UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Triple Bottom Line Assessment of Rooftop Catchment System

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APSC 261

March 31, 2011

TRIPLE BOTTOM LINE ASSESSMENT OF ROOFTOP CATCHMENT SYSTEM

Submitted to Dr. Dawn Mills

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Source: Ubyssey, 2011,
< http://ubyssey.ca/culture/thinking-inside-the-box-sets-the-stage-for-new-subs-theatre>

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ABSTRACT

"Triple Bottom Line Assessment of Rooftop Catchment System"

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The University of British Columbia (UBC) plans to implement a rainwater harvesting system atop the roof of the new student union building (SUB). An investigation into the rooftop design and potential catchment materials was carried out to determine the associated economic, environmental and social impacts. A material analysis for the water supply and drainage piping is also considered. A low sloping roof design is chosen for its ability to prevent excessive loading due to factors such as ponding of rainwater.

The four potential roofing types studied for a low slope roof design were asphalt, concrete, green roof, and aluminum. Overall, concrete roofing was deemed most appropriate due to its superior economic and environmental implications. Although green roof is seen as the more socially viable option, its adverse economic and environmental implications are too great to base the roof design solely on appearance. Cast iron piping for the drainage system appeared most advantageous when compared with **acrylonitrile butadiene styrene** (ABS) for its long design life and recyclability. It is also considered more economically and environmentally sound over the lifetime of the SUB building. Polypropylene pipes are recommended for the water supply piping as they are most cost effective, and strongly support Leadership in Energy and Environmental Design (LEED) initiatives. Lastly, the optimal material for the gutter system, an intermediary of the rooftop and piping systems, is galvanized steel. This is proposed as a result of its long life span and ability to resist corrosion.

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GLOSSARY

Galvanize	Add layers of zinc to protect from corrosion
Galvanic Anodes	The main component of a system used to protect buried or submerged metal structures from corrosion
Bitumen	Naturally occurring impure mixtures of hydrocarbons
Cistern	The tank in which the collected rainwater is being stored
Biofilm	An aggregate of microorganisms in which cells adhere to each other and/or to a surface
Carcinogenic Compounds	Agents directly involved in cancer
Disinfected Byproducts	Water Pollutants

LIST OF ABBREVIATIONS

UBC	University of British Columbia
LEED	Leadership in Energy and Environmental Design
SUB	Student Union Building
ABS	**Acrylonitrile Butadiene Styrene**
SEEDS	Social, Ecological, Economic, Development Studies
FBD	Free Body Diagram
PAH	Polycyclic Aromatic Hydrocarbons
SCM	Supplementary Concrete Materials
USGBC	United States Green Building Council
CSA	Canadian Standards Association

1.0 INTRODUCTION

The roof catchment atop the new SUB is proposed to span 2719m^2, which is approximately half the total projected roof area. The scope of this project includes a comparison of various roof designs and materials, along with the gutter and piping systems. As it is primarily a flat roof, a few simple designs to reduce extensive loading are discussed. An analysis of several possible roofing materials is conducted including asphalt, concrete, green roof, and aluminum. The advantages and disadvantages of galvanized steel and aluminum gutter systems are assessed. There are two separate piping systems which will be in place, one which carries water from the rooftop into the cistern where the water will be stored, and one which carries the water out of the cistern and to into the new building. Upon considering possibilities for building materials we will explore their long-term economic, environmental and social repercussions. This provides a basis for a triple bottom line assessment and will allow for optimal material choice in order to successfully meet LEED standards for the New SUB.

2.0 ROOFTOP CATCHMENT DESIGN

A simple rooftop design is suggested to minimize rooftop loading due to wind, rain and snow.

2.1 PROJECTED RAINFALL ACCUMULATION

To determine the net rainwater accumulated per annum Google Earth software was utilised. The region highlighted in red (Figure 1) represents the catchment area of the new Student Union Building. The building below the shaded zone is the existing SUB.

Figure 1: Annual rainfall accumulation as determined by Google Earth Software.

Google Earth uses satellite data and precipitation records collected by the Government of Canada to estimate the net annual accumulation into this region. The program provided an estimate of a total of 1300mm of rainwater to collect in this catchment zone over an average year, which is equivalent to 36525450 litres of water.

To provide a more practical understanding of this very large volume, the problem was interpreted as the total number of possible toilet flushes. If the average toilet uses about 6 litres of water per use then the total number of possible flushes can be calculated as:

$$\frac{36525450 litres}{6 litres / flush} =$$ 6087575 flushes from one year of rainwater harvest

These numbers are quite substantial and provide evidence that there is excellent opportunity in exploitation of rainwater resources for the New SUB catchment zone.

2.2 HAZARDS IN POTENTIAL LOADING

A simple catchment design is proposed to reduce loading as well as maximize rainfall potential.

2.2.1 CLIMATIC LOADING VARIABLES FOR THE GREATER VANCOUVER AREA

The new SUB catchment must be designed to withstand the following loading factors for Vancouver's climate and hydrology (Table 1):

WIND	Maximum loads of 0.48 kPa
RAIN	A maximum of 124mm (0.2 kpa) accumulation within a 24 hour period
SNOW	Maximum loads of 1.9kPa

Table 1: Maximum loads due to wind, rain and snow

Note: the above values are quoted from the SUB 75% Schematic Design Guidelines

From the data provided in the table above it can be concluded that the strength of the roofing material must be able to withstand a maximum load of 1.9kPa. Although snow provides a greater maximum instantaneous impact on the roof structure, rainfall is a prominent climate feature and will therefore be the most consistent forcing mechanism. The minimum temperatures are rarely above freezing and rainfall occurs almost constantly throughout the seasons. However, the annual average temperatures remain above zero degrees Celsius (Environment Canada). Although rainfall applies smaller instantaneous loads than both snow and wind, the duration of loading is much longer. For this reason, rainwater is the most critical loading factor for the design and structural integrity of the rooftop of the New SUB. The average wind speed is also quite constant as Vancouver is sheltered by coastal mountain ranges.

Overall, snow loads create the greatest maximum loads of all three climatic mechanisms. It may, however, be noted that periods of sub zero temperatures are very uncommon compared to ideal conditions for rainfall accumulation.

2.2.2 WATER PONDING

Water ponding is caused by concentrated snow and rainwater loads which act to deform the structural integrity of flat roofs. This has the potential to prevent the catchment area from effectively transmitting flows into the gutter system. A free body diagram of this occurrence is provided in Figure 2 below. The deflection in the centermost part of the catchment volume (V) is a function of the total length and net applied loads (Blaauwendraad, 2007). Potential designs to reduce the possible adverse effects associated with such loads on a flat roof may be found in section 2.2.3 below.

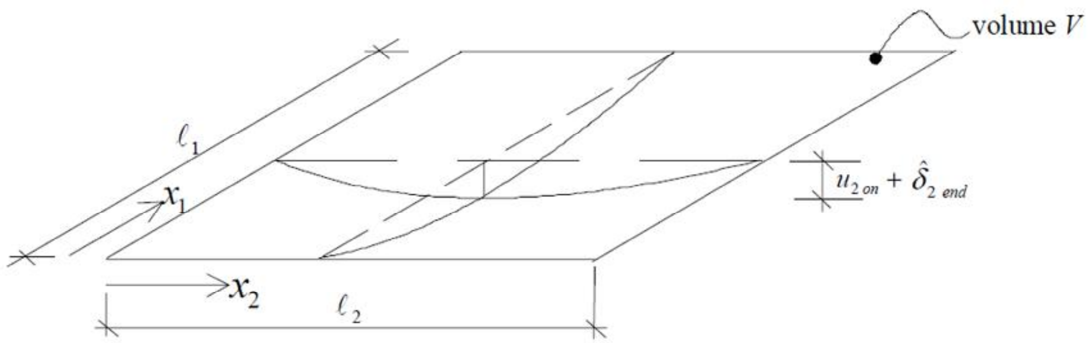

Figure 2: Free Body Diagram of deflection of roofing material due to water ponding.

2.2.3 CATCHMENT DESIGN

The optimal catchment design for the New SUB reduces the possible adverse effects associated with rain and snow loads, while increasing the rainwater catchment potential. Orientations A, B, C and D (Figure 3) illustrate four different structural options frequently used in rooftop design. The triangular region above each profile represents the net loading shadow imposed on the catchment surface. These distributions have been determined using an equilibrium relationship of various force vectors acting on the 2D plane. For the flat roof (A), a uniform and horizontal load results, while B, C and D carry a triangular loading pattern. Option B clearly has the smallest loading area, thus it is the most effective design for minimising the applied load.

The implementation of a sloped roof appears to be optimal, however if the roof is too steep it will increase the water velocity and may lead to possible overflow and potential loss of collected rainwater. Thus, option B oriented between 10-30 degrees is the most ideal orientation for careful flow into the gutters and finally to the underground cistern.

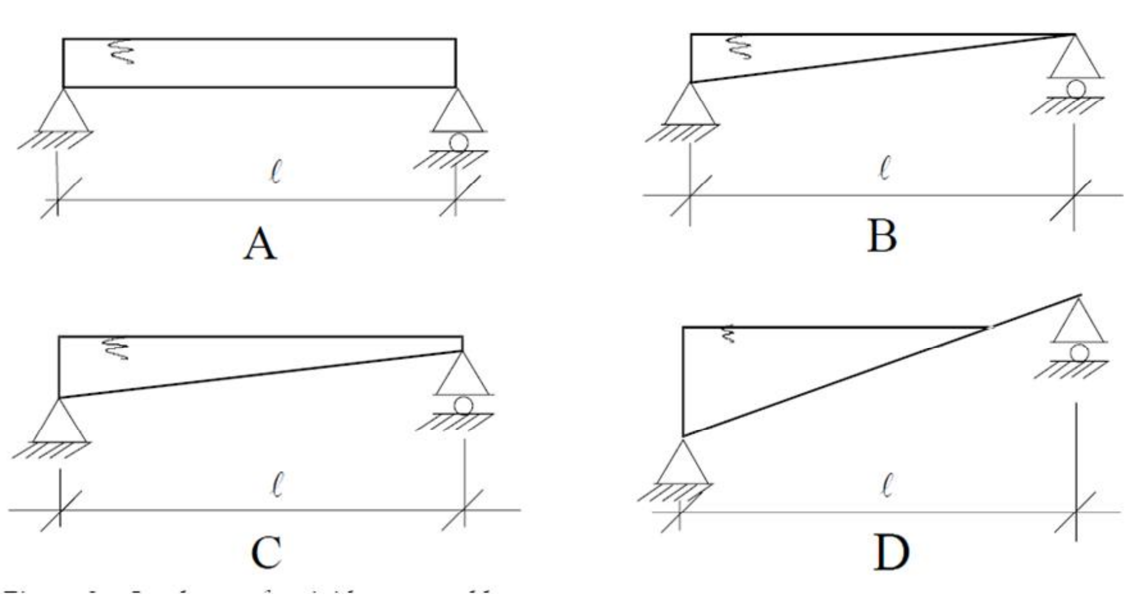

Figure 3: Four possible orientations of catchment slope.

3.0 ECONOMIC MATERIAL ANALYSIS: ROOFING

This section encompasses a breakdown of several roofing materials, distinctive material properties and their initial costs, along with their expected lifespan. The total cost of materials is based on the 100 year expected design life of the New SUB, thus it includes the cost of all replacements needed. Through further investigations beyond the scope of this report it can be determined that extra expenses due to maintenance are consistent for all roofing materials except green roofs.

3.1 ASPHALT

Asphalt is generally used to describe asphalt concrete, a combination of bitumen and a conglomeration of various minerals (Trumbore et al., 2005). This type of roofing is best suited for colder weather climates due to its dark colour and ability to absorb heat. A comparative cost analysis is shown in Table 2 below. The expected lifetime of asphalt is 20-30 years, leading to extra expenses associated with the need for multiple replacements. Although it appears to be the most economically viable option, further social and environmental analysis will prove it inadvisable.

3.2 CONCRETE

Concrete is the most resistant of all materials and has been proven to last for long periods of time in many roofing applications. There are no anticipated replacement expenses if concrete is used as the rooftop of the New SUB. As well, there are little to no related maintenance costs as it does not rust or burn. Concrete is generally an impermeable material, dependent primarily on the grain size of the aggregate used (Hoseini, Bindiganavile, & Banthia, 2009). If exposed to extensive chemical or mechanical weathering, the design life may be greatly reduced. Due to Vancouver's milder climate there is low risk of these adverse processes such as freeze thaw weathering. As it is a fairly heavy material, initial transportation costs may be high. This may be easily balanced by the lack of replacements needed. With a minimal total cost of $29 900, it is the recommended rooftop material from a well-informed economic standpoint. As there is extensive loading associated with this roof type, this recommendation is highly dependent on the structural materials chosen for the entire New SUB, and is based on the proposed 75% schematic design.

3.3 ALUMINUM

Aluminum roofing is highly resistant to corrosion and is a very lightweight yet durable material used in many roofing applications. This material also has the unique ability to reflect light in the summer season, which will help keep the New SUB building cool (Alvarado & Martínez, 2008). Aluminum roofs, however, are significantly more prone to the occurrence of damage and deformation. The installation process may be quite costly as further insulation would be needed to prevent excessive noise due to weather. It is difficult to find many, if any, commercial roofing applications which use aluminum for large areas of flat roof. As a result of its high initial cost, and potential need for extensive maintenance, aluminum is not the economically favourable material for the rooftop catchment of the New SUB.

3.4 GREEN ROOF

A green roof is undoubtedly the most environmentally friendly and socially pleasant roofing material on the market. However its use as a roofing material for rainwater catchment systems is still a widely debated topic (Czemiel Berndtsson, 2010). A green roof consists of a vegetated rooftop surface with an impermeable layer below. With the initial cost of a green roof at $25.00 per square foot, it is the most expensive material included in this analysis. This cost includes the addition of the above mentioned impermeable layer needed. The green roof is the only option requiring maintenance on a weekly basis, adding an additional yearly cost of 30000 dollars. This type of roofing has a design life of around 40 years as the base layer deteriorates (Carter & Keeler, 2008). From an economic standpoint, it would be near impossible to balance the economic implications with the environmental and social benefits arising from such a material

TABLE 2: COMPARATIVE MATERIAL COST ANALYSIS

Product	**Cost per ft^2 ($)**	**Initial Cost ($)**	**Lifetime (Years)**	**Replacements Needed**	**Replacement Cost ($)**	**Total Cost ($)**
Asphalt	0.86	2300	20-30	4	9200	11 500
Concrete	11.00 m^3	29 900	100	0	0	29 900
Aluminum	9.50	25 800	40+	1	25 800	51 600
Green Roof	25.00	67 900	40+	1	67 900	135 800

Table 2 shows a comparative cost analysis of the initial and replacement costs for all four roofing materials over the catchment area (2719 m^2). Transportation costs are not included as they are often negated due to the general trend of heavier materials having a much longer design life.

4.0 ECONOMIC MATERIAL ANALYSIS: PIPE AND GUTTER SYSTEMS

A general analysis of the materials to be used for both the piping and gutters systems for the catchment of rainwater was executed, along with a cost analysis. A material lifetime and expense summary can be found in Table 3 below.

4.1 DRAINAGE PIPING

Drainage piping consists of the pipes exiting the underground cistern, and may be composed of either cast Iron or ABS (Acrylonitrile Butadiene Styrene). The pipes will most likely be located underground and thus subject to external loading.

4.1.1 CAST IRON

Cast Iron is most commonly seen in older model buildings, such as those built in the 19^{th} century, and is often replaced today by ductile iron pipe which is very similar in composition (Bilgin & Stewart, 2009). The greatest benefit is its long service life, as it is expected to last from 75 to 100 years providing that a few measures are taken in order to prevent corrosion. Corrosion occurs because of physical and chemical weathering, and may be reduced by methods of coating or casing the pipes or by galvanic anodes (Cenoz, 2010). The price of cast iron piping quoted at $9.60 per foot with a four inch diameter includes protection against corrosion. The long life of this material is largely due to the fact that its strength is not compromised by time. Cast iron has a low value for thermal expansion, allowing for little to no deformation under an applied load and only breaks down through weathering or corrosion. As fewer joints are needed to allow for expansion due to decreased deformation, the cost may be minimized. Cast iron piping needs to originate near the site of development, as shipping by weight can be very costly. The density of iron is beneficial due to its ability to dampen noise when the pipes are in use, though this may not be a concern with the pipes location being underneath the building. This material is often used in commercial applications for its many advantages and as such it is our recommendation for the drainage piping in the New SUB. Although comparatively it appears to be twice the cost of ABS piping, its long life expectancy and resistance to loads makes it the ideal material from an economic standpoint.

4.1.2 ABS (ACRYLONITRILE BUTADIENE STYRENE)

This plastic piping material is lightweight and inexpensive with its cost approximately half that of cast iron. The need to replace ABS piping after 50 years effectively makes ABS and cast iron cost equivalent (Lu, Davis, & Burn, 2003). The long life of ABS may be attributed to the reduced internal friction and turbulence in the pipe, thus reducing the required pumping energy. Smooth walls are also much less likely to collect debris or bacteria which may still be in the filtered rainwater. ABS pipes are rendered useless in the case of fire and must be replaced. As well, this type of piping is subject to deformation under loading (Burn, Davis, & Gould, 2009). If too much load is applied, there is a possibility of brittle failure and consequent pipe burst. ABS has a high coefficient of thermal expansion, leading to potential weakening over time due to cycles of expansion and contraction (Rosík, Kovářová, & Pospíšil, 1996). This apparent incompatibility with varying temperature along with the possibility of brittle failure leads to the conclusion that ABS pipes are not the most economically viable option for drainage piping.

4.2 WATER SUPPLY PIPING

The water supply piping is that which carries the rainwater from the rooftop catchment into the cistern. These pipes will not be subject to any external loads.

4.2.1 COPPER

Although copper is an excellent drainage piping material due to its ability to resist corrosion, it's extremely high cost makes it an economically unviable option for the New SUB (Hultquist et al., 2011). With the value of copper sitting at 4.50 cents per pound, the cost of copper piping is of a comparatively high rate at $62.50 per one foot with a four inch diameter. It is nearly impossible to set a definite budget on a future project when the material value remains unpredictable which is the case for most metals. With a projected design life of greater than 75 years, copper is a nearly ideal material to fit the New SUB's 100 year lifespan. The addition of copper piping would increase the value of this project providing it maintained its current worth or continued rising. It is more favourable than its counterpart, polypropylene, due to its recyclable value. Although at this time copper piping is not recommended due to its high cost, there are several material benefits which must not be overlooked. Copper, like most metals, is fire resistant and will not burn in the event of a fire nor create noxious fumes (Swain, 2007). Due to the high temperature soldering of joints, the full length of piping will remain intact, greatly reducing the probability of replacement and the costs associated. Copper also has a unique ability to resist the formation of bacteria such as biofilm which may form within the pipe (Lehtola et al., 2004).

4.2.2 POLYPROPYLENE

The proposed type of polypropylene to be used is the Aquatherm Lilac pipe. Sitting at a cost of only $14.40 per foot with a four inch diameter, this is the recommended material for the New SUB building due to its adaptability. It is the obvious choice for this building as the developing company works closely with the USGBC (United States Green Building Council) to design sustainable materials with the LEED (Leadership in Energy and Environmental Design) program. Lilac piping is specifically designed for rainwater harvesting and irrigation. As such, it is highly resistant to corrosion by means of rainwater which has the potential to be highly oxygenated (Aquatherm, 2011). As it is an inert material, there is little risk of corrosion or the leaching of chemicals. It has a design life of 50 years, and would only need to be replaced once in the lifetime of the New SUB.

TABLE 3: COMPARATIVE COST ANALYSIS: PIPES

Product	**Cost ($), [Dimensions]**	**Lifetime**	**Comparative Value ($) [4” 1’]**	**Replacements**	**Total Cost ($)**
ABS	37.99, [4” 10’]	50 years	4.20	1	8.40
Cast Iron	96.30, [4” 10’]	100+ years	9.60	0	9.60
Polypropylene	236.20, [4”16.4’]	50 years	14.40	1	28.80
Copper	249.96, [4”4’]	75+ years	62.50	0	125.00

Table 3 shows the comparative costs of all four piping materials for a one foot section approximately four inches in diameter.

4.3 GUTTER SYSTEM

The gutter system will divert the rooftop water directly towards the water supply pipes, where it will then be transported into the basement cistern. An expense summary can be found in Table 4 below.

4.3.1 ALUMINUM VERSUS GALVANIZED STEEL

Although aluminum is the material of choice for most residential gutter systems, it is not always best suited for large commercial applications. This is due to its short service life of about 40 years, less than half the lifespan of steel. Aluminum is also approximately half the cost of the alternative, galvanized steel. For comparison, the cost of aluminum gutter is $4.00 per linear foot compared to $7.00 for steel.

It can be determined that the difference in price may be negated due to the additional replacement expenses associated with aluminum gutters in the 100 year projection of the New SUB. Galvanized steel is a heavier material, increasing the initial transportation costs. This extra cost may be deemed insignificant when multiple replacements of the aluminum are taken into account. Aluminum's short lifespan may be attributed to a high coefficient of expansion, about two times larger than that for steel products. As it is generally stretched into thin sheets, it can become easily dented or deformed which may compromise the materials integrity. Unfinished aluminum may form a layer of aluminum oxide on its surface which acts to prevent further corrosion.

Galvanized steel is a strong metal material with a long design life of approximately 100 years. It is subject to corrosion after long periods of time, when extensive weathering processes have acted to decrease the effectiveness of the incorporated protective zinc layers (Gosset & Buchlin, 2007). Ideally its incorporation into the New SUB would provide a reliable gutter system which need not be replaced.

TABLE 4: COMPARATIVE COST ANALYSIS: GUTTER SYSTEM

Product	**Cost ($)**	**Lifetime (years)**
Aluminum 5"	4.00 linear ft	40
Galvanized 5"Steel	7.00 linear ft	100

Table 4 shows the comparative cost and lifetime of the two proposed gutter materials.

5.0 ENVIRONMENTAL MATERIAL ANALYSIS: ROOFING

The quality of the rainwater collected varies greatly with the type of roofing material used for the catchment system being applied to the new SUB. Materials that have less impact on the environment are favourable due to the aspiration of maximizing LEED points as well as the effect the material will have on the catchment and ecosystem. In order to determine the most feasible roofing material, a few common materials were analyzed and compared for the impacts each has on collected rainwater as well as the environment.

5.1 CONCRETE

Concrete is one of the most common construction materials utilized. Its ability to take any form as well as its durability and weather repelling properties make it an ideal product for most structure types. Certain production facilities separate and reuse wet concrete and, if hardened, crush and use it as hardcore or aggregate (Brocklesby & Davison, 2000). This is, however, only significant in the case that concrete from construction sites is returned to the manufacturer, which only occurs if the mix is not suitable for the pour location and cannot be fixed on-site. In fact, waste is minimal when manufacturing concrete due to the fact the production process is quite efficient with most of the material delivered being used. Lastly, rainwater experiences an increase in pH of about 1.5 after contacting a concrete catchment, (Mendez et al., 2011) which is still within the standard range of secondary drinking water (See Figure 4).

Conversely, although concrete is a fairly eco-friendly material, its construction process is rather harmful to the environment when considering transportation and machinery. Overall, approximately 1200 kg of CO_2 per unit is emitted during the construction process. This is equivalent to driving over 3800 km in an average sized car (Mendez, et al., 2011).

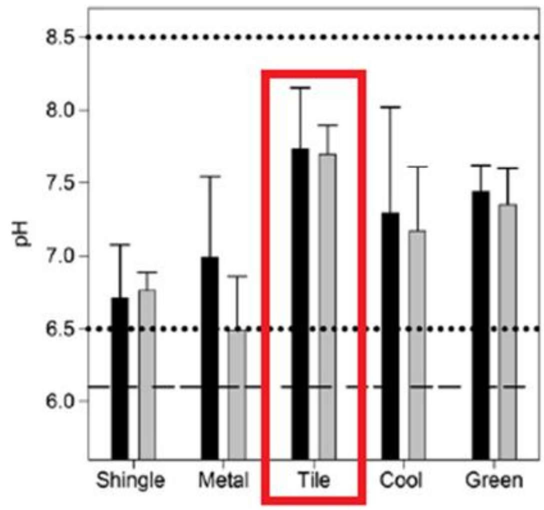

Figure 4: Average pH Chart (Mendez, et al.). (Concrete material is outlined in red. Black bars represent quality of first flush. Grey bars represent quality after first flush. Dotted lines represent USEPA standard range of drinking water (pH 6.5 – 8.5). Dashed line represents the ambient sampler.)

5.2 ASPHALT

A material often used for roads, asphalt is the foundation for most construction. Its efficiency in paving makes it an ideal candidate for transportation engineering as well as other construction projects. However, efficiency may not necessarily mean eco-friendly. In fact, asphalt is quite harmful to both the environment and the paving crew. Its main hazardous components are PAHs (Polycyclic Aromatic Hydrocarbons) and alkyl PAHs which are toxic pollutants that can often leach into the ecosystem and injure or kill wildlife and humans when ingested . Also, asphalt contains carcinogenic compounds which are known to be agents directly involved in cancer (Irwin, 1997). This risk is greatly amplified when asphalt and petroleum fumes are inhaled by the paving crew during the construction process. For these reasons, asphalt is not seen to be an appropriate construction material under LEED standards.

5.3 ALUMINUM

Aluminum roof, also known as the "Cool Roof", is favourable in many hot temperature climates. This is mainly due to the fact that aluminum works as a good insulator when keeping cool air inside as well as reflecting the heat from the sun outwards. In perspective, this roofing material is known to lower the amount of energy consumed to condition homes which, in return, correlates to improving the environment by using less resources. In fact, aluminum exhibits a 5 degrees Celsius decrease of temperature in a home due to natural convection and heat reflection (Alvarado & Martínez, 2008). However, one can see the problem that arises with this form of thermal insulation. As the SUB is being constructed in Vancouver, a generally cold city, aluminum roofing would be deemed counter-productive since the goal is to contain thermal heat indoors and exclude exterior cool air. Otherwise, constant heating during cold months would be necessary thus consuming large quantities of energy and, in turn, harming the environment. On the other hand, aluminum roofs are considered good candidates for rainwater harvesting due to the fact that they have little effect on the quality of rainwater in a catchment (Mendez, et al., 2011).

5.4 GREEN ROOF

Green Roofs have recently become trending topics for eco-friendly construction due mainly to the fact that it involves creating a natural habitat on the roof of a building (as seen in Figure 5). This unique form of construction is greatly beneficial to the environment as it allows growth of agriculture, creation of animal habitat, plants, and organisms. This roofing style also improves the air quality through oxygen production. This can also result in a decrease in disease rates such as asthma due to the pollutant and carbon dioxide filtration from surrounding air. Green Roofs also work as thermal insulators which can maintain cooler temperatures during the summer time and warmer temperatures during the winter season. However, old buildings of poor insulation benefit most from thermal insulation. In contrast, when considering the effects of a Green Roof on rainwater harvesting, supplementary filtration must be considered due to the chemical runoff from the soil. Although the plant life may serve as a filter for some rainwater pollutants, it can also be a source of chemicals such as nitrates, nitrogen, phosphate, and copper (Gregoire & Clausen). Manure and vegetation are often sources of these chemicals and may impact the quality of the rainwater runoff. Green Roofs can also be a source of dissolved organic carbon compounds in harvested rainwater which are precursors of regulation disinfected byproducts, more commonly known as water pollutants (Mendez, et al., 2011).

Figure 5: Green Roof <http://www.scholtensroofing.com/Rooftypes-Vancouver/Green-Roofing>

6.0 ENVIRONMENTAL MATERIAL ANALYSIS: PIPE AND GUTTER SYSTEMS

The environmental impacts of various pipe and gutter materials were analyzed for appropriateness and feasibility when considering LEED standards. Each material was compared in order to determine a catchment system with the least negative impact on the collected rainwater as well as the environment.

6.1 DRAINAGE PIPING

(See Section 4.1 for drainage piping definition)

6.1.1 CAST IRON

Cast Iron is one of the oldest materials in engineering history. It came into great use towards the end of the 19th century and has been serving many cities for long periods of time. However, since then, some cast iron pipes have become superseded by newer ductile iron material due to signs of deterioration resulting in breaks and leaks in water mains (Bilgin & Stewart, 2009). These deteriorations are mainly due to external corrosion from the environment which often weakens the pipe walls and causes malfunction. On the other hand, cast iron material is generally known to oxidize slowly which, in turn, delays corrosion and maintains quality over time. In an ideal environment with, perhaps, proper sealant, the lifespan of cast iron can be quite high and, over time, insignificant amounts of metal pollutants (in comparison to other materials) can be traced in the water supply. This approach can assist in maintaining the quality of rainwater throughout transportation as well as decrease the amount of material being replaced. When considering pipe material with a long lifespan, a general positive environmental impact can be seen over time throughout processes like pipe maintenance, waste, and corrosion. Minimizing these three categories consequentially minimizes energy input as well as harmful chemical pollutants.

6.1.2 ABS (ACRYLONITRILE BUTADIENE STYRENE)

ABS pipe and fittings have been the choice material since the 1960's due to their reliability and economical feasibility. However, this product poses negative impacts on the environment and ecosystem due to its lack of durability as well as chemical seepage over time. Pollution of plastic is at dangerous levels and is now accumulating in massive amounts in desolate ocean areas. Although most plastic waste can be recycled, some may not and will eventually occupy landfills. Also, with the general production of plastic products, some plastic nodules “escape” into the ecosystem and get washed out into the ocean where they become mistaken for food and can be fatal if ingested (Addicted to Plastic, 2008). ABS pipe’s brittleness and low hardness (Moore, 1973) can also mean constant maintenance which exerts energy and, in turn, expends resources. Along with this, chemical wearing over time may also affect the quality of water by leaching harmful chemicals into the system (Chang, Tanong, Xu, & Shon, 2011).

6.2 WATER SUPPLY PIPING

(See Section 4.2 for water supply piping definition)

6.2.1 POLYPROPYLENE

Polypropylene pipe is often used for industrial purposes due to its resistance to strong acids and highly active oxidizers. Not only is this material very durable, it is also recyclable and is CSA approved and LEED recognized. This is a key factor when replacing the material which, as a polymer, can be continuously heated and formed and reused in other means. When considering the impact this material has on the environment, polypropylene produces emission factors of approximately 2.5 in air, 3.2 in water, and 2 in soil (as seen in Figures 6, 7, and 8). Overall, polypropylene piping produces an average of less than 50% the emissions as copper piping and requires less than 50% of energy to manufacture (as seen in Figure 9) (Aquatherm, 2011). With this, it is also recommended to implement high-quality, polypropylene, Lilac pipe due to its resistance to corrosion and chemical breakdown. This can maintain the overall quality of the rainwater passing through the system.

6.2.2 COPPER

Copper pipe, a material introduced in the 1900’s, is both durable and recyclable. However, problems arise when considering its corrosion over time. As copper can be quite harmful if seeped into the environment or ingested by humans, this material is not ideal for rainwater harvesting. In fact, copper does not break down in the environment which causes serious threats when it accumulates in plants and animals.

Also, considering the impact copper has on the environment, it can produce emission factors of approximately 15 in air, 3.5 in water, and 12 in soil (as seen in Figures 6, 7, and 8). On average, these impacts are greater than those polypropylene produces by a factor of 50% (Aquatherm, 2011).

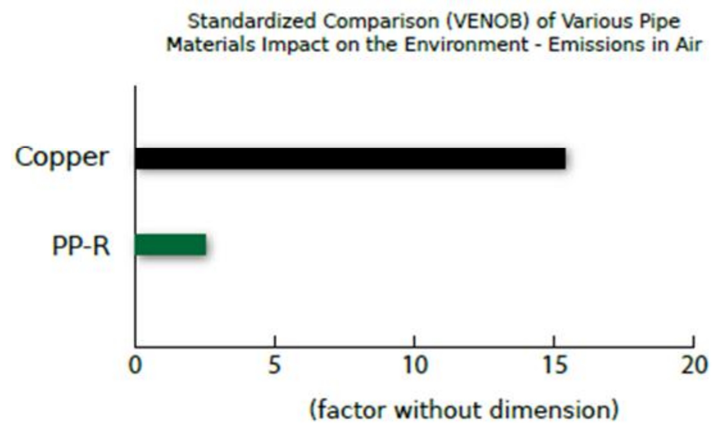

Figure 6: Emissions in Air, (Aquatherm, 2011)

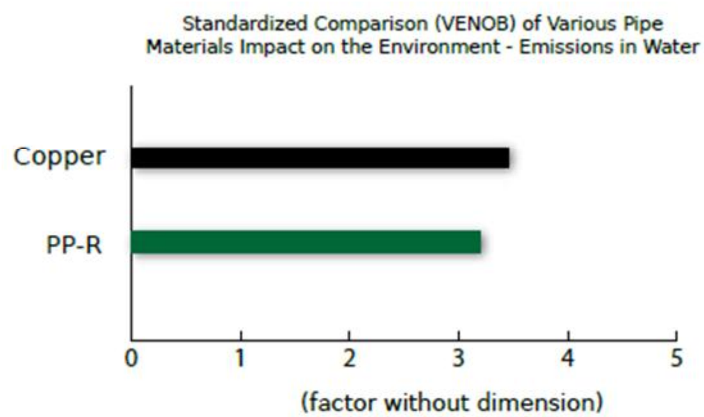

Figure 7: Emissions in Water, (Aquatherm, 2011)

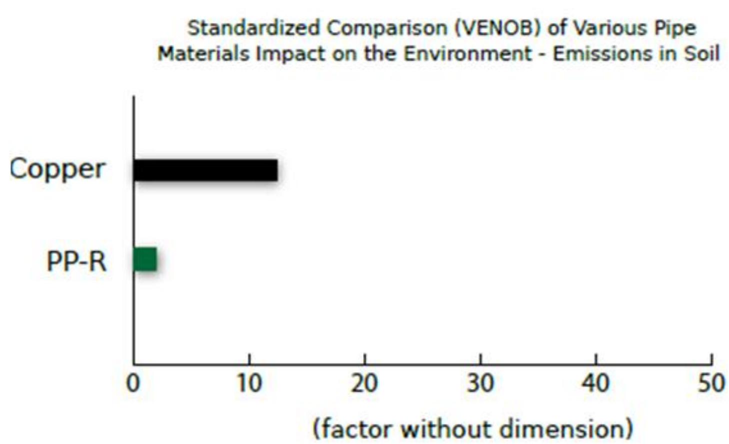

Figure 8: Emissions in Soil, (Aquatherm, 2011)

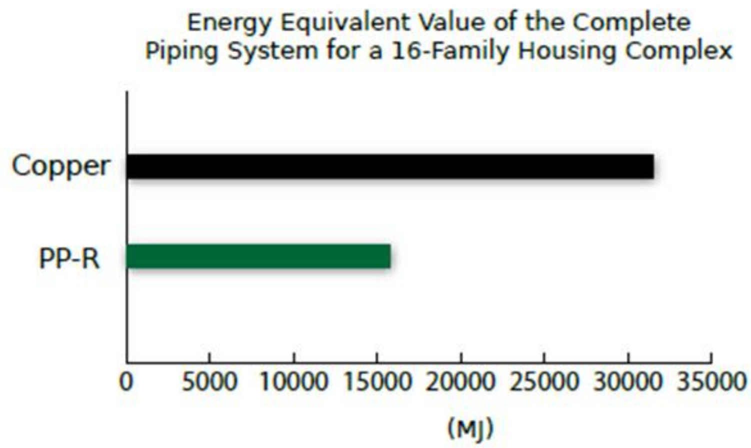

Figure 9: Energy Equivalent Value, (Aquatherm, 2011)

6.3 GUTTER SYSTEM

(See Section 4.3 for gutter system definition)

6.3.1 ALUMINUM VERSUS GALVANIZED STEEL

As mentioned in section 4.3.1, Galvanized Steel is essentially steel material coated with a protective layer of zinc which decreases the prevalence of corrosion in the pipe. The excellent corrosion protection that zinc provides greatly improves the durability and lifetime of galvanized steel which, in turn, conserves natural resources (International Zinc Association, 2000). Galvanized steel is also recycled in mass amounts and can be manufactured from scrap material. Aluminum, on the other hand, is a much less durable material and can oxidize significantly over time. The accumulation of aluminum in the ecosystem can be quite detrimental to plants and wildlife and is also known to contaminate fish from high concentrations in lakes. Overall, it is recommended to implement galvanized steel instead of aluminum for all gutter systems in the new SUB.

7.0 SOCIAL IMPLICATIONS OF ROOFING, GUTTER, PIPING MATERIALS

Care must be taken in choosing materials which enforce a positive community environment and promote sustainable initiatives on campus. Ideally, they should not provide any serious injury to workers involved in production, assemble or installation. This discussion is divided into the three structural components for our analysis: Roofing, Gutter and Piping material. Each material considered for the design of these components is then critiqued for its ability to meet the aforementioned criteria.

7.1 ROOFING MATERIALS

To begin this discussion the four roofing materials Aluminum, Asphalt, Concrete and Green Roofing are addressed.

7.1.1 ASPHALT

Local residents in an Idaho community (2006) complained that the smell and odour of asphalt production plants to be highly intolerable. Residents living a maximum of 3.2 km downwind of the plant complained of the odour, caused by the escape of hydrogen sulphide gas (Cook, Apel, & Gostomski, 1999). This is emitted when blending and heating latex polymers in order to create asphalt.

The used of this product also has many environmental activists concerned, as the use of large volumes of petroleum in asphalt production is inadvisable with the current peak oil crisis. In addition, there is the less than ideal emission of fossil fuels which is a major concern to all living organisms.

7.1.2 ALUMINUM

Polycyclic Aromatic Hydrocarbons (PAH) exposure is a common among workers in the aluminum industry. The PAH are released by the evaporation of carbon electrode materials used in electrolysis processes from the metal production. A case study in a large Canadian cohort indicated that there was an increased risk of bladder and lung cancer due to exposure to PAH. Additional harmful substances used in Aluminum production include asbestos, fluorides and sulphur dioxide gas (Boffetta, Jourenkova, & Gustavsson, 1997).

7.1.3 CONCRETE

Currently initiatives are being undertaken by the Federal Government of Canada to limit the CO2 emissions associated with concrete production. Concrete consist of a slurry of carbonate minerals which are mixed with a variety of aggregates. To reduce the environmental footprint of these concrete manufacturing facilies, more sustainable aggregates, Supplementary Cementing Materials (SCM) will be required. These regulations would be set by guidelines published by the Federal Government of Canada.

The environmental regulation of concrete manufacture should provide some incentive for the purchase of this product from Canadian production companies. The increase in sustainable practice would mean an accumulation of LEED points with is one of the SEEDS initiatives for the construction of new campus infrastructure. Additionally, by purchasing Canadian concrete for the SUB construction social concerns regarding the country's current recessional trend will be addressed as more employment opportunities are provided for local workers

7.1.4 GREEN ROOF

Green Roofing is a highly beneficial community project. The construction of such a project could require involvement from the UBC community and other environmental groups which would help to promote a sustainable culture within the campus community. This would significantly enhance the appearance of the roof and provide habit for birds, bugs, worms and all sorts of organisms (Oberndorfer et al., 2007).

7.2 GUTTER MATERIALS

Below are the materials analyzed for the intermediary gutter system.

7.2.1 GALVANIZED STEEL

Galvanised steel production involves the immersion of steel strips into a boiling zinc bath. Studies have shown that there are no significant health risks associated with this process. In addition to safe manufacture, this material is a more aesthetically attractive option as it provides a more cohesive and uniform appearance.   The protective coating Tin Oxide coating can also be coloured with dies to provide a variety of attractive colour pallets (Gosset & Buchlin, 2007).

7.2.2 ALUMINUM

Please refer to the aforementioned analysis found in section 6.1.2.

7.3 PIPING MATERIALS

For drainage piping, cast iron and ABS piping are analyzed below along with Aluminum and Polypropylene for water supply piping.

7.3.1 CAST IRON

No evidence of health or environmental concerns for society at large were found regarding this piping material.

7.3.2 ABS

ABS piping can be hazardous in high temperatures as it may become combustible and very high volumes of smoke may be emitted (Smith, 1972). If the new SUB were to ever catch fire, these pipes could provide challenges for the fire crew in quenching the flames.

7.3.3 COPPER

Copper is an antibacterial agent and effective germicide. Enzymes within the metal are able target the bacteria by binding to reactive groups, resulting in their precipitation and inactivation (Zevenhuizen, Dolfing, Eshuis, & Scholten-Koerselman, 1979).

In particular, copper is widely used as an algicide for water filtration systems in mineral sanitizers, swimming pools and spas. The reaction of copper alloys with many strains of bacteria could be highly beneficial as a means of providing sanitization for the grey water which is enters the catchments cistern system. Cleaner water will expand opportunity for grey water application with in the building, benefiting the users of the new SUB at large.

7.3.4 POLYPROPYLENE

No evidence of health or environmental concerns for society at large were found regarding this piping material.

8.0 CONCLUSION

After analyzing several design components of the new student union building, building material recommendations were made in order to maximize LEED points and improve overall quality of the building and surrounding environment. By assessing social, economic, and environmental impacts of each material, an overall verdict in response to roofing, gutters, and piping material is made. These recommendations are based solely on the individual research and suggestions of the team members.

The materials recommended with respect to their social implications are as follows: green roof, cast iron drainage piping, polypropylene water supply piping, and galvanized steel gutters.

The materials recommended with respect to their economic and environmental implications are coincidentally similar. They are as follows: concrete roof, cast iron drainage piping, polypropylene water supply piping, and galvanized steel gutters. These similarities are mainly due to the fact that economic and environmental impacts vary greatly with the durability of construction materials. A durable material will, in the long run, be more economically efficient and, in turn, require less energy input to maintain and replace.

The overall recommendations of material when considering social, economic, and environmental implications are as follows: concrete roof, cast iron drainage piping, polypropylene water supply piping, and galvanized steel gutters. Although a green roof is seen as a more socially appropriate material, its adverse economic and rainwater quality implications do not outweigh the overall environment benefits.

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