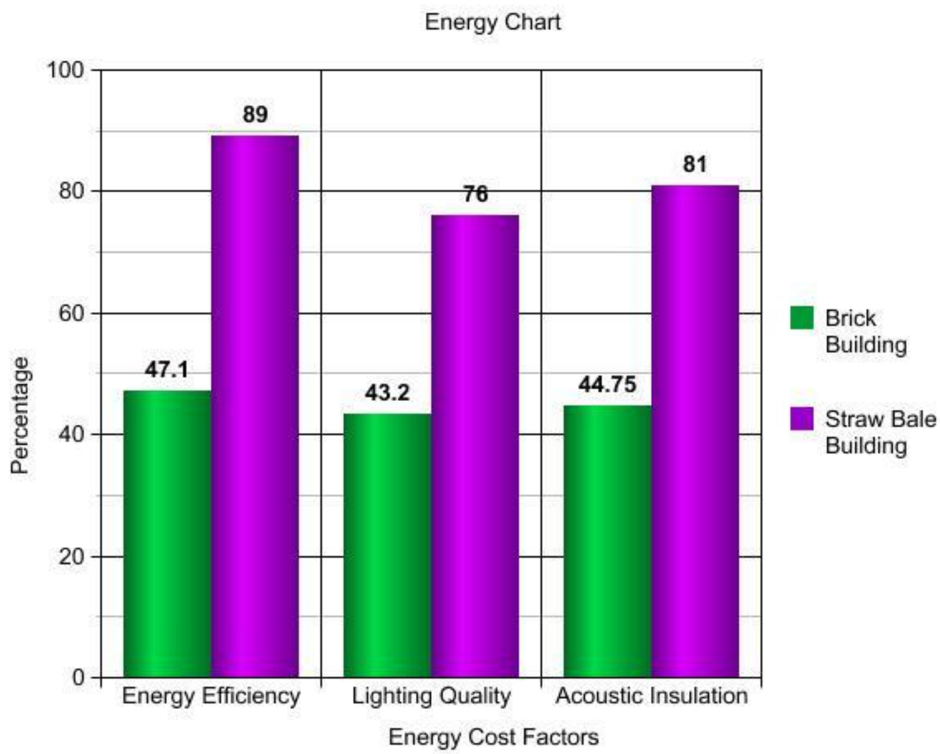
Table 1: Cost Chart. Adapted from “Straw bale construction as an economic environmental building alternative- A case study,” by G. Garas, 2009, *Journal of Engineering and Applied Sciences, 4*(9), p. 56. Copyright 2006-2009 by the Asian Research Publishing Network.



3.3.2 Energy Costs

Straw in itself is a natural insulator, thereby creating a wall with a K value “three times lower than contemporary materials” (Farm, 8). While it is a great insulator on its own, the buildings efficiency can be optimized when build in conjunction with the climate and environment in mind. By utilizing proper orientation of the building with natural lighting, straw bale buildings have been calculated to achieve an 89% increase in energy efficiency compared to traditional brick buildings, see Table 2 below. With such drastic thermal insulative properties, one may be lead to believe that the building must be sealed tightly with few windows that offer clear lighting. However, opposing slots may be cut in the building “which improves the quantity and quality of internal lighting rate by 76%”, without impairing the thermal insulative properties of the building. Straw bale construction is also acoustically insulative, able to reduce the “transport of noise by up to 81%” (Garas, 56).

Table 2: Energy Chart. Adapted from “Straw bale construction as an economic environmental building alternative- A case study,” by G. Garas, 2009, *Journal of Engineering and Applied Sciences, 4*(9), p. 56. Copyright 2006-2009 by the Asian Research Publishing Network.



3.3.3 Maintenance Costs

As it is stated above, cob buildings are very durable and if maintained properly is able to last as long as traditional buildings. Repairing straw walls are also very easy, and can be done by pulling out “wedges of bale” to replace with fresh ones. The most difficult process during maintenance is creating “a hole through the straw due to the density of the bale”. Yet this task may be accomplished by using “the claw on a hammer or a crowbar” (Farm, 54). The durability and versatility of the material allows for ease of maintenance and has allowed straw bale houses “in the USA” to “[endure] for over 50 years with no signs of deterioration” (Farm, 51). Although the “first straw bale house was built only 130 years ago”, there are almost a “dozen houses nearing 100 years old” in the US which are “still inhabited and showing no problems” (Farm, 53).

4.0 Conclusion

Upon the analysis of various case studies as well as factoring in the social, economic and environmental variables, this report strongly recommends the use of cob and/or straw bale in non-residential buildings. However given possible time constraints and limited amount of resources the recommendation of having a section of the building built out of cob and straw will be more reasonable.

Steel, concrete and timber have and still are in contemporary use in the building and construction industry. However the extraction/harvesting, processing and transportation process requires a large amount of energy and leaves a heavy carbon footprint.

Straw is "considered a waste material from grain harvest" and cob is a mixture of straw, clay and sand; both of which provides a more efficient and sustainable production path (Lovegrove, 1). Straw and/or cob offers the most cost efficient material in construction as well as being easily accessible due to the possibility of sourcing from UBC farms. Low-tech and low cost natural housing generally require significant amounts of labour compared to conventional methods; however this provides a great opportunity for the community and Friends of the Farm to get involved. The building of cob and/or straw bale buildings require next to none power tools, offering a safe environment to the untrained volunteers.

The use of cob bales as building materials for the walls is only recommended if the approved space is relatively small ($<150m^2$); otherwise the use of straw bales is suggested. Construction of a large building out of cob will require strenuous work and time. Straw and cob bale have been "included in several North American building codes within the last 20 years", this provides the confidence that any structure made out of cob and/or straw is durable and structurally sound (Lovegrove, 7).

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