

**An Investigation into the Use of Wood vs. Steel and Concrete in
Construction of the New SUB**

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THE UNIVERSITY OF BRITISH COLUMBIA



An Investigation into the Use of Wood vs. Steel and Concrete in
Construction of the New SUB

APSC 261: Technology and Society I

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ABSTRACT:

The University of British Columbia is a one of the many leaders in North America in terms of sustainability. The New UBC Student Union Building (SUB), which is to be completed in 2014, will aim for LEED Platinum+, the highest Green Building rating in North America with considerations for the Living Building Challenge.

The design of the New SUB is a joint process between UBC students, Alma Mater Society of UBC Vancouver (AMS) and HBBH + BH Architect Company.

This report will be devoted to a triple bottom-line analysis of constructional materials commonly used in buildings: hard wood, timber, concrete, and steel. For each material, this report will provide environmental, economic, and social advantages and disadvantages. At the end it will provide recommendations based on facts and findings.

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1.0 INTRODUCTION

Wood has been one of the primary sources of building material of humans for thousands of years. From the great ancient wooden palaces in China to the towering wooden churches in Russia (Figure 1), human beings had created countless architecture marvels that they have become as much part of our culture as they are our history. Even today, people such as the Japanese and majority of the population in North America still prefer their structures and houses (Figure 2) to be built in wood than their concrete or brick counter parts. For the Japanese, the use of wood and paper in their buildings is a part of their undying tradition, while for the people in North America it is mainly an economical reason due to the fact of the easier accessibility in their part of the world.



Figure 1: Wooden Russian church



Figure 2: A typical 19th century North American house

Wood is a green and sustainable material in the sense that it is a natural and renewable resource that is available aplenty in the province of British Columbia, which is where our new Student Union Building (SUB) will be build at. Due to its cheaper costs, lower environmental impact and long history of usage in North America, wood is one of the most suitable building materials that is available to construction of the new SUB.

However, as the size of the building continue to increase throughout the ages, wood alone is no longer enough to support the sheer mass and weight of the structure. It is impossible to construct buildings that are three stories or high with only wood, the frame of the building will need something stronger and more durable such as concrete and steel. Since the new SUB is going to be five stories high, we have to make use of steel, a very strong metallic material for the frame and concrete for strong foundation.

2.0 HARD WOOD

In this section the triple bottom line analysis of hard wood is discussed and in each subsection, the advantages and disadvantages are stated.

2.1 ENVIRONMENTAL ASPECTS

Hard wood is a product of nature; they came from trees such as oak, beech and ash which can be found easily in British Columbia (See figure 3) and thus making them a renewable material. Hard wood is the strongest and most durable type of wooden material in the world, its strength and toughness exceeds that of timber. It is the most long lasting wooden building material around. Certain parts of a building such as the hard wood flooring can be renewed, sanded and refinished almost indefinitely. Although it lacks the strength and longevity of both concrete and steel, it is a much more flexible building material, able to adapt easily to the design changes of an architect and it is a better thermal insulator than concrete or steel.

The following are some of the major advantages of hard wood.

- It is strong and durable.
- Comes with large arrays of beautiful natural patterns.
- It is easier to modify and tweak during construction.
- Hard wood is a naturally grown and renewable material.
- Wood has better thermal mass properties than steel, able to retain heat during the day and release it at night.
- It produces less green house gas than either concrete or steel.



Figure 3: Oak forest

With all the advantages listed above, hard wood also comes with a whole array of disadvantages.

- It is vulnerable to moisture, humidity and termite infestation like all the other wooden materials.
- It is extremely noisy when walking on it. (flooring)

- It is not suitable for certain rooms in the house such as kitchen, washroom or any places that can easily get wet.
- As a wooden material, it is very flammable.
- Hard wood being a natural grown material, deteriorates with age and is subject to rot, fungus and decay and attack by insects and woodpeckers all of which will reduce the strength of the material; this does not happen to steel.

For UBC New SUB

British Columbia is a province blessed with natural beauty and plenty of natural resources with hard wood being one of them. The main theme of the new SUB is sustainability; hard wood is almost a perfect candidate for this job due to the fact that it is both a clean and renewable resource, very strong and durable and also one of the most sustainable materials out there today.

2.2 ECONOMIC ASPECTS

Hard wood is one of the cheaper construction materials comparing to both steel and concrete due to the sheer abundance of it in British Columbia. The lumber industry (See figure 4) is also one of the main exports and income of this province which leads to the few following advantages:



Figure 4: Lumber Industry

- The use of wooden material in British Columbia helps stimulating the economy of this province.
- Hard wood costs much less than either concrete or steel.
- Since it is naturally grown in British Columbia it can be easily replaced or repaired.
- Hard wood is very durable and highly resistant to wear and tear which leads to a low maintenance costs.

The economic downside for hard wood and wooden material is that too much of it must be used in an average house than either concrete or steel. In fact, an average home requires 6 ton

of steel vs. 20 ton of lumber which leads to less transportation costs. Also, comparing hard wood to other wooden material such as the timber, it is extremely expensive.

For UBC New SUB

Hard wood is an abundant and cheaper building material comparing to either concrete or steel in British Columbia; therefore it is rather common sense to make use of this advantage for the construction of this new SUB.

2.3 SOCIAL ASPECTS

Hard wood comes from trees such as oak. First, it has to be cut down by either lumberjacks or machines and then processed in saw mills. Figure 5 shows a two stories house built entirely out of wood. This creates different job opportunities in both the logging industry and the saw mill with jobs such as lumberjacks and lumber mill workers.



Figure 5: Wooden house frame

Human beings have been making construction with wood since the dawn of time, even today the majority of the population in North America and Japan still have the preference of wood houses over their concrete counterparts. Here in North America, people are used to the presence of wooden buildings for generations it has somewhat become part of the North American tradition. Other building materials such as concrete, steel or brick do not come cheap in this part of the world, resulting in difficulty for people to adopt these materials from both the cultural and economical perspective.

For UBC New SUB

As stated above, wood has better thermal mass properties than steel or concrete, making it a better thermal insulator and able to retain heat during the day and release it at night. This will keep the students inside the new SUB building warmer and more comfortable during winter and

cooler during summer. Wooden building can also be decorated with beautiful wooden carvings such as the first nation arts and crafts (See figure 6) which are not only beautiful to look at, but also introduce the first nation cultures to both local and international students.



Figure 6: Haida wooden carving

3.0 TIMBER

Lumber or timber is basically wood in any of its stages from readiness for use as structural material for construction, to wood pulp for paper production. Wood construction is common for many single-family houses throughout the world. Large buildings can also be constructed using wood (with steel reinforcements); we have an example of a building mostly made of wood in UBC: our forestry science building. Since BC has one of world largest rain forest, timber and wood materials are very easily accessible and cheaper than any other form of construction.

Lumber is supplied either rough or finished. It is available in many species, usually hardwoods. Finished lumber is supplied in standard sizes, mostly for the construction industry.

Only some of the main types of wood construction types is stud-wall frame with plywood/gypsum board sheathing (Figure 7), which is popular worldwide and is the main type used in the United States (WHE Report 90), Canada (WHE Report 82), and Japan (WHE Report 86). For this type, walls are made of vertical timber elements of rectangular cross section covered in light plywood or composite sheathing, with roofs made of timber members or prefabricated trusses, which are sheathed similar to the walls. The building foundations are usually concrete but sometimes are made of stone.



Figure 7: Typical house made from lumber and timber

Now let us look that the advantage and disadvantage of wood based building:

Advantage	Disadvantage
<ul style="list-style-type: none"> • A shortened construction period • The construction period is not weather dependent • Parts are premade • A higher thermal value per given wall width when compared to other forms of construction • Sound insulation performance that can exceed Building Regulation requirements in a cost effective way • Reduced foundation costs due to a lighter structure • Improved dimensional accuracy with an engineered product • Effectively insulated so that this, lowers energy costs in winter, and helps keep buildings cooler in the summer 	<ul style="list-style-type: none"> • Highly flammable • Quickly absorb moisture • Material decay leads to relatively shorter lifespan • Generally destroyed by earthquake or big natural disaster

3.1 ECONOMIC ASPECTS

The following table, states the amount of energy required to process timber and produce the specific product. The cost we are looking is in term of Mega-Joules of energy required to produce only one kilogram of product from raw timbers. In today's value for 1 MJ of energy is approximately \$0.28. We never actually use one kilogram of the product; we consume in the size of tons.

Source	Product	Energy (MJ/kg)	Cost(\$/ton)
Alcorn and Baird (1996)	Kiln-Dried, Dressed	2.5	\$694.44
	Glulam	4.6	\$1,277.78
	Medium-density Fiberboard	11.9	\$3,305.56
Buchanan and Honey (1994)	Kiln-Dried, Treated	9.4	\$2,611.11
	Glulam	9	\$2,500.00
	Rough	1.7	\$472.22
	Air-Dried, Treated	2.4	\$666.67
	Timber Formwork	0.6	\$166.67
	Hardboard	41.2	\$11,444.44
	Softboard	31.2	\$8,666.67
FEMP (2001)	Lumber	4-7	\$1,944.44
	Particleboard	14-20	\$5,555.56
	Plywood	18	\$5,000.00
Lawson (1995)	Softwood Stud	3.5	\$972.22
	Particleboard (Softwood)	8.0	\$2,222.22
	Hardboard	24.0	\$6,666.67
	Imported Western Red cedar Frame	4.5	\$1,250.00
	Hardwood Engineered Product	11.0	\$3,055.56
	Floors	1.9	\$527.78
	Frame, Weatherboards, Plasterboard	1.5	\$416.67
	Stud with Plasterboard	1.3	\$361.11

For UBC New SUB

The demand of timber for a typical long lasting house is 12.13 cubic meters per house and density of timber is 800 kg/m³. So if our sub is the size of 4 houses then we need about 39 tons of timber. So, in term of raw timber we would need to spend about \$11.3 million, which is a lot cheaper than concrete and steel.

3.2 ENVIRONMENTAL ASPECTS

BC Timber Sales, a stand-alone organization within the Ministry of Forest and Range, manages approximately 16 million cubic meters of timber. Last year BCTS sold about 10 million cubic meters of timber which covers a very large amount of lands.

As the demand for timber increases, machines are moved into the forest. When there are machines, people and wood gatherers in one place, there is a very high risk of forest fire. This year alone, we have lost about 600 hectares of forest.

Also, the wild habitats are constantly forced to move around, that in turn, have a very large effect on the local ecosystem. Though we are getting better at managing and regulating a sustainable environment, wood cutting would still affect the ecosystem. BCTS meets all legal forestry requirements, including silviculture obligations, and annually plants over 40 million seedlings. It is advertised that the seeds and seedlings are of consistently high quality.

For UBC New SUB

As the need for sustainability has come to be the new goal for UBC, we will see an increase in tree plantation and global forest protection.

3.3 SOCIAL ASPECTS

Socially, wooden buildings are a lot more appealing. With wood ones, we can construct quite a big variety of shapes, textures and colors compared to concrete or steel. Staying enclosed in a wood structured building or even design allows people to feel more in tune with nature. It creates a relaxing environment for social and formal events.

For UBC New SUB

For the SUB, a lot of people would really appreciate a wood structured building. Just like most engineering students like the forestry building because of it being made of wood and for the open space available there.

4.0 CONCRETE

Concrete is the most commonly used construction material in the world. It is a composite construction material composed of cement and other the cementitious materials. Through its entire life cycle: extraction, processing, construction, operation, demolition and recycling, as a construction material, concrete definitely makes contribution to the triple bottom line from environmental, social, and economic impacts.

How the concrete contributes to sustainable building design:

4.1 ENVIRONMENTAL ASPECTS

In order to consider the construction material as green, the environmental impact for concrete is basically quantified by the CO₂ emission and energy consumption during its life cycle.

The thermal mass of concrete contributes to operating energy efficiency and reduced cooling cost. Concrete can be used to build up long lasting structures, so the energy is consumed when having maintenance and reconstruction. Concrete based building needs an accurate design before setting up any constructions. According to the design, ordering the right amount of cement, results in less construction waste during the construction. Concrete is also locally available material, less transportation costs will be made. Concrete walls can be painted any color. When painted in light colors, the interior lighting requirements will be reduced due to light reflectance.

Permeable concrete pavement and interlocking concrete pavers can be used to reduce runoff and allow water to return to the water table.

Some concrete construction can be reused, such as concrete pavers and precast wall panels. For example, “dry stone” retaining walls are made from concrete sidewalk slabs. However, the reuse of crushed concrete is restricted due to experiences, standards. To meet the technical specifications and performance expectations, they require extensive testing for the recycled concrete products to produce recycled aggregate. However, the results from recent researches show that recent projects have proven that the aggregate can be build by recycled concrete. Moreover, recycled concrete can be 100% used in roadbed, parking lots and other applications as a granular material. 45% to 80% of coarse aggregate comes from concrete to form new concrete mixtures.

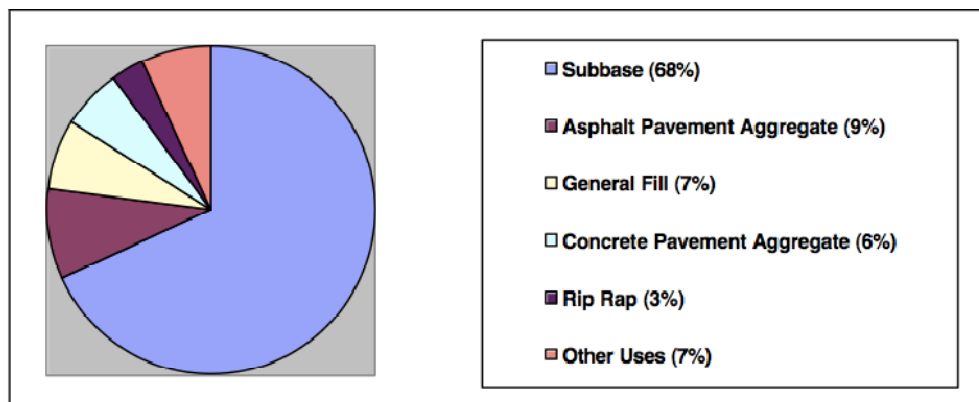


Figure 8: Uses of Recycled Concrete Aggregate (Deal 1997)

The use of recycled aggregate does not substantially affect the compressive strength and splitting tensile strength of the concrete when only the coarse aggregates were replaced by coarse fragments of demolition debris. Therefore, recycling and reuse of concrete can offer much environmental benefits.

Using concrete as construction material can improve indoor air quality. According to the property of concrete, there are no off-gassing, toxic and organic compounds from it. Furthermore, polished concrete does not need carpeting, since carpeting may nourish dust mites and molds which affect human health. Exposed concrete walls do not require paints or sealants, such as the roof and the sun deck slab of buildings. Concrete buildings can be easily cleaned.

For UBC New SUB

The recycled aggregate from the old SUB can be replaced to build partial of the new SUB. Although it cannot have the perfect performance, it is considered as green.

4.2 ECONOMIC ASPECTS

Economic impact is also very significant to evaluate the type of construction material. Because natural resources are limited, construction materials have seen a substantial increase in cost. When the environmental impacts of concrete are considered, the economic impacts are also involved within.

Because the concrete is produced locally, there are very low transportation costs. Transporting concrete to the landfill can cost as much as \$0.25 per ton per mile. It is easy to find a concrete supplier, so the material is very cost effective. Due to the long lasting characteristics of its properties, concrete buildings need less maintenance. In fact, it has lower operating cost as well because its thermal mass characteristics help to moderate heating and cooling peaks and lower HVAC equipment requirements. Lower lighting costs due to reflectance of material. Concrete buildings last longer because they are resistant to wear and tear, severe weather, rot, insects and fire.

For UBC New SUB

According the price tag of the new SUB, the final cost will be approximately \$103 million. One of the draw backs of concrete is that it is more expensive than other wooden construction material. However because the new SUB is 5 stories high, the weight of it is high. Therefore, concrete is a good choice for the SUB's foundation.

4.3 SOCIAL ASPECTS

Because the better indoor air quality, there are no VOC's to contribute to sick building syndrome. Unlike those aged wooden house, as long as the air circulation works fine in the building, bacteria can be prevented. It is safer to stay in a concrete building, since the concrete walls are resistant to fire, wind, vibration, sound transmission and seismic waves.

5.0 STEEL

In this section the triple bottom-line analysis of steel is discussed and in each subsection, the advantages and disadvantages are stated.

5.1 ENVIRONMENTAL ASPECTS

To make steel, one has to mine earth and extract iron ore. Then it is smelted and combined with a prescribed amount of carbon to make steel. Steel is, by far, the strongest material in construction, and its strength to weight ratio is much higher than wood or concrete. Theoretically, steel can have infinite lifetime, if corrosion is maintained. This can be done by a lot of methods like galvanizing and nickel plating to name a few. Here are some more advantages of steel in the environmental sense:

- In case of a fire, steel is not flammable, resulting in less damage.
- Steel is highly recyclable (See figure 9). Almost 69 percent of all steel is recycled in North America each year – more than paper, aluminum, plastic and glass combined. North America's average recycling rate has been in excess of 60 percent since 1970.



Figure 9: Steel recycling from cars

- Air and water emissions are 90% lower today than 10 years ago.
- More than 95% of the water used in manufacturing steel is recyclable.
- Steel is very energy efficient to operate and maintained. Once a steel structure is built, you don't need any form of maintenance.
- Steel is safe from termites, rotting and drying out. It won't shrink, warp or swell.
- Greenhouse gas emissions per ton of steel shipped have been reduced by nearly 45% since 1975.

There are a lot of advantages to steel, however there are some major disadvantages which must be considered. These are:

- High energy in manufacturing. The process of smelting of iron ore and combining it with carbon, or steel refinery, on average, uses two times the energy than wood manufacturing per one Kg of material.
- Steel, being a metal, conducts heat about 310 times faster than wood. This results in high energy consumption in heating and cooling.
- Because steel is mostly made up of iron, it is prone to corrosion. This results in decrease in strength and increase in weight, which put together, cause collapse of steel structure.

For UBC New SUB

Vancouver is on a major earthquake zone on Earth (the collision zone between Pacific Plate and North American Plate). For this reason buildings must be structurally reinforced. The UBC New SUB must have a lifetime of at least 50 years, which means there is high probability that it will see some earthquakes. Because the New SUB is 5 stories high it is really important to use steel beam in major stress areas.

As for the old sub, it is environmentally sustainable to recycle all of the steel structures in it. It is even better to reuse the steel beams, if they are in good condition.

5.2 ECONOMIC ASPECTS

Although the price of steel is higher than wood, it has remained stable for a long time and this allows accurate budget estimates. From an economic point of view, steel has a lot of advantages. Some of these are as follows:

- Steel structures can be built from pre-engineered parts (See figure 10), which results in much faster construction time. This, in turn, reduces project expenses.



Figure 10: Pre-engineered steel structure.

- In North America, the cost of steel is higher than wood, however from an in-depth analysis of the total cost per living area in an average house (See figure 11), it appears that the difference between a steel house and a wood house is less than \$8 per square foot.

House	Total Living Area (ft ²)	Material Cost (\$)	Builder's Labor Cost (\$)	Builder's Total Cost (\$)	Total Cost/FT ² of Living Area (\$/ft ²)	Total Hours/FT ² of Living Area (Hr/ft ²)
Steel House	1,428	\$63,014	\$32,229	\$95,243	\$66.70	0.696
Wood House	1,428	\$58,141	\$25,237	\$83,378	\$58.39	0.674

Figure 11: Cost comparison between steel and wood house.

- Because of the reliability of steel, the insurance cost of a steel structure is lower than that of a wood structure.
- Steel is sturdy and durable; therefore it is free of high maintenance costs. Walls stay straight, floors are flat, doors and windows do not stick. For example, a metal roof lasts 2-3 times longer than an asphalt shingle roof.
- An average home requires 6 ton of steel vs. 20 ton of lumber which leads to less transportation costs.

The economic downside to steel is that it costs a lot more than wood or any construction material per kilogram. The reason for this is that steel, to be used in construction has to be available in specific shapes as illustrates in figure 12.

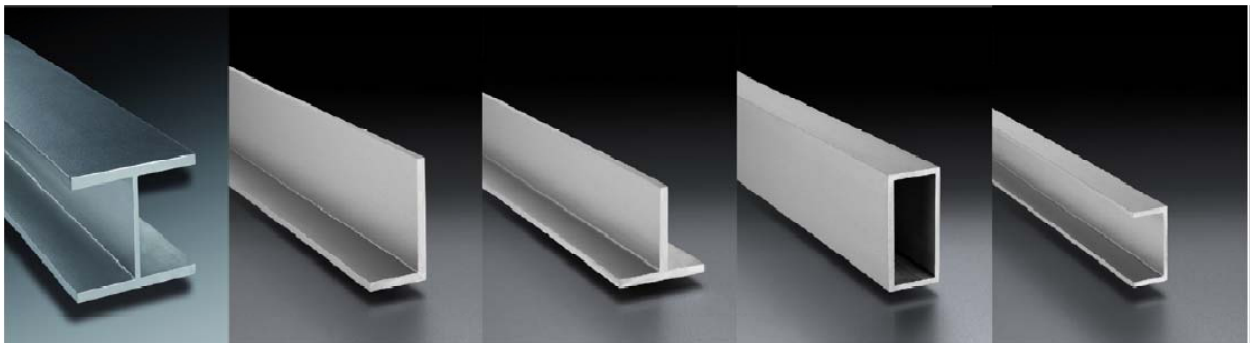


Figure 12: Pre-manufactured steel beams used in construction.

Also because steel is a very good conductor, there are high costs in gas and electricity bills for heating and cooling a steel structure than a wood structure.

For UBC New SUB

The estimated price tag for the New SUB is \$103 million and more than 75% of is paid by students (\$25 million from UBC, \$78 million from students). Therefore, students want to get the most out of their money. This means reusing steel structures and beams that are in good condition from the old SUB, and implementing them in the new SUB, instead buying newly manufactured steel.

5.3 SOCIAL ASPECTS

The process in which steel is made either from iron ore and carbon or from recycled steel consist a lot of parts. This, in turn, makes a lot jobs available, for example it helps making communities around mine sites, refinery plants, and construction parts manufacturing plants.

Also, steel structures give a sense of confidence to the people living inside them. Logically, general public know that a steel structure is less affected in case of an earthquake, or fire. Therefore, they will feel more comfortable living inside them and have a peace of mind. In case of other natural disasters, such as a lightning strike, a steel structure, because of good conductivity, will transfer all the electricity right down to earth – a wood structure will burn upon impact.

For UBC New SUB

If student know that their new SUB has steel reinforcements, then they will feel more comfortable and are assured that it will never topple in case an earthquake. This means having visible steel structure. This idea has been implemented in Arup Campus in Blythe Valley Park, West Midlands (See figure 13).



Figure 13: Steel Structure in Arup Campus

RECOMMENDATIONS AND CONCLUSION

The new sub will be a building with 5 stories and covers an area of 250,000 square feet, a building that size can no longer be built by wood alone. The following are the conclusion of the list of material that should be used to compliment wood in the overall construction of the new SUB building.

For a massive building of that size we need an extremely solid and strong foundation as the support. Concrete will be the perfect material here since it is a stronger, more durable than wood.

Even with concrete as the foundation, the bulk of the entire building will be still hold on to by the frame of the building; some wooden materials are not able to support that. The frame of the new SUB has to be extremely strong, durable and can with stand the test of time. Steel is a good material to use here since it is not only the strongest building material out there today, it has an almost infinite life time and also energy efficient to maintain and operate with a lower insurance cost.

Staying true to our original topic that is the use of wood in constructions, the rest of the building will still be made from wooden construction materials. The overall interior structures such as the walls and flooring will be constructed with hard wood and timber for their extremely good insulating property and sustainability.

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