UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the Use of Cob and/or Straw Bale Construction in Non-Residential Buildings

Connor Burgess, Emmar Kenneth Mariano, Ryan Richman

University of British Columbia

APSC 261

November 22, 2012

Connor Burgess

Emmar Kenneth Mariano

Ryan Richman

Date Submitted: November 22nd 2012

APSC 261

An Investigation into the Use of Cob and/or Straw Bale Construction in Non-Residential Buildings

Tutorial Instructor: Dr John Grace

Abstract

This report aims to assess the validity of using either cob or straw-bale in the construction of a new learning centre at the UBC farm using a triple bottom line assessment. For each of the construction materials, the team addresses issues pertaining to the economic, social, and environmental aspects in order to derive a conclusion and recommendation. Furthermore, it was specified that both cob and straw-bale were not required to be used exclusively. This research is accomplished through the usage of publications presented by Universities, coalitions of private companies, and through various sources in the internet.

The main concerns to be addressed using a triple bottom line assessment were the following; economics - the suitability and pricing of both construction materials in British Columbia, social factors - building safety and comfort, and the environmental footprint - pollution due to the production of either material.

It was found that it is optimal to use cob and straw-bale in conjunction with each other in order to build the new learning centre, as using both materials eliminates the negative aspects of the other. While cob was found to have a more uniform structural compressive resistance and weak heat insulating property, straw-bale was found to have excellent insulation, but perform poorly in uniform compressive resistance tests.

Table of Contents

List of Illustrations

Glossary

Axial Compression - Compressive forces causing displacement in a body in parallel with its axis of rotation.

Biome - Geographical locations on Earth with common climates and communities of animal life.

Rototiller - A rotary style cultivator used in farming to loosen soil

I-beam - An alloy of iron and coal (steel) formed in the shape of a capital I, that is used to create the backbone (steel girders) of modern structures.

1.0 Introduction

The act of erecting the first multi-story building is in itself was both a challenge and a feat for mankind. The knowledge of the physical forces of the Universe have allowed us to build structures as tall as the World Trade Centre, despite the hazards brought forward by mother nature. The tall structures are made possible by the variety of construction materials used, such as steel girders and concrete, two of the most common and durable building materials. Buildings are usually erected with these two materials on foundations where steel girders are supported by concrete. The method of construction is always as follows: steel I-beams are arranged to provide shape and integrity of a particular building, essentially creating the backbone of a building, while the concrete is spread out to usually encase the I-beams in order to provide compressive support and hold up the majority of the weight of the building.

On the road to a ‘greener’ society some people have taken the initiative, starting with building houses from cheap, non polluting renewable materials - cob and straw-bale in particular. However, green initiatives do not restrict construction to using just these two materials; it can also include their recycled waste. With the environment in mind, the amount of pollution generated in the manufacturing process of concrete could significantly alter the environment, giving proof that an effort for ‘green’ buildings must be in order.

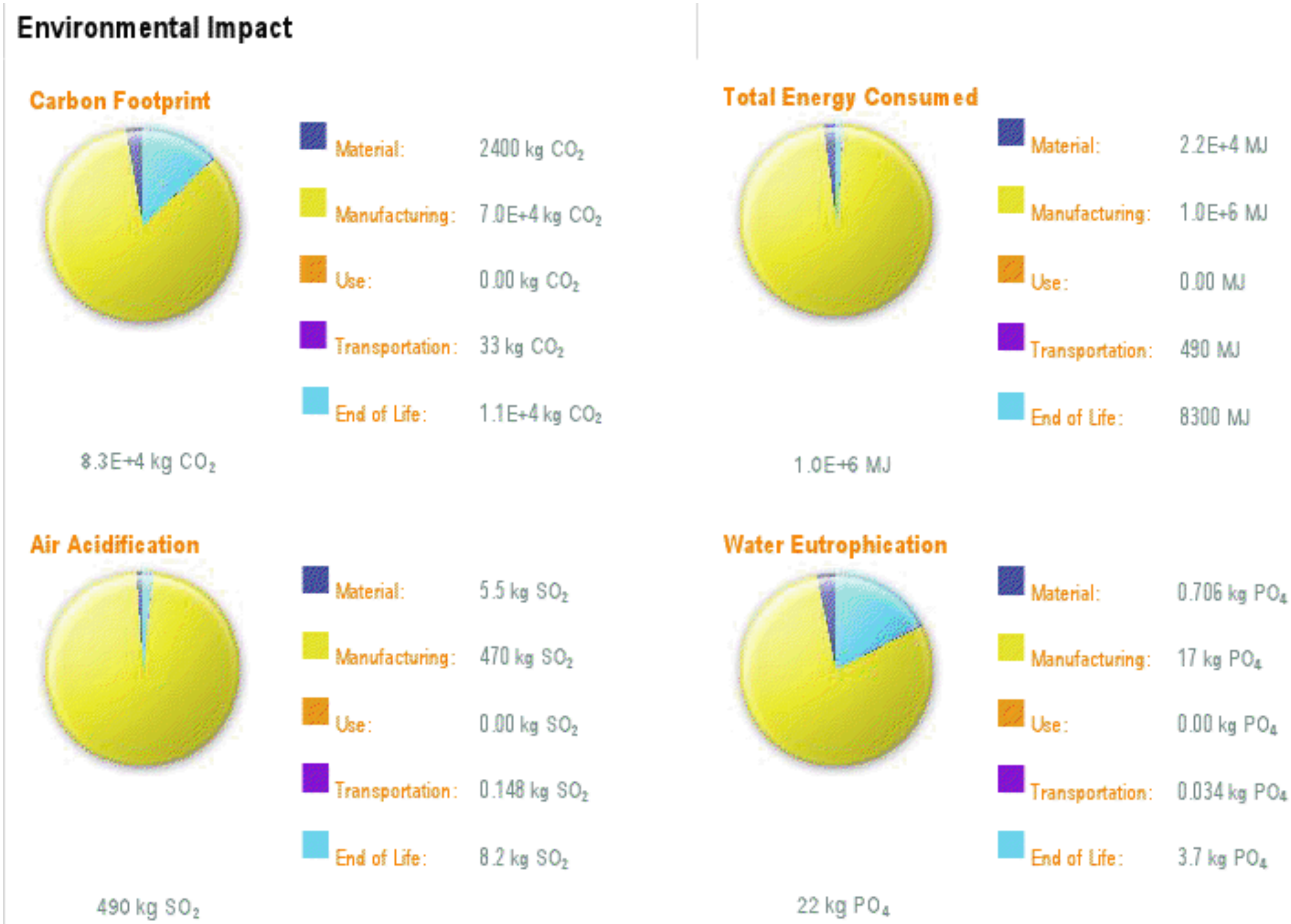

Figure 1 - Concrete Environmental Impact

The focus of this report is to use a triple bottom line assessment to derive a conclusion and recommendation highlighting the advantages and disadvantages of using cob and straw-bale to construct a new learning centre at the UBC farm.

2.0 Cob

2.1 Introduction to Cob

Cob construction in western Canada poses both great benefits as well as respective downfalls. The following portion will outline the economic, social and environmental aspects cob construction faces on the UBC farm. Through various cob constructed structures and buildings, a strong analysis can be made regarding industrial building applications. For example, a recent push towards cob can be witnessed within Stanley park where a small popcorn hut has been constructed.

Figure 2 - Stanley Park Popcorn Hut

Currently, it is difficult to build a large building out of cob due to the uncommon usage of the construction material in industry. Construction of buildings smaller than 100 square feet is plausible without an official building code permit, however larger buildings are required to have proof that the designed structure can withstand seismic activity and thus provide a safe enclosure. Research is currently being done at the UBC civil engineering department to test the seismic durability of a cob structure. Aside from the legal requirements for cob to be constructed, the following triple bottom line assessment can be done to assess the benefits and fallbacks from cob structures.

In North Carolina, Warren Wilson College initiated a COB storage facility in 2009. From the initial conception of the idea, it took three years before the structure was completed in 2012. The main idea behind this building was to provide a recycling storage depot and office space for the school.

Figure 2: Cob Recycling Office and Shed

The construction was comprised of timber supports for a “living roof” and a rock base. This allowed the structure to be as environmentally green as possible by allowing almost all the materials within the structure the ability to be broken down and put back into the environment. The college community was involved in the construction, which led to a cheap and student involved project.

This project is a good example of a student project that constructed a building that is economically, socially and environmentally beneficial to the agricultural operations within Warren Wilson College.

2.2 Economic Availability and Impact

At a first glance, cob construction appears to be a cheap alternative to conventional methods. Cob has been used in England for generations and it itself can be seen as a fairly primitive and inexpensive construction material despite the humid and wet English climate. Cob is mainly composed of, but not restricted to chalk, clay, and a slight amount of road grit, as it is possible to have an addition of straw to the mixture as a filling. In Western Canada, it is common to use mined pumice in order to create a better insulation.

Traditional cob construction is a community effort that relies on a large number of man hours to develop structures two feet at a time. However in the modern construction methods of cob, through the aid of a rototiller in mixing the mixture, the construction can be sped up by a factor of five. With this efficient construction method, an industrial building can be built at roughly $100 a square foot. This price includes the designing, engineering, and constructing costs.

A money saving alternative to paid labour construction would be to encourage a community involvement in the construction of the new building. This will alleviate the financial burden found in erecting a new building. For example, instead of spending money on a new rototiller, the community can cooperate in an event to mix cob mixtures using only the feet.

In the event of a structural failure, since a cob based structure is very prone to moisture, the construction may possibly end up wasting the owner a large amount of money, considering the climate here in British Columbia. It is ideal to apply a sealant to the surface of the dried section of the cob structure before shifting focus to the next portion.

2.3 Social Implications

Cob construction is perceived by the public as a very early time and back to earth method. A large number of community members can be involved with the construction of a building that they themselves will value. Building a “green” building not only promotes a sense of contribution to the environment but also creates pride in the community; this pride encourages individuals to think “green” towards other projects that may occur later in their life.

The cob building community is growing due to the awareness of this conventional building method and has since built momentum in Vancouver. There are a number of cob building that help represent sustainable living within Vancouver. Stanley park’s popcorn shack has been a substantial marketing tool in lieu of cob construction.

Materials for cob construction consist of local materials that can be dug up within a 100 mile radius. Local materials create a beneficial community market that encompasses a dynamic community within Vancouver.

2.4 Environmental Effects

Cob was initially used due to the abundant supply of earthly materials within close vicinity. New technology has forced a few factors to change from the initial construction however a large amount of materials used can be put back into the environment.

Cob is traditionally composed of 70% clay, 20% chalk and 10% road grit. Local ingredients can be substituted to produce a more environmentally friendly case. The natural tendency is for cob to absorb and disperse moisture similar to a porous plant pot. The solution to this is to use an exterior plaster on the walls which require the structure to be enclosed in a layer of plaster and then a waterproof paint or exterior coating.

Modern day constructions of cob buildings use a rototiller to create the wall mixture. An average amount of gasoline used to run this device to create a 2000 square foot building is 20 litres.

The negative materials that go into a cob structure are the reinforcing cables that help for seismic activity, windows, electrical wiring, and the plaster that is required to be on the outside of any western-Canada built cob structures. Cob roofs are supported by conventional building code that uses a wood structured outlay. Cob consists of 20% clay that must be brought in from a mine. An industrial setting requires all ingredients to be brought in from off the property resources.

3.0 Straw bale

3.1 Introduction to straw bale

Straw bale construction has been around for hundreds of years. Throughout the years of use, different methods of utilizing straw bale as a construction material have evolved into something that can be considered functional even by critical North American building standards today.

Figure 4 Straw Bale and Plaster Sample

Straw bale construction is simply the use of bales of hay or straw as a thermal insulator as a wall and structural component. By layering the straw bale with plaster, the bale can be protected from moisture and overcome its biggest setback, rot. An additional layer of wire mesh is added between the plaster and the bale to assist in adhesion to the straw and to reinforce the plaster.

A wide variety of companies exist in North America that aid, not only in supplying materials for straw bale construction, but also in methods. This building material is already being used today for homes in our society.

3.2 Economic Impact

In terms of product life, if the structure is made correctly, it will outlast its expected building renovation cycle. With the current rate of building expansion at the University of British Columbia, buildings are being renovated and reconstructed faster than straw bale construction would break down, which can last for thousands of years.

In terms of strength, the maximum compressive pressure was deemed to be highly variable for straw bale by a study done at the Polytechnic Institute of Massachusetts, with a final rating of approximately 40 psi, or 0.276 MPa. Commercial concrete can withstand around 28 MPa, making it just over a hundred times stronger than straw bale.

Thermally speaking, a typical wall allows more heat to pass through it per inch than straw bale. Thermal resistivity constants compare at 7.39 and 10.97 for concrete and straw bale respectively. To supplement this, straw bale walls are typically twice as thick as a typical concrete wall. This almost triples the thermal efficiency of the building, which is beneficial for both heat retention, and energy consumed by air conditioners in the summer. Stats Canada calculated an average household consumed 107 GJ of energy in 2007. If a building made of straw bale were able to recuperate those losses through its more efficient insulation, each building would be saving almost 200 MJ per day.

With regard to financial aspects of straw bale, the material is typically deemed as waste by farmers. For small scale construction, material costs are virtually negligible assuming there is rural farmland within a reasonable distance of the construction site. Construction costs are further reduced in the event that volunteer labour is readily available. Since heavy equipment is not required for construction, energy and machinery rentals are unnecessary.

Another major aspect of straw bale is safety. Though there is a minimal amount of numerical data on earthquakes or fires. However it is widely accepted that, counter intuitively, that the risk of fire is small due to the nature of the straw bale's density. The relatively small amounts of air inside the bale disallow for rapid or violent ignition of the material. Instead it tends to smolder slowly, similar to that of treated timber. Earthquake effects are still relatively uncertain due to the variability of wall strength.

3.3 Social Impact

Since the material is already being produced as waste in farming; there are very few negative social implications that could arise from the use of straw bale in construction. Plastering the bales and erecting walls is also considered to be an unproblematic task, yet very time consuming. This allows for large quantities of student involvement which is also discussed above in the benefits of COB construction.

Depending on funding, straw bale construction could provide anything from student summer jobs to large scale volunteer hours for community service learning. This can promote a sense of unity, environmental awareness, and personal satisfaction amongst students at the university that are involved with the project.

3.4 Environmental Impact

Straw bale is typically disposed of by incineration. This releases 56 tonnes of carbon dioxide into the atmosphere for every thousand tonnes of straw burned. Using straw bale in construction removes the opportunity to burn and emit greenhouse gases. By this standard, using straw bale in construction actually reduces carbon dioxide emissions

Additionally, when comparing to a traditional concrete wall, manufacturing does not have an environmental effect when it is assumed that volunteer labour is both free and readily available. From the charts included above, it is clear that the manufacturing process for typical construction have the most detrimental effect on our environmental footprint. Straw bale construction almost cuts this out completely.

For a 12 by 20 foot wall made of straw bale, at an approximate weight of 45 pounds per bale, the wall will weigh 1800 pounds. From the given above numbers, the equivalent concrete wall will produce 5280 lbs of carbon dioxide where using straw bale will actually remove just over 100 pounds of CO_2 that would otherwise be added to the atmosphere through incineration.

4.0 Conclusion and Recommendations

For the economic analysis, the costs of either material can be assumed to be negligible. The ingredients required to create a cob mixture are freely available wherever there is free dirt. With regards to straw-bale, the material is considered waste by most farmers, and consequently the UBC farm can simply request for the non compostable excess to be used to build the new building. Provided a farm with a straw related produce is within preferable distance to the location of interest.

In terms of social factors, the UBC farm could propose to have volunteers from either its own or the UBC community to work together in order to create the new building. For example, suggestions could be queried to the department of Civil Engineering to allow students to take part in the design of the learning centre. Afterwards, the same group of students can choose to join a set of volunteers to do the manual labour. This will create a better sense of community due to the fact that everyone on the project is set to a common goal - to finish the learning centre.

In terms of the environment, there is a negligible positive impact when using straw-bale as a building material, as opposed to concrete. With the magnitude of CO_2 pollution a factor of 500 times less than that in the manufacturing process of concrete. With cob on the other hand, when choosing a location for a dig site, great care must be taken in particular in order to prevent harming the existing biome encompassing the covered area.

This report has found that it entirely plausible to have a building built out of either cob, or straw-bale, or a mixture of the two. It is recommended that cob is used for the structural support of the building, while straw bale is used as the internal heat insulator due to its better insulating property. Since, there is an above average rainfall per year in British Columbia, it is also imperative to have a quick setting sealant applied to the walls of the cob structure in order to prevent leakage, that may lead to an eventual structural breakdown. In terms of structural integrity, straw-bale alone is a suitable construction material with numerous conditions, the first being strength. Its high variability compressively may be acceptable for a home, but for a commercial building, more lives are at stake. Because of this, multiple stories made entirely of straw bale should not be considered. This danger is further heightened by the potential to have students and volunteers manufacturing the upper levels.

Reference List

Jafferji, Raczka, Wang (2011, January 14) Straw Bale Construction: The Application in Massachusetts. Massachusetts: Worcester Polytechinic Institute

Jenkins, B. M., Blunk, S. L., & Summers, M. D. (2003, August 12). How straw decomposes: Implications for straw bale construction. Retrieved from Ontario Straw Bale Building Coalition website: http://www.osbbc.ca/Resources/Documents/Technical/how_straw_decomposes.pdf

Koko, S. (2010, December 28). Straw bale vs. cob. Build Naturally. Retrieved from http://buildnaturally.blogspot.ca/2010/12/strawbale-vs-cob.html

Marcuse, I. Interview with Ian Marcuse [Web log message]. Retrieved from http://www.davidsheen.com/firstearth/interviews/marcuse.htm

Warren Wilson Storage hut. [Web Photo]. Retrieved from http://www.warren-wilson.edu/~recycle/cobshed.php

McCann, J. (2004). Clay and Cob Buildings. (3rd ed.) Gutenberg Press Limited.

Natural building 101: Building a cob house. (2008, September 12). Retrieved from Green Building Elements website: http://ecostrawhouse.com/2011/06/10/building-with-clay-sand-straw-cob-style-in-stanley-park/

(n.d.). *Stanley park popcorn hut*. [Web Photo]. Retrieved from http://farm4.static.flickr.com/3177/2697056973_bd932314b4.jpg

Vardy, MacDougal (2005). Compressive Testing and Analysis of Plastered Straw Bales. Kingston: Queens University

Wells, Woods. (1999). Designing Your Natural House. John Wiley and Sons

[Web log message]. (2010, 9 29). Retrieved from http://www.colorcoat-online.com/blog/index.php/2010/09/15-impressive-green-and-recycled-homes/

Wilson, J. (2004). Chapter 11. In Sun Rise (pp. 135-161). World Peace Communications.

Wood, K. (n.d.). Building with clay, sand & straw: Cob style in Stanley park. Retrieved from Green | Sustainable |Eco Friendly |Straw Bale | and other Natural Homes website: http://ecostrawhouse.com/2011/06/10/building-with-clay-sand-straw-cob-style-in-stanley-park/

Living Roofs Incorporated. (2011). *Green Roof System.* Retrieved from http://www.livingroofsinc.com/portfolio/small-green-roofs/warren-wilson-cob-storage-building/

Warren Wilson College (2012). ***Recycling Crew's Earthen Building Project***. Retrieved from http://www.warren-wilson.edu/~recycle/cobshed.php