UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the Use of Laminated Wood as a Construction Material

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ABSTRACT

This report contains a Triple Bottom Line Assessment on the use of cross-laminated timber (otherwise known as “laminate wood”) as a viable alternative to more common construction materials such as concrete and steel for the new Student Union Building (SUB). The purpose is to determine whether or not laminate wood is more sustainable than concrete and steel, yet still maintains the same amount of structural integrity without compromising the safety of the building users. The methodology used to assemble this report is primarily based on various electronic sources available on the web. Numerous websites were visited relating to architecture, environmental awareness and building design in an attempt to justify whether or not this material is sound and sustainable enough to use in the construction of the new SUB. The results are that laminate wood largely outperforms concrete and steel in terms of environmental impact both from initial energy input to expected GHG emissions. The social and economic impacts however, are relatively similar to that of its counterparts. On the basis of these findings the recommendation is that the design team for the new SUB strongly consider incorporating as much laminate wood as possible into the architecture of the new building.

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GLOSSARY

Biogas:	Gas resulting from the breakdown of organic matter
Calcination:	Decomposition of limestone into carbon dioxide and calcium oxide
Formaldehyde:	A toxic chemical used in many applications, such as wood adhesives
Glulam:	Another name for laminate wood
Life cycle:	The life span of a building, beginning at manufacturing and ending at completion or disposal
Methylene diphenyl isocyanate:	A chemical compound with possible use as a formaldehyde-free adhesive
Ore-based:	The manufacturing of steel from iron ore
Polyvinyl acetate:	A type of material used widely as wood glue
Scrap-based:	The manufacturing of steel products from previously used steel

LIST OF ABBREVIATIONS

GHG	Greenhouse Gas
LEED	Leadership in Energy and Environmental Design
SUB	Student Union Building
UBC	University of British Columbia

1.0 INTRODUCTION

UBC pride's itself on being a world leader in sustainable management and building design. As such, when it was decided to begin the design phase for a new Student Union Building (SUB), the target was set for no less than LEED Platinum. To achieve this lofty goal, every level of the building must be considered in terms of a triple bottom line assessment – that is, an environmental, economic and social assessment. Some aspects of the new SUB that need to be considered are obvious, such as water management and energy sources, however most would not consider the type of building material to be used. It has become the norm or "status quo" in our society to assume that large commercial buildings will be composed of steel or concrete, but a new technology known as laminate wood, is emerging and could potentially replace steel and concrete. Laminate wood consists of several layers of timber, held together by some sort of adhesive. This product can be used as structural beams in large buildings or as design features to enhance the aesthetics of a building.

Many are not aware of the environmental issues associated with common building materials such as concrete and steel. However, because there are few alternatives available, suitable in terms of structural strength, society has turned a blind-eye to the environmental downfalls of these two materials. This report aims to investigate the improvements from an environmental standpoint that would result if the new SUB used laminate wood as a primary construction material. However, due to budget restraints, the main driving force of any project is always money and as such it is extremely important to investigate the economic pros or cons that would result from using laminate wood. An economic assessment of laminate wood is included in this report to discuss whether using it in the new SUB will be feasible. As important as the environmental or economic standpoint, is the social view of laminate wood. It is incredibly important for future generations of students who will use the SUB to appreciate the building in terms of sustainability as well as aesthetics and for the building to have a positive impact on them.

With these three main headings considered, this report conducts a triple bottom line assessment (environmental, economic and social) on the use of laminate wood as a construction material in the new SUB.

2.0 ENVIRONMENTAL ASSESSMENT

In order to assess the environmental impacts and potential sustainability of the use of laminate wood in the new SUB, it must be compared to other commonly used building materials. The two most widely used materials, for both structural members and building aesthetics, are steel and concrete. The environmental portion of the triple bottom line assessment largely investigates the energy usage and net GHG emissions of laminated wood in comparison to steel and concrete. This comparison is necessary to shed light on the relatively new technology of laminate wood and attempt to shift engineer's and architect's designs away from the "status quo." However, to get exact values on the environmental affects, several assumptions must be made since the building has not yet been constructed and those assumptions are addressed below. As a true assessment of any material involves, not only the positives but also the negatives, the potential drawbacks and problems of laminated wood are also investigated.

2.1 Laminate Wood in Comparison to Steel

Recent construction on the Gardermoen Airport in Oslo, Norway has paved the way for laminate wood to replace steel in large-scale construction projects. A study by [1] at the Department of Forest Sciences at the University of Norway has compared laminate wood (glulam*) with steel and aims to determine the GHG emissions over the life cycle of glulam and steel as well as calculate the avoided emissions by using glulam. In order for such an analysis to be conducted, some assumptions had to be made. The first assumption made by [1] is regarding waste disposal of the wood after the building has fulfilled it's life cycle*. In this case, it was assumed that the wood would be disposed of in a sustainable way such as recycling or burning. Other assumptions by [1] are based on steel, namely whether the steel is ore-based* or scrap-based* manufactured and the type of energy that is used to produce the steel.

When these assumptions are considered, it was determined by [1] that the overall total energy consumption of steel was 2-3 times higher than that of glulam and in terms of manufacturing, the production of glulam causes 1/5 the GHG emissions caused by steel if the steel is produced through an ore-based method.

****This term and all other marked terms can be found in the glossary***

2.2 Laminate Wood in Comparison to Concrete

Possibly the most widely used building construction material is concrete, mainly being used as structural members such as beams and columns. One of the main production steps of concrete is the manufacturing of cement in large-scale industrial plants (see figure 1 below), which is highly carbon intensive. According to [2], the manufacturing process produces one tonne of CO_2 for every tonne of cement.

Source: http://www.understanding-cement.com
Figure 1 – Cement Plant

In Metro Vancouver, cement production accounts for 50% of industrial emissions and 13% of total CO_2 emissions and, as [2] points out, these emissions are not easily avoided since the process of calcinating* limestone naturally emits carbon dioxide. When comparing concrete frames to laminate wood frames in buildings, [3] states the net GHG emissions are 1.5-2 times higher overall and the primary energy input is 60-80% for concrete. The emissions of concrete are roughly comparable to using laminate wood and then disposing of it in a landfill without any form of biogas* capture system [3].

2.3 Disposal of Laminate Wood

As [3] states, the environmental benefits of laminate wood as a construction material is heavily dependent on the type of disposal method used after the building has completed its lifecycle. In the case of the new SUB, this is projected as being 100 years which, although is quite long, for a truly sustainable building, plans for disposal must be made in advance. There are basically four options for laminate wood disposal, although a combination of each is also possible. The most sustainable method would be to burn the wood and use the energy produced which would then theoretically replace fossil fuels [1]. To avoid landfill use, the wood could also be recycled in new buildings, not necessarily as structural members since the integrity of the wood may have degraded but for materials such as doors and stairs [3]. If landfill disposal is necessary, there must be some sort of biogas capture system in place to avoid GHG emissions. As [3] states, the biogas can then also be used as a fuel theoretically replacing fossil fuel usage. The least sustainable disposal method would be landfill deposition with no biogas capture system, as much of the net GHG emission avoided by using laminated wood would be reproduced in the landfill due to the decomposition of wood [3].

2.4 Potential Drawbacks of Laminate Wood

Possibly the most well known problem for laminate wood would be the type of adhesive used. Traditionally, a formaldehyde*-based glue has been used which is not only toxic for humans, being classified as a carcinogen by the World Health Organization [4], but also harmful to the environment. However, recent research has shown that more environmentally friendly alternatives are now available, such as methylene diphenyl isocyanate* and polyvinyl acetate* [4]. The chemical treatment that the wood undergoes during manufacturing could also pose a problem as it may make it unusable as a fuel and any fungus or insect infestation would render it useless from a recycling standpoint [3].

From an initial development standpoint, laminate wood is not as readily available as concrete and this is one reason why many engineers are more supportive of a less sustainable concrete or steel framed building. To be readily available, deforestation must occur and this could lead to the issues surrounding sustainable forest management [3], potentially reemitting any avoided GHG emissions.

Although the aforementioned drawbacks could make laminate would less sustainable, they are easily avoided with proper planning and knowledge.

3.0 ECONOMIC ASSESSMENT

Timber has been used as a construction material for generations, and there is no denying the beauty of quality wood products. The large-scale building market has been dominated by steel and concrete design because of its availability worldwide, fire resistant properties and general ease of design. However, laminate wood design is beginning to change this, with the environmental benefits and increased cost competitiveness with steel and concrete has made laminate wood a viable alternative to steel and wood construction. There are some economic challenges associated with laminate wood, but if these problems can be overcome, laminate wood could be a cost-effective alternative to steel and concrete construction for UBC's new Student Union Building.

3.1 Economic Challenges with Laminate Wood

Wood construction is used extensively for residential building design. However, there is very little use of wood in both non-residential buildings as well as large-scale buildings in general. This may change in the near future, because as global steel prices continuing to rise, wood design, and specifically laminate wood design may take a larger share of the non-residential building market [5]. In order for that to happen, there needs to be improvements in a number of aspects. One aspect is ease of design. Some engineers believe that wood design is not cost effective on a personal level because of the extra time and effort that it takes them to design wood structures [6]. If more standardized and easy to use wood design data tables, span tables and pre-engineering systems were available, the wood design process could be expedited [6]. Improving this would make wood design, including laminate wood design, more cost effective for engineers, by saving them valuable time in the design stage of construction.

3.2 Economics of Laminate Wood Beams

Laminate wood beams offer a competitive comparison to steel and concrete beams. In addition to having aesthetic appearance, laminate wood beams are cost competitive with steel beams. In general laminate wood beams are ±20% of the price of steel beams [1]. The variation in price is due to the specific building design and the types of beams that are needed for the particular building. Steel beams are less expensive than laminate wood when beams are plain, similar and multiple, but when beams are irregular in shape, for example curved or round, laminate wood beams can be more cost-effective [1]. For long span and complex structures, laminate wood beams are less cost-effective than steel beams because of the difficulty of design [6].

3.3 Economics of Laminate Wood Adhesives

A key aspect of laminate wood construction and laminate wood beams is the adhesive that is chosen. The cost of the glue can greatly alter the total price of the laminate wood. Life-cycle analysis must be done in order to determine the true cost over the life of product. Higher quality, high durability adhesives may have higher initial cost, but often these costs can be offset over the life-cycle of the building [7]. Many times the durable wood adhesives have lower life-costs than the cheaper alternatives [7].

4.0 SOCIAL ASSESSMENT

The social aspect of a triple bottom line assessment evaluates the consequences a decision may have on the human capital that is invested into that decision. The goal of our social assessment on the use of laminate wood is to examine how its use will affect the people who will come into contact with the new SUB throughout its entire life cycle. We focused on investigating jobs that would be affected during construction and the faculty, staff and students – the population who will use the new SUB the most – after its completion. This section is largely theoretical as numbers are extremely difficult to come by when studying the social implications of a specific construction material.

4.1 Effect on Jobs

The standard method of using laminate wood in construction is to indicate exactly what pieces are needed which the laminate wood company will then put together before being sent to the construction site for assembly. This method can be problematic if the company chosen to assemble the wooden frames is located outside of Canada since it translates into a loss of jobs to foreign labour markets. It may seem that this situation can easily be avoided by utilizing a local laminate wood company but laminate wood is a fledgling market in North America whereas Europe has many more established businesses with experience in this area of work [8]. Therefore, choosing between local and foreign in this case will potentially be a quality control concern. In contrast, concrete is normally made at the construction site, which may take longer, but those jobs go directly into the local labour market. As well, there will not be any noticeable differences in the quality of the concrete if it is produced locally.

4.2 Effect on Faculty, Staff and Students

Once completed, the social impact of laminate wood will primarily concern the faculty, staff and students that pass through it in their day-to-day activities. As an architectural design tool it will be interesting to see how the laminate wood is incorporated in terms of aesthetic appeal. Many people prefer the look of wood and the ambience it creates when shown in a room. Architects around the world have many interesting designs regarding laminate wood [10-12], which indicates that the material is versatile and that there is immense room for creativity. According to [8,9] laminate wood provides superior building performance over traditional residential building materials in terms of sound insulation, fire protection, earthquake protection (seismic strength), living space comfort and potential gains in space from using a thinner material. Overall the fact that the building uses laminate wood provides an abundance of opportunities for different designs to enhance visual appeal without compromising building performance.

4.3 Other Considerations

Another thing to consider for the use of laminate wood is whether or not the company making the wood uses formaldehyde-based adhesive. Doing so would more than likely have social repercussions for those that will regularly frequent the new SUB upon its completion. However, innovative alternatives exist but the project managers for the new SUB must keep this in mind when searching for a company to supply laminate wood.

5.0 CONCLUSION AND RECOMMENDATIONS

This report conducted a triple bottom line assessment on the feasibility of utilizing laminate wood as a construction material in the new SUB. Since this material is a relatively new technology, many engineers and architects are hesitant to use it in large-scale, commercial buildings. However, laminate wood has immense potential to emerge as a leading construction material, possibly taking the place of steel and concrete.

From an environmental standpoint, laminate wood is much more advantageous over steel or concrete when designing a building aimed at the LEED Platinum certification. As mentioned above, it is much less energy intensive during manufacturing and has a fraction of the net GHG emissions compared with steel and concrete. The only realistic environmental challenge arises during demolition of the building and disposal methods however, proper planning can easily overcome this issue. From an economic standpoint, laminate wood is comparable to both steel and concrete however, there may be a risk of higher cost due to the fact that laminate wood is a newer technology and building designers are more reluctant to use it. When analyzing the actual beams, laminate wood beams are within 20% of the cost of steel beams [1]. From a social standpoint, laminate wood has the potential to create or take away jobs depending on where it is coming from. Laminate wood however, is considered by many to be aesthetically pleasing with many options for interesting designs [10-12].

With these points considered, our recommendation to the SUB stakeholders is to utilize laminate wood as much as possible. This building material will provide a sustainable, cost-effective and aesthetically pleasing framework for a world-leading student union building.

LIST OF REFERENCES

[1] A.K. Petersen, B. Solberg, "Greenhouse gas emissions, life-cycle inventory and cost-efficiency of using laminated wood instead of steel construction.:Case: beams at Gardermoen Airport," Environmental Science and Policy, vol. 5, no. 2, Apr., pp. 169-182.

[2] Ecosmart™ Concrete, "Environmental Impact, cement production and the CO_2 challenge," [Online Document] 2004-2010, [2010 Oct], Available at HTTP: http://www.ecosmartconcrete.com/enviro_cement.cfm

[3] P. Borjesson, L. Gustavsson, "Greenhouse gas balances in building construction: wood versus concrete from life-cycle and forest land-use perspectives" Energy Policy, vol. 28, no. 9, Jul., pp. 575-588

[4] Healthy Building Network, "Formaldehyde and Wood" [Online Document] 2008, [2010 Nov 21], Available at HTTP: http://www.healthybuilding.net/formaldehyde

[5] A. Skulsky, "Multi-level Wood-Framed Structures: Requirements For Building Beyond Four Stories", Prepared for Ministry of Forests and Range British Columbia, 2008 Available HTTP: http://www.boabc.org/assets/Latest~News/SR-Multi-storey%20wood%20frame-revJune%2030%202008.pdf

[6] J. O'Connor, R. Kozak, C. Gaston and D. Fell, Wood use in nonresidential buildings: Opportunities and barriers, Forest Products Journal; Mar2004, Vol. 54 Issue 6

[7] T. Sellers, "Wood Adhesives and Applications in North America", Forest Products Journal; Jun2000, vol. 51, issue 6

[8] P. Perkins, K. McCloskey, "A Strategic Plan for the Commercialization of Cross-Laminated Timber in Canada and the US," [Online Report] Mar. 2010, [cited 2010 Oct. 20], Available at: http://www.cwc.ca/NR/rdonlyres/061FE042-FC95-4631-B906-27965F2F2E20/0/CrossLaminatedTimberReportSpreads.pdf

[9] J. Vessby, B. Enquist, H. Petersson, T. Alsmarker, "Experimental study of cross-laminated timber wall panels," European Journal of Wood and Wood Products, vol. 67, no. 2, May, pp. 211-218.

[10] KLH Massivholz GmbH, "KLH," [Online Website] Oct. 2010, [cited 2010 Oct. 20], Available at: http://www.klh.at/home-klh.html?L=3

[11] M. Katz, "L41 Home," [Online Website] Mar. 2010, [cited 2010 Oct. 20], Available at: http://l41home.com/L41home.com/Home.html

[12] 5] P. Kobelt, "Montana Sustainable Systems," [Online Website] Oct. 2010, [cited 2010 Oct. 20], Available at: http://www.smartwoods.com/