# Life Cycle Analysis Forest Sciences Centre

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**CIVL 498C**

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# PROVISO

This study is part of a larger study – the UBC LCA Project – which is continually developing. As such the findings contained in this report should be considered preliminary as there may have been subsequent refinements since the initial posting of this report.

If further information is required or if you would like to include details from this study in your research please contact rob.sianchuk@gmail.com.

# Life Cycle Analysis

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## Abstract

In this paper, Life Cycle Analysis (LCA) is carried out to assess the environmental impacts of the Forestry Science Center (FSC), which is located at the University of British Columbia (UBC). LCA processes and methodologies applied are discussed in detail.

The scope of this project is defined as cradle-to-gate. In particular, takeoff is done by using OnScreen and impacts are estimated by using Impact Estimator (IE). Due to the limitation of the software and lack of the construction drawings of the building, uncertainties are introduced into the final results.

Sensitivity analysis is performed for five specific building materials of FSC, in order to achieve a better understanding of the contribution to the environmental impact. In conclusion, concrete has the most significant impacts on the overall results.

Furthermore, building performance is carried out to explore the payback period of envelope upgrades in terms of energy consumption. Recommendation is then made regarding to the future renovation to FSC or similar building type constructions.

Note this project is part of a regionalized study of buildings at UBC, which is also the largest LCA analysis run by students.

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## 1. Introduction

The Forest Sciences Centre (FSC) is located at 2424 Main Mall at Agronomy Rd. The FSC is built in 1998, which is one of the newest buildings on the University of British Columbia campus and cost $47 million. (UBC Library) This building consists of 11 Classrooms, 2 lecture theatres, 230 offices, 36 Testing labs, 6 Storage rooms, 11 Washrooms/locker, and 25 Mechanical/Electrical rooms, which in total is 17,505 meter square. (UBC Forestry Department) To illustrate the usage of massive wood construction materials, parallam tree columns and wood interior wall finishing are designed. (UBC Library) The FSC is the facility house for three departments: the Departments of Wood Science, Forest Science, and Forest Resources Management. (UBC Forestry Department) The FSC is famous for its large, open and L-shape study areas with a high skylight, which spanning from the ground floor to the fourth floor. The building structural and envelope characteristics are tabulated as follows:

**Table 1 Specific Building System Characteristics**

| Building System | Specific Building Characteristics |
|---|---|
| Structure | Columns: Concrete and parallam<br>Beams: Concrete |
| Floors | Basement: Concrete slab on grade, 150mm<br>First to Fourth Floor: Unknown, model as concrete slab on grade on concrete columns and beams. |
| Exterior Walls | 39x152 mm, double layered of steel stud wall with two layer of regular 5/8" gypsum board, fiberglass of insulation, vapor barrier |
| Interior Walls | Facing the open L-shape atrium: 39x152mm steel stud with plywood finishing<br>Others: 39x59mm steel stud wall with regular 5/8" gypsum board, vapor barrier, and fiberglass of insulation |
| Windows | All windows are modeled as aluminum frame with standard glazing |
| Roof | Steel, concrete and curtain roof. Unknown thickness |

# 2. Goal and Scope

## 2.1. Goal of Study

This life cycle analysis (LCA) of the FSC at the University of British Columbia was carried out as an exploratory study to determine the environmental impact of it's design. This LCA of the FSC is also part of a series of twenty-nine others being carried out simultaneously on respective buildings at UBC with the same goal and scope.

The main outcomes of this LCA study are the establishment of a materials inventory and environmental impact references for the FSC. An exemplary application of these references is in the assessment of potential future performance upgrades to the structure and envelope of the FSC. When this study is considered in conjunction with the twenty-nine other UBC building LCA studies, further applications include the possibility of carrying out environmental performance comparisons across UBC buildings over time and between different materials, structural types and building functions. Furthermore, as demonstrated through these potential applications, this FSC LCA can be seen as an essential part of the formation of a powerful tool to help inform the decision making process of policy makers in establishing quantified sustainable development guidelines for future UBC construction, renovation and demolition projects.

The intended core audience of this LCA study are those involved in building development related policy making at UBC, such as the Sustainability Office, who are involved in creating policies and frameworks for sustainable development on campus. Other potential audiences include developers, architects, engineers and building owners involved in design planning, as well as external organizations such as governments, private industry and other universities whom may want to learn more or become engaged in performing similar LCA studies within their organizations.

### 2.2. Scope of Study

The product system being studied in this LCA are the structure and envelope of the FSC on a square foot finished floor area of academic building basis. In order to focus on design related impacts, this LCA encompasses a cradle-to-gate scope that includes the raw material extraction, manufacturing of construction materials, and construction of the structure and envelope of the FSC, as well as associated transportation effects throughout.

### 2.3 Tools, Methodology and Data

Two main software tools are to be utilized to complete this LCA study; OnCenter's OnScreen TakeOff and the Athena Sustainable Materials Institute's Impact Estimator (IE) for buildings.

The study will first undertake the initial stage of a materials quantity takeoff, which involves performing linear, area and count measurements of the building's structure and envelope. To accomplish this, OnScreen TakeOff version 3.6.2.25 is used, which is a software tool designed to perform material takeoffs with increased accuracy and speed in order to enhance the bidding capacity of its users. Using imported digital plans, the program simplifies the calculation and measurement of the takeoff process, while reducing the error associated with these two activities. The measurements generated are formatted into the inputs required for the IE building LCA software to complete the takeoff process. These formatted inputs as well as their associated assumptions can be viewed in Annexes A and B respectively.

Using the formatted takeoff data, version 4.0.64 of the IE software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the FSC in the Vancouver region as an Institutional building type. The IE software is designed to aid the building community in making more environmentally conscious material and design choices. The tool achieves this by applying a set of algorithms to the inputted takeoff data in order to complete the takeoff process and generate a bill of materials (BoM). This BoM then utilizes the Athena Life Cycle Inventory (LCI) Database, version 4.6, in order to generate a cradle-to-grave LCI profile for the building. In this study, LCI profile results focus on the manufacturing (inclusive of raw material extraction), transportation of construction materials to site and their installation as structure and envelope assemblies of the FSC. As this study is a cradle-to-gate assessment, the expected service life of the FSC is set to 1 year, which results in the maintenance, operating energy and end-of-life stages of the building's life cycle being left outside the scope of assessment.

The IE then filters the LCA results through a set of characterization measures based on the mid-point impact assessment methodology developed by the US Environmental Protection Agency (US EPA), the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2. In order to generate a complete environmental impact profile for the FSC, all of the available TRACI impact assessment categories available in the IE are included in this study, and are listed as;

- Global warming potential
- Acidification potential
- Eutrophication potential
- Ozone depletion potential
- Photochemical smog potential
- Human health respiratory effects potential
- Weighted raw resource use
- Primary energy consumption

Using the summary measure results, a sensitivity analysis is then conducted in order to reveal the effect of material changes on the impact profile of the FSC. Finally, using the UBC Residential Environmental Assessment Program (REAP) as a guide, this study then estimates the embodied energy involved in upgrading the insulation and window R-values to REAP standards and generates a rough estimate of the energy payback period of investing in a better performing envelope.

The primary sources of data used in modeling the structure and envelope of the FSC are the original architectural and structural drawings from when the was initially constructed in1998. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as their associated envelope and/or openings (ie. doors and windows). The decision to omit other building components, such as flooring, electrical aspects, HVAC system, finishing and detailing, etc., are associated with the limitations of available data and the IE software, as well as to minimize the uncertainty of the model. In the analysis of these assemblies, some of the drawings lack sufficient material details, which necessitate the usage of assumptions to complete the modeling of the building in the IE software. Furthermore, there are inherent assumptions made by the IE software in order to generate the bill of materials and limitations to what it can model, which necessitated further assumptions to be made. These assumptions and limitation will be discussed further as they emerge in the Building Model section of this report and, as previously mentioned, all specific input related assumption are contained in the Input Assumptions document in Annex B.

## 3. Building Model

### 3.1 Takeoffs

Two-six architectural and construction drawings are providing for takeoff. In particular, except Basement Plan is the construction drawing, others are architectural, such as: ground floor, second floor and roof plan. As a matter of fact, these drawings are in good quality that information can be easily and clearly read.

Takeoff is carried out using the software, On-Screen Takeoff. In particular, walls are measured applying linearly condition; footing, doors, columns, and beams are measured using count condition; slab on grade, floor, and roof are calculated with area condition. For windows, both area and counts conditions are applied. Elevation drawing of the building is used to determine the height of the column and walls.

Due to lack of the construction detail drawings and material schedules, alternative methodologies and assumptions are applied to overcome the challenge. In particular, from the architectural drawings, there is a difficulty to locate the beams; Wall, column and beams schedule are not available; due to the limitation of Impact Estimator (IE), thickness of the footing or wall would need to be recalculated. To keep the overall objective in mind that to assemble the total volume of each constructional material, applied methodology and assumptions would have the advantage to accomplish the takeoff but introducing the uncertainties to the final IE results at the same time.

## 3.2 Assembly Groups

There are six assembly groups for this project: foundation, walls, mixed columns & beams, floors, roofs, and extra base materials. The following sections will discuss each assembly group in detail, along with its assumptions.

### 3.2.1 Foundation

In this project, foundation consists of two groups: slab on grade and footings.

Slag on grade (SOG) at the FSC is 150mm, which is not an available input selection in IE. Length and width are recalculated to match the total volume of the SOG while assuming the thickness is 100mm. Concrete strength and flyash percentage is assumed as 20 MPa and average.

For footings, whose detailed construction information are available, are named the same as the schedule, such as: F1, F2 and F3. For information can be obtain from the drawings, footings are names as CF1, CF2 etc.; same methodology for strip footings, which are then named as SF1, SF2 etc. Since there is a maximum allowable thickness in IE, to match the overall volume of the footing, adjusted width and length are manually calculated. Please refer to Appendix B for detailed calculation. Similar adjustment are made to rebar, concrete strength and concrete flyash percentage regarding the availability of IE input selection. In particular, rebar are adjusted to #20M; concrete strength is adjusted from 25 MPa to 20 MPa; all the concrete flyash percentage is assumed at average.

### 3.2.2 Walls

Walls are modeled and named in three categories for the FSC: cast in place, steel stud and curtain wall. Such as: for steel stud interior wall, it is named as: *Wall_SteelStud_W06*. Because the wall schedule is not available, assumptions are made accordingly. General characteristic of walls and assumptions are listed in Table 1. Furthermore, for concrete walls, strength is adjusted from 25MPa to 30MPa due to the limitation of the input selection in IE; reinforcement is assumed as #20; and the flyash is at the average percentage. Additional assumptions to the walls are the envelope types. For instance: for exterior wall, W06, its envelope is assumed to be assembled with two layers of regular gypsum board, 3 mil polyethylene of the vapor barrier, 88.9 mm fiberglass batt, and split faced brick. Please refer to Appendix B for detailed assumptions for each wall.

Windows on the wall are measured using both area and count condition in OnScreen. All the windows are assumed to have aluminum frame with standard glazing. Doors are measured using count condition. Both windows and doors are named with a prefix, the wall they are on. For example: windows on the exterior wall, *Wall_SteelStud_W06*, are named as *Wall_SteelStud_W06_Window*.

### 3.2.3 Columns and Beams

Columns are modeled using count condition in OnScreen. To keep the consistency and high accuracy, columns and beams are counted at each floor; for the same reason, columns and beams are named with their construction material and the floors they are on. In general, column and beam type are assumed as concrete. Due to the limitation of IE input for the bay size and supported span, both values are recalculated by taking the square root of the measured supported floor area divided by the counted number of columns. By doing so, area supported per column is calculated. Please refer to Appendix B for the detailed calculation of each bay size and supported span. For the parallam column in FSC, different methodology is used to do the takeoff, which will be discussed in the following Extra Material section.

### 3.2.4 Floor

Including basement, there are five floors in FSC. In this project, for simplicity, all the floors are assigned the same type. The total floor area is calculated by summing up each floors area, which is measured using area condition in OnScreen. Due to the maximum span for the IE input can not exceed 9.75m, 9m is used as the span. Thus, the width of the floor is calculated as 1018.2m. Please refer to Appendix B for detailed calculations. Additional assumptions are listed as follow:

- The concrete strength is 30MPa;
- The concrete flyash is at average percentage;
- The live load is 3.6 kPa;
- It is assembled with ½” regular gypsum board.

### 3.2.5 Roof

From the architectural drawing of the roof, we can exam that it is formed by three portions. In this project, due to the lack of the detailed construction information, roof is modeled as: metal, concrete and curtain wall. Particularly, to overcome the limitation of the input material availability in IE, the skylight roof is modeled as curtain wall. The total length of roof is measured using linear condition and the Viewable glazing is assumed as 95% with metal spandrel panel. To overcome the limitation of the input material availability in Impact Estimator, the skylight roof is modeled as curtain wall. The total length of roof is measured using linear condition.

### 3.2.6 Extra Materials

For the special feature in FSC, the parallam columns and roof supporting structure, the linear condition is used to measure their length, width and thickness in OnScreen. There are eight repeated structure for the columns and roof supporting. Thus, only one set of the structure is measured and the total volume of parallam would be eight times the previous result. Specifically, 92.2 $m^3$ of parallam is used for this structural construction.

The steel staircases are also modeled using linear condition in Onscreen. Total length, width and height of the staircases are measured. Total volume is then calculated. Using the total volume to time the density of the rolled steel, which is 7850 $kg/m^3$. (SI Metric) The total mass of the steel is obtained.

## 4. Bill of Materials

The following table is the summary bill of materials (BoM) for FSC.

**Table 2 Bill of materials Report**

| Material | Quantity | Unit |
|---|---|---|
| 1/2" Regular Gypsum Board | 10080.18 | m2 |
| 3 mil Polyethylene | 20408.2262 | m2 |
| 5/8" Regular Gypsum Board | 27044.7494 | m2 |
| 6 mil Polyethylene | 6321.5574 | m2 |
| Aluminum | 43.0044 | Tonnes |
| Ballast (aggregate stone) | 106029 | kg |
| Batt. Fiberglass | 81957.4276 | m2 (25mm) |
| Cold Rolled Sheet | 0.4636 | Tonnes |
| Concrete 20 MPa (flyash av) | 3121.6356 | m3 |
| Concrete 30 MPa (flyash av) | 5797.7152 | m3 |
| EPDM membrane | 1767.2805 | kg |
| Expanded Polystyrene | 10518.7215 | m2 (25mm) |
| Galvanized Decking | 16.2014 | Tonnes |
| Galvanized Sheet | 14.4762 | Tonnes |
| Galvanized Studs | 85.2408 | Tonnes |
| Glazing Panel | 56.3253 | Tonnes |
| GluLam Sections | 20.099 | m3 |
| Joint Compound | 37.0514 | Tonnes |
| Metric Modular (Modular) Brick | 409.2765 | m2 |
| Modified Bitumen membrane | 4833.117 | kg |
| Mortar | 173.38 | m3 |
| Nails | 4.2446 | Tonnes |
| Open Web Joists | 8.3625 | Tonnes |
| Oriented Strand Board | 18868.9638 | m2 (9mm) |
| Paper Tape | 0.4252 | Tonnes |
| PVC membrane | 8494.101 | kg |
| Rebar, Rod, Light Sections | 778.6587 | Tonnes |
| Screws Nuts & Bolts | 3.5284 | Tonnes |
| Small Dimension Softwood Lumber, kiln-dried | 40.0656 | m3 |
| Softwood Plywood | 2061.9578 | m2 (9mm) |
| Solvent Based Alkyd Paint | 124.781 | L |
| Split-faced Concrete Block | 46331.3053 | Blocks |
| Standard Glazing | 1867.49 | m2 |
| Water Based Latex Paint | 308.9364 | L |
| Welded Wire Mesh / Ladder Wire | 5.8753 | Tonnes |

Note that the largest five amount of materials in terms of the assemblies contributing to the building constructions are Concrete 30 MPa (5797.7152 $m^3$), Batt. Fiberglass (81957.4276 $m^2$), Oriented Strand Board (18868.9638 $m^2$), Galvanized Studs (85.2408 Tonnes), and Softwood Plywood (2061.9578 $m^2$). Those five materials would have significant effects on the IE result due to these five materials are the main construction materials for the walls, roofs, columns and beams. Since assumptions are made regarding the limitation of IE, the final BoM would be impacted by the assumptions. Particularly, the concrete strength for all walls is adjusted to 30MPa from 25MPa, instead of to 20MPa. If original assumption is 20 MPa, the total amount of Concrete 30 MPa would decrease and the amount of Concrete 20MPa would increase. However, the total amount of concrete would not be impacted much regarding this assumption. Furthermore, for most of cases, the assumption would directly affect the final BoM. Without wall schedules, Batt Fiberglass is assumed within most of the walls at FSC. In reality, different material would be used instead. In this case, Batt Fiberglass could be over estimated.

## 5. Summary Measures

The following table is the Summary Measure Table.

**Table 3 Summary Measure Table**

| | Manufacturing | | | Construction | | |
|---|---|---|---|---|---|---|
| | Material | Transportation | Total | Material | Transportation | Total |
| **Primary Energy Consumption MJ** | 54120997 | 1403934.544 | **55524932** | 1589013.39 | 2262954.14 | **3851968** |
| **Weighted Resource Use kg** | 34548232 | 951.4795524 | **34549183** | 45797.5458 | 1541.965563 | **47339.51** |
| **Global Warming Potential (kg CO2 eq)** | 5652443.3 | 2637.458251 | **5655081** | 111406.722 | 4362.567401 | **115769.3** |
| **Acidification Potential (moles of H+ eq)** | 2293760.1 | 845.3905527 | **2294605** | 52790.9985 | 1375.92796 | **54166.93** |
| **HH Respiratory Effects Potential (kg PM2.5 eq)** | 19019.094 | 1.016664724 | **19020.11** | 75.7516109 | 1.653556027 | **77.40517** |
| **Eutrophication Potential (kg N eq)** | 1593.3069 | 0.876676129 | **1594.184** | 46.2906344 | 1.425319283 | **47.71595** |
| **Ozone Depletion Potential (kg CFC-11 eq)** | 0.028661 | 1.08116E-07 | **0.028661** | 5.7537E-09 | 1.78625E-07 | **1.84E-07** |
| **Smog Potential (kg NOx eq)** | 18727.967 | 18.90879926 | **18746.88** | 1160.95616 | 30.71000932 | **1191.666** |

The following table summarizes the total measurements along with its total measurement per square foot.

**Table 4 Total Summary Measure Table**

| | Manufacturing | Construction | | |
|---|---|---|---|---|
| | Total | Total | Total | Total per ft2 |
| Primary Energy Consumption MJ | 55524931.5 | 3851967.53 | **59376899** | **242.897** |
| Weighted Resource Use kg | 34549183.5 | 47339.51135 | **34596523** | **141.526** |
| Global Warming Potential (kg CO2 eq) | 5655080.77 | 115769.2895 | **5770850.1** | **23.6072** |
| Acidification Potential (moles of H+ eq) | 2294605.47 | 54166.92648 | **2348772.4** | **9.60827** |
| HH Respiratory Effects Potential (kg PM2.5 eq) | 19020.111 | 77.40516692 | **19097.516** | **0.07812** |
| Eutrophication Potential (kg N eq) | 1594.18356 | 47.71595371 | **1641.8995** | **0.00672** |
| Ozone Depletion Potential (kg CFC-11 eq) | 0.02866109 | 1.84379E-07 | **0.0286613** | **1.2E-07** |
| Smog Potential (kg NOx eq) | 18746.8763 | 1191.666165 | **19938.542** | **0.08156** |

Since the total/$ft^2$ value is about 240, which is close to 300, the rule of thumb value, the IE assessment result is in the acceptable range.

## 6. Uncertainties

To evaluate the value of the final products of LCA, uncertainties analysis becomes essential. The following section would discuss major uncertainties containing in this project.

- Regional Effects

  Note that the impact assessment methodology TRACI is the averaged values of North American. For some specific environmental impact, it could take place in other regions, such as: Vancouver would have a smaller impact of acidification compared with other heavy industry cities. In another word, IE could over/under weight the impacts due to its regional database.

- Linear Manner

  TRACI is also using the linear relationship to assess the environmental impacts from ecological processes. In reality, the possible exponential increase/decrease could exist when the emission reaches certain concentration.

## 7. Sensitivity Analysis

A sensitivity analysis is carried out for the FSC. Five materials are assessed in this section. Each material is compared between its original impacts with 10% weight increment impact.

**Table 5 Sensitivity Analysis Detailed Values**

| Name of Material to be Tested | Total Amount in Original Model's BoM | 10% of Total in BoM | Waste Factor for Material (%) | Extra Basic Material Input Value |
|---|---|---|---|---|
| Concrete 30 MPa (flyash av) | 5128.1917 | 512.81917 | 5% | 488.40 |
| 1/2" Regular Gypsum Board | 10080.18 | 1008.018 | 10% | 916.38 |
| Galvanized Studs | 85.2408 | 8.52408 | 1% | 8.44 |
| Oriented Strand Board | 18868.9638 | 1886.89638 | 5% | 1,797.04 |
| Softwood Plywood | 2061.9578 | 206.19578 | 5% | 196.38 |

**Table 6 10% Increase of Concrete 30 MPa (flyash av)**

| Impact Category | Units | Overall | Difference | % Difference |
|---|---|---|---|---|
| Primary Energy Consumption | MJ | 60,825,214.73 | 1,448,315.67 | 2.44% |
| Weighted Resource Use | kg | 36,223,785.00 | 1,627,262.03 | 4.70% |
| Global Warming Potential | (kg CO2 eq / kg) | 5,990,502.85 | 219,652.79 | 3.81% |
| Acidification Potential | (moles of H+ eq / kg) | 2,420,773.41 | 72,001.02 | 3.07% |
| HH Respiratory Effects Potential | (kg PM2.5 eq / kg) | 19,657.73 | 560.22 | 2.93% |
| Eutrophication Potential | (kg N eq / kg) | 1,666.07 | 24.17 | 1.47% |
| Ozone Depletion Potential | (kg CFC-11 eq / kg) | 0.03 | 0.00 | 2.65% |
| Smog Potential | (kg NOx eq / kg) | 20,473.17 | 534.63 | 2.68% |

**Table 7 10 % Increase of 1/2" Regular Gypsum Board**

| Impact Category | Units | Overall | Difference | % Difference |
|---|---|---|---|---|
| Primary Energy Consumption | MJ | 59,453,031.26 | 76,132.20 | 0.13% |
| Weighted Resource Use | kg | 34,610,511.74 | 13,988.76 | 0.04% |
| Global Warming Potential | (kg CO2 eq / kg) | 5,775,420.98 | 4,570.92 | 0.08% |
| Acidification Potential | (moles of H+ eq / kg) | 2,350,651.13 | 1,878.74 | 0.08% |
| HH Respiratory Effects Potential | (kg PM2.5 eq / kg) | 19,111.67 | 14.16 | 0.07% |
| Eutrophication Potential | (kg N eq / kg) | 1,642.18 | 0.29 | 0.02% |
| Ozone Depletion Potential | (kg CFC-11 eq / kg) | 0.03 | 0.00 | 0.00% |
| Smog Potential | (kg NOx eq / kg) | 19,943.13 | 4.59 | 0.02% |

**Table 8 10% Increase of Galvanized Studs**

| Impact Category | Units | Overall | Difference | % Difference |
|---|---|---|---|---|
| Primary Energy Consumption | MJ | 59,587,296.47 | 210,397.41 | 0.35% |
| Weighted Resource Use | kg | 34,627,724.74 | 31,201.77 | 0.09% |
| Global Warming Potential | (kg CO2 eq / kg) | 5,787,930.53 | 17,080.47 | 0.30% |
| Acidification Potential | (moles of H+ eq / kg) | 2,352,809.88 | 4,037.49 | 0.17% |
| HH Respiratory Effects Potential | (kg PM2.5 eq / kg) | 19,114.00 | 16.48 | 0.09% |
| Eutrophication Potential | (kg N eq / kg) | 1,645.68 | 3.78 | 0.23% |
| Ozone Depletion Potential | (kg CFC-11 eq / kg) | 0.03 | 0.00 | 0.00% |
| Smog Potential | (kg NOx eq / kg) | 19,973.94 | 35.40 | 0.18% |

**Table 9 10% Increase of Oriented Strand Board**

| Impact Category | Units | Overall | Difference | % Difference |
|---|---|---|---|---|
| Primary Energy Consumption | MJ | 59,565,068.43 | 188,169.38 | 0.32% |
| Weighted Resource Use | kg | 34,655,277.79 | 58,754.82 | 0.17% |
| Global Warming Potential | (kg CO2 eq / kg) | 5,777,105.35 | 6,255.30 | 0.11% |
| Acidification Potential | (moles of H+ eq / kg) | 2,369,398.85 | 20,626.46 | 0.88% |
| HH Respiratory Effects Potential | (kg PM2.5 eq / kg) | 19,151.50 | 53.98 | 0.28% |
| Eutrophication Potential | (kg N eq / kg) | 1,667.13 | 25.23 | 1.54% |
| Ozone Depletion Potential | (kg CFC-11 eq / kg) | 0.03 | 0.00 | 3.50% |
| Smog Potential | (kg NOx eq / kg) | 20,418.31 | 479.77 | 2.41% |

**Table 10 10% Increase of Softwood Plywood**

| Impact Category | Units | Overall | Difference | % Difference |
|---|---|---|---|---|
| Primary Energy Consumption | MJ | 59,387,606.45 | 10,707.39 | 0.02% |
| Weighted Resource Use | kg | 34,601,267.47 | 4,744.50 | 0.01% |
| Global Warming Potential | (kg CO2 eq / kg) | 5,771,142.67 | 292.61 | 0.01% |
| Acidification Potential | (moles of H+ eq / kg) | 2,348,888.48 | 116.09 | 0.00% |
| HH Respiratory Effects Potential | (kg PM2.5 eq / kg) | 19,098.46 | 0.95 | 0.00% |
| Eutrophication Potential | (kg N eq / kg) | 1,642.19 | 0.29 | 0.02% |
| Ozone Depletion Potential | (kg CFC-11 eq / kg) | 0.03 | 0.00 | 0.25% |
| Smog Potential | (kg NOx eq / kg) | 19,939.39 | 0.85 | 0.00% |

From above tables, concrete has most significant changes with 10 percentage increment, followed by oriented strand board, galvanized studs, ½” regular gypsum board, and softwood plywood. Above results could be used for future renovation reference.

## 8. Building Performance

Examining the building performance would be beneficial to long term operating cost over building’s life span. In this project, to improve the building performance, R values for windows, roofs, and walls are assigned to a higher value so that the building would lose less energy during its operation. The following figure is showing the difference between the original building and improved insulation one.

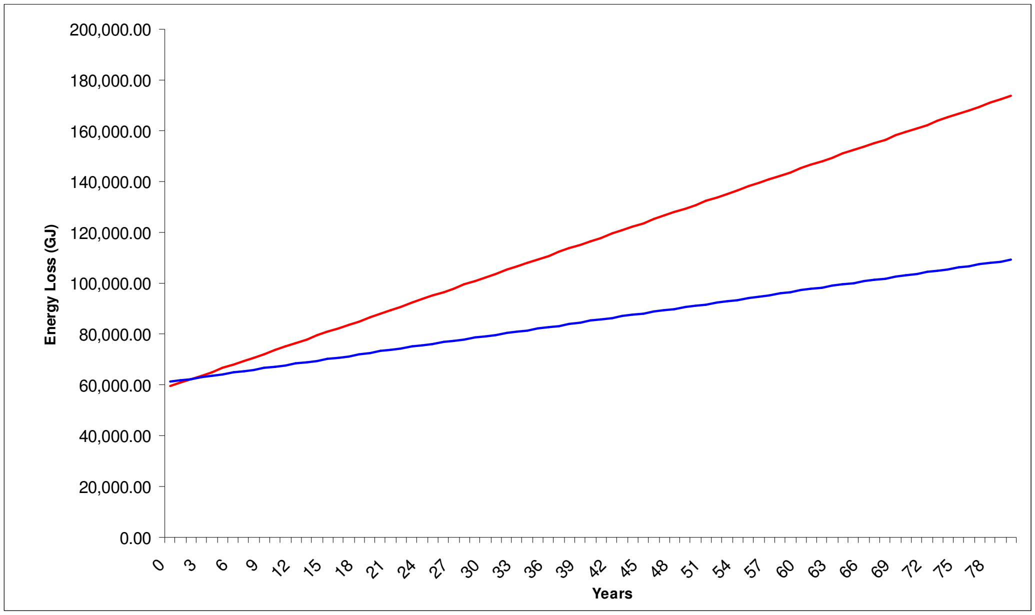


**Figure 1 Building Performance**

The red line in the figure indicates the original building performance, and the blue one indicates the improved one. Taking 30 years as the building life time, the difference of energy loss between the two mentioned above is about 20 GJ. In terms of energy efficiency, the improved one is significant better than the original one. However, the initial cost to build a better insulation building, with high R values, would have a longer payback period.

## 9. Conclusions

In this project, the environmental impacts of the FSC are assessed applying LCA. The project scope is defined as cradle-to-gate. In particular, OnScreen and IE are the software used to perform the takeoff and quantify the environmental impacts. To get a better understanding of the value of this project, along with its final results accuracy, uncertainties analysis are carried out to discuss the major methodologies and tools in LCA, which would contribute the most to the uncertainties of the final products. Later, five construction materials are examined applying sensitivity analysis. Then building performance would give an overall idea of the impacts caused by the different architectural design in terms of consumption of the energy.

In conclusion, concrete would contribute significantly more in terms of environmental impacts than other materials. Also, the architectural design is a major part to determine the energy consumption of the building other than building material. Note that the FSC contains several traditionally environmental friendly structural, such as: skylight roof and parallam column. To perform the LCA, solid evidence, such as: numbers, figures and tables, would be provided regarding to global warming, energy consumption and Eutrophication potential.

As a matter of fact, including, but not limited to, the future renovation and similar building design and construction could benefit from the final products of this project. In particular, to improve the building performance while aiming at lower the environmental impacts, building should construct with less sensitive materials in terms of overall contribution to the environmental impact.

## 10. Reference

Forestry Department, the University of British Columbia, 2010, www.forestry.ubc.ca

SI Metric, 2010, http://www.simetric.co.uk/si_metals.htm

UBC Library, www.library.ubc.ca/archives/bldgs/forestscientre.htm

Wayne Trusty, The U.S. LCI Database Project and Its Role in Life Cycle Assessment, November, 2005

# Appendix A

# FSC Input Document

| Assembly Group | Assembly Type | Assembly Name | Input Fields | Input Values | |
|---|---|---|---|---|---|
| | | | | Known / Measured | EIE Inputs |
| 1 Foundation | | | | | |
| | 1.1 Concrete Slab-on-Grade | | | | |
| | | 1.1.1 SOG_150mm | | | |
| | | | Length (m) | 80.6 | 80.6 |
| | | | Width (m) | 80.6 | 80.6 |
| | | | Thickness (mm) | 150.0 | 100.0 |
| | | | Concrete (MPa) | 20.0 | 20.0 |
| | | | Concrete flyash % | - | average |
| | 1.2 Footing | | | | |
| | | 1.2.1 Footing_F01_Basement | | | |
| | | | Length (m) | 1.4 | 1.4 |
| | | | Width (m) | 1.0 | 1.0 |
| | | | Thickness (mm) | 200.0 | 200.0 |
| | | | Concrete (MPa) | 25.0 | 30.0 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #10 | #10 |
| | | 1.2.2 Footing_F02_Basement | | | |
| | | | Length (m) | 1.5 | 1.5 |
| | | | Width (m) | 1.5 | 1.5 |
| | | | Thickness (mm) | 350.0 | 350.0 |
| | | | Concrete (MPa) | 25.0 | 30.0 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #15 | #15 |
| | | 1.2.3 Footing_F03_Basement | | | |
| | | | Length (m) | 2.4 | 2.4 |
| | | | Width (m) | 2.4 | 2.4 |
| | | | Thickness (mm) | 450.0 | 450.0 |
| | | | Concrete (MPa) | 20.0 | 20.0 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #20 | #20 |
| | | 1.2.4 Footing_F04_Basement | | | |
| | | | Length (m) | 2.0 | 2.0 |
| | | | Width (m) | 2.0 | 2.0 |
| | | | Thickness (mm) | 400.0 | 400.0 |
| | | | Concrete (MPa) | 20.0 | 20.0 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #20 | #20 |
| | | 1.2.5 Footing_F05_Basement | | | |
| | | | Length (m) | 2.2 | 2.2 |
| | | | Width (m) | 2.2 | 2.2 |
| | | | Thickness (mm) | 450.0 | 450.0 |
| | | | Concrete (MPa) | 25.0 | 30.0 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #20 | #20 |

| | | | |
|---|---|---|---|
| 1.2.6 Footing_F06_Basement | | | |
| | Length (m) | 1.7 | 1.7 |
| | Width (m) | 1.7 | 1.7 |
| | Thickness (mm) | 300.0 | 300.0 |
| | Concrete (MPa) | 25.0 | 30.0 |
| | Concrete flyash % | - | average |
| | Rebar | #20 | #20 |
| 1.2.7 Footing_F07_Basement | | | |
| | Length (m) | 1.8 | 1.8 |
| | Width (m) | 1.8 | 1.8 |
| | Thickness (mm) | 400.0 | 400.0 |
| | Concrete (MPa) | 25.0 | 30.0 |
| | Concrete flyash % | - | average |
| | Rebar | #20 | #20 |
| 1.2.8 Footing_F08_Basement | | | |
| | Length (m) | 2.8 | 2.8 |
| | Width (m) | 2.8 | 3.1 |
| | Thickness (mm) | 550.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | #30 | #20 |
| 1.2.9 Footing_F09_Basement | | | |
| | Length (m) | 1.8 | 1.8 |
| | Width (m) | 1.6 | 1.76 |
| | Thickness (mm) | 550.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 30.0 |
| | Concrete flyash % | - | average |
| | Rebar | #35 | #20 |
| 1.2.10 Footing_F10_Basement | | | |
| | Length (m) | 1.8 | 1.8 |
| | Width (m) | 1.8 | 1.8 |
| | Thickness (mm) | 350.0 | 350.0 |
| | Concrete (MPa) | 20.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | #25 | #20 |
| 1.2.11 Footing_F11_Basement | | | |
| | Length (m) | 1.5 | 1.5 |
| | Width (m) | 1.5 | 1.8 |
| | Thickness (mm) | 600.0 | 500.0 |
| | Concrete (MPa) | 20.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | #25 | #20 |
| 1.2.12 Footing_F12_Basement | | | |
| | Length (m) | 2.1 | 2.1 |
| | Width (m) | 1.2 | 1.2 |
| | Thickness (mm) | 250.0 | 250.0 |

| | | | | |
|---|---|---|---|---|
| | | Concrete (MPa) | 10.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | #25 | #20 |
| | 1.2.13 Footing_F13_Basement | | | |
| | | Length (m) | 1.2 | 1.2 |
| | | Width (m) | 1.2 | 1.2 |
| | | Thickness (mm) | 400.0 | 400.0 |
| | | Concrete (MPa) | 15.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | #25 | #20 |
| | 1.2.14 Footing_F14_Basement | | | |
| | | Length (m) | 3.9 | 3.9 |
| | | Width (m) | 1.8 | 1.8 |
| | | Thickness (mm) | 400.0 | 400.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| | 1.2.15 Footing_F15_Basement | | | |
| | | Length (m) | 3.8 | 3.8 |
| | | Width (m) | 2.0 | 2.8 |
| | | Thickness (mm) | 700.0 | 500.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| | 1.2.16 Footing_F16_Basement | | | |
| | | Length (m) | 3.1 | 5.0 |
| | | Width (m) | 1.6 | 1.6 |
| | | Thickness (mm) | 800.0 | 500.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| | 1.2.17 Footing_F17_Basement (not used) | | | |
| | | Length (m) | - | - |
| | | Width (m) | - | - |
| | | Thickness (mm) | - | - |
| | | Concrete (MPa) | - | - |
| | | Concrete flyash % | - | - |
| | | Rebar | - | - |
| | 1.2.18 Footing_F18_Basement(not used) | | | |
| | | Length (m) | - | - |
| | | Width (m) | - | - |
| | | Thickness (mm) | - | - |
| | | Concrete (MPa) | - | - |
| | | Concrete flyash % | - | - |
| | | Rebar | - | - |

| | | | |
|---|---|---|---|
| 1.2.19 Footing_F19_Basement (not used) | | | |
| | Length (m) | - | - |
| | Width (m) | - | - |
| | Thickness (mm) | - | - |
| | Concrete (MPa) | - | - |
| | Concrete flyash % | - | - |
| | Rebar | - | - |
| 1.2.20 Footing_F20_Basement | | | |
| | Length (m) | 9.0 | 9.0 |
| | Width (m) | 9.0 | 18.0 |
| | Thickness (mm) | 1000.0 | 500.0 |
| | Concrete (MPa) | - | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | #20 | #20 |
| 1.2.21 Footing_F21_Basement | | | |
| | Length (m) | 12.0 | 12.0 |
| | Width (m) | 12.0 | 24.0 |
| | Thickness (mm) | 1000.0 | 500.0 |
| | Concrete (MPa) | - | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | #20 | #20 |
| 1.2.22 Footing_F22_Basement | | | |
| | Length (m) | 7.0 | 7.0 |
| | Width (m) | 7.0 | 14.0 |
| | Thickness (mm) | 1000.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.23 Footing_F23_Basement | | | |
| | Length (m) | 6.0 | 6.0 |
| | Width (m) | 11.0 | 19.8 |
| | Thickness (mm) | 900.0 | 500.0 |
| | Concrete (MPa) | varied | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | varied | #20 |
| 1.2.24 Footing_F24_Basement | | | |
| | Length (m) | 4.5 | 4.5 |
| | Width (m) | 22.0 | 44.0 |
| | Thickness (mm) | 1000.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.25 Footing_F25_Basement | | | |
| | Length (m) | 20.2 | 20.2 |
| | Width (m) | 20.2 | 40.4 |
| | Thickness (mm) | 1000.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.26 Footing_F27_Basement | | | |
| | Length (m) | 8.8 | 8.8 |
| | Width (m) | 8.8 | 17.6 |
| | Thickness (mm) | 1000.0 | 500.0 |

| | | | | |
|---|---|---|---|---|
| | | Concrete (MPa) | 25.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | - | #20 |
| 1.2.27 Footing_F28_Basement | | | | |
| | | Length (m) | 13.0 | 13.0 |
| | | Width (m) | 7.0 | 14.0 |
| | | Thickness (mm) | 1000.0 | 500.0 |
| | | Concrete (MPa) | 25.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | - | #20 |
| 1.2.28 Footing_F29_Basement | | | | |
| | | Length (m) | 4.0 | 4.0 |
| | | Width (m) | 13.0 | 31.2 |
| | | Thickness (mm) | 1200.0 | 500.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| 1.2.29 Footing_F30_Basement (not used) | | | | |
| | | Length (m) | - | - |
| | | Width (m) | - | - |
| | | Thickness (mm) | - | - |
| | | Concrete (MPa) | - | - |
| | | Concrete flyash % | - | - |
| | | Rebar | - | - |
| 1.2.30 Footing_F31_Basement | | | | |
| | | Length (m) | 77.0 | 77.0 |
| | | Width (m) | 3.0 | 6.0 |
| | | Thickness (mm) | 1000.0 | 500.0 |
| | | Concrete (MPa) | 25.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | - | #20 |
| 1.2.31 Footing_F32_Basement | | | | |
| | | Length (m) | 7.0 | 7.0 |
| | | Width (m) | 7.0 | 14.0 |
| | | Thickness (mm) | 1000.0 | 500.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| 1.2.32 Footing_F33_Basement | | | | |
| | | Length (m) | 14.0 | 14.0 |
| | | Width (m) | 4.0 | 8.0 |
| | | Thickness (mm) | 1000.0 | 500.0 |
| | | Concrete (MPa) | varied | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | varied | #20 |
| 1.2.33 Footing_F34_Basement | | | | |
| | | Length (m) | 1.3 | 1.3 |
| | | Width (m) | 0.6 | 0.6 |
| | | Thickness (mm) | 300.0 | 300.0 |
| | | Concrete (MPa) | 15.0 | 20.0 |
| | | Concrete flyash % | - | average |
| | | Rebar | - | #20 |

| | | | |
|---|---|---|---|
| 1.2.34 Footing_Concrete CF1_Basement | | | |
| | Length (m) | 2.4 | 2.4 |
| | Width (m) | 2.4 | 5.8 |
| | Thickness (mm) | 1200.0 | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | 20.0 |
| 1.2.35 Footing_Concrete CF2_Basement | | | |
| | Length (m) | 1.8 | 1.8 |
| | Width (m) | 0.9 | 1.6 |
| | Thickness (mm) | 900.0 | 500.0 |
| | Concrete (MPa) | 15.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.36 Footing_Concrete strip F30_Basement | | | |
| | Length (m) | 49.0 | 49.0 |
| | Width (m) | 2.0 | 2.0 |
| | Thickness (mm) | - | 500.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | 20.0 |
| 1.2.37 Footing_Concrete Strip SF1_Basement | | | |
| | Length (m) | 15.0 | 15.0 |
| | Width (m) | 1.1 | 1.1 |
| | Thickness (mm) | 300.0 | 300.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | 20.0 |
| 1.2.38 Footing_Concrete Strip SF2_Basement | | | |
| | Length (m) | 170.0 | 170.0 |
| | Width (m) | 3.3 | 3.3 |
| | Thickness (mm) | 300.0 | 300.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.39 Footing_Concrete Strip SF3_Basement | | | |
| | Length (m) | 10.0 | 10.0 |
| | Width (m) | 1.2 | 1.2 |
| | Thickness (mm) | 300.0 | 300.0 |
| | Concrete (MPa) | 25.0 | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | #20 |
| 1.2.40 Footing_Conrete Wall CF1_Basement | | | |
| | Length (m) | 8.0 | 8.0 |
| | Width (m) | 0.6 | 0.6 |
| | Thickness (mm) | - | 500.0 |
| | Concrete (MPa) | - | 20.0 |
| | Concrete flyash % | - | average |
| | Rebar | - | 20.0 |

| | | | | | |
|---|---|---|---|---|---|
| 2 Walls | 2.1 Cast In Place | 2.1.1 Wall_CastInPlace_W01 | | | |
| | | | Length (m) | 83.0 | 83.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Thickness (mm) | varied | 300.0 |
| | | | Concrete (Mpa) | 25.0 | 30.0 |
| | | | Concrete flyash % | - | average |
| | | | Reinforcement | - | #20 |
| | | Opening | Number of Doors | 13.0 | 13.0 |
| | | | Door Type | - | Steel Interior Door |
| | | Envelope | Category | - | Vapour Barrier |
| | | | Material | - | Plyethylene 6 mil |
| | | 2.1.2 Wall_CastInPlace_W02 | | | |
| | | | Length (m) | 99.0 | 99.0 |
| | | | Height (m) | 6.5 | 6.5 |
| | | | Thickness (mm) | Varied | 300.0 |
| | | | Concrete (Mpa) | 25.0 | 30.0 |
| | | | Reinforcement | - | #20 |
| | | | Concrete flyash % | - | average |
| | | Opening | Number of Doors | 15.0 | 15.0 |
| | | | Door Type | - | Steel Interior Door |
| | | Envelope | Category | - | Cladding |
| | | | Material | - | Brick - Modular (metric) |
| | | 2.1.3 Wall_CastInPlace_W03 | | | |
| | | | Length (m) | 393.0 | 393.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Thickness (mm) | Varied | 300.0 |
| | | | Concrete (Mpa) | 25.0 | 30.0 |
| | | | Reinforcement | - | #20 |
| | | | Concrete flyash % | - | average |
| | | Opening | Number of Doors | 3.0 | 3.0 |
| | | | Door Type | - | Steel Interior Door |
| | | Envelope | Category | - | Vapour Barrier |
| | | | Material | - | Polyethylene 6 mil |
| | | 2.1.4 Wall_CastInPlace_W04 | | | |
| | | | Length (m) | 622.0 | 622.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Thickness (mm) | Varied | 200.0 |
| | | | Concrete (Mpa) | 25.0 | 30.0 |
| | | | Reinforcement | - | #20 |
| | | | Concrete flyash % | - | average |
| | | Wall_SteelS | Sheathing Type | - | None |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud spacing | - | 600 o.c. |
| | | | Stud Thickness | - | 39x92 |
| | | Opening | Number of Doors | 23.0 | 23.0 |
| | | | Door Type | - | Steel Exterior Door |

| | | | | | |
|---|---|---|---|---|---|
| | | | Total Window Area | 203.00 | 203.00 |
| | | | Fixed/Operable | Fixed | Fixed |
| | | | Frame Type | Alumimum | Almimum |
| | | | Glazing Type | - | Standard Glazing |
| | | Envelope | Category | - | Vapour Barrier |
| | | | Material | - | Polyethylene 6 mil |
| | | | Category | - | Insulation |
| | | | Material | - | fiberglass Batt |
| | | | Thickness (mm) | - | 88.9 |
| | | | Category | - | Vapour Barrier |
| | | | Material | - | Polyethylene 3 mil |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Gypsum Board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | 2.2 Steel Stud | 2.2.1 Wall_Cast-In-Place_SteelStud_W05 | | | |
| | SteelStud_W05 | | Length (m) | 362.0 | 362.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Thickness (mm) | Varied | 300.0 |
| | | | Concrete (Mpa) | 25.0 | 30.0 |
| | | | Reinforcement | - | #15 |
| | | | Concrete flyash % | - | average |
| | | | Sheathing Type | - | None |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud spacing | - | 600o.c. |
| | | | Stud Thickness | - | 39x92 |
| | | Opening | Number of Doors | 12.0 | 12.0 |
| | | | Door Type | - | solid Wood door |
| | | Envelope | Category | - | Insulation |
| | | | Material | - | fiberglass Batt |
| | | | Thickness (mm) | - | 88.9 |
| | | | Category | - | Gypsum Board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | 2.2.2 Wall_SteelStud_W06 | | | |
| | SteelStud_W06 | | Length (m) | 707.0 | 707.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Sheathing Type | - | None |
| | | | Stud Weight | - | Heavy (25Ga) |
| | | | Stud spacing | - | 600o.c. |
| | | | Stud Thickness | - | 39x152 |
| | | SteelStud_V | Sheathing Type | - | None |
| | | | Stud Weight | - | Light (20Ga) |
| | | | Stud spacing | - | 400o.c. |
| | | | Stud Thickness | - | 39x92 |

| | | | | | |
|---|---|---|---|---|---|
| | | Opening | Number of Windows | 188 | 188 |
| | | | Total Window Area | 1,064.00 | 1,064.00 |
| | | | Fixed/Operable | Fixed | Fixed |
| | | | Frame Type | Alumimum | Aluminum |
| | | | Glazing Type | - | Standard Glazing |
| | | Envelope | Category | - | Vapour barrier |
| | | | Material | - | Polyethylene 3 mil |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Cladding |
| | | | Material | - | Brick - Split Faced |
| | | | Type | - | - |
| | | | Category | - | Gypsum board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Gypsum board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Insulation |
| | | | Material | - | Fiberglass Batt |
| | | | Thickness (mm) | - | 88.9 |
| | | 2.2.3 Wall_SteelStud_W07 | | | |
| | | | Length (m) | 484.0 | 484.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | SteelStud_W07 | | Sheathing Type | None | None |
| | | | Stud Weight | Light (25Ga) | Light (25Ga) |
| | | | Stud spacing | - | 400 oc |
| | | | Stud Thickness | 32x92 | 32x92 |
| | | Opening | Number of Doors | 52.0 | 52.0 |
| | | | Door Type | - | solid Wood door |
| | | Envelope | Category | - | Gypsum board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Insulation |
| | | | Material | - | Fiberglass Batt |
| | | | Thickness (mm) | - | 88.9 |
| | | 2.2.4 Wall_SteelStud_W08 | | | |
| | | | Length (m) | 3058.0 | 3058.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | Wall_SteelStud_W08 | | Sheathing Type | None | None |
| | | | Stud Weight | Light (25Ga) | Light (25Ga) |
| | | | Stud spacing | 400 o.c. | 400 o.c. |
| | | | Stud Thickness | 39x92 | 39x92 |
| | | Opening | Number of Doors | 377.0 | 377.0 |
| | | | Door Type | - | solid Wood door |

| | | | | | |
|---|---|---|---|---|---|
| | | | Category | - | Vapour Barrier |
| | | | Material | - | Polyethylene 3 mil |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Gypsum Board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | 2.2.4 Wall_SteelStud_W12 | | | |
| | | | Length (m) | 415.0 | 415.0 |
| | | | Height (m) | 4.2 | 4.2 |
| | Wall_SteelStud_W12 | | Sheathing Type | None | None |
| | | | Stud Weight | Light (25Ga) | Light (25Ga) |
| | | | Stud spacing | 400 o.c. | 400 o.c. |
| | | | Stud Thickness | 39x92 | 39x92 |
| | | Opening | Number of Windows | 105 | 105 |
| | | | Total Window Area (m2) | 291.00 | 291.00 |
| | | | Fixed/Operable | Fixed | Fixed |
| | | | Frame Type | Alumimum | Aluminum |
| | | | Glazing Type | - | Standard Glazing |
| | | Envelope | Category | - | Insulation |
| | | | Material | - | fiberglass Batt |
| | | | Thickness (mm) | - | 88.9 |
| | | | Category | - | Vapour Barrier |
| | | | Material | - | Polyethylene 3 mil |
| | | | Thickness (mm) | - | - |
| | | | Category | - | Gypsum Board |
| | | | Material | - | Gyspum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | 2.3 Curtain W | 2.3.1 Wall_Curtain Wall_W10 | | | |
| | | | Length (m) | 85 | 85 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Percent Viewable Glazing ( | 95 | 95 |
| | | | Percent Spandrel Panel (%) | 5 | 5 |
| | | | Thickness of Insulation (m | 2.54 | 2.54 |
| | | | Spandrel Panel Type | Metal | Metal |
| | Door Opening | | Number of Doors | 20 | 20 |
| | | | Door Type | - | Aluminum Exterior Door, 80% glazing |
| | | 2.3.2 Wall_Curtain Wall - W11 | | | |
| | | | Length (m) | 98 | 98 |
| | | | Height (m) | 4.2 | 4.2 |
| | | | Percent Viewable Glazing ( | 95 | 95 |
| | | | Percent Spandrel Panel (%) | 5 | 5 |
| | | | Thickness of Insulation (m | 2.54 | 2.54 |
| | | | Spandrel Panel Type | Metal | Metal |
| | Door Opening | | Number of Doors | 7 | 7 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Door Type | - | Steel Interior Door |
| | 2.4 Roof | 2.4.1 Roof_Curtain | | | |
| | | | Length (m) | 79 | 79 |
| | | | Height (m) | 11 | 11 |
| | | | Percent Viewable Gl | 95 | 95 |
| | | | Percent Spandrel Pa | 5 | 5 |
| | | | Thickness of Insulati | 0 | 0 |
| | | | Spandrel Panel Type | Metal | Metal |
| 3.0 Mixed Column and Beams | | | | | |
| | | 3.1.1 Column_concrete_basement | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 45 | 45 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.2 | 4.2 |
| | | | Bay sizes (m) | 9.81 | 9.81 |
| | | | Supported span | 9.81 | 9.81 |
| | | | Live load (kPa) | 4.8 | 4.8 |
| | | 3.1.2 Column_Concrete_GroundFloor | | | |
| | | | Number of Beams | 16 | 16 |
| | | | Beam Type | - | Concrete |
| | | | Number of Columns | 112 | 112 |
| | | | Column Type | Concrete | concrete |
| | | | Floor to floor height | 4.2 | 4.2 |
| | | | Bay sizes (m) | 5.89 | 5.89 |
| | | | Supported span | 5.89 | 5.89 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| | | 3.1.3 Column_Concrete_SecondFloor_North | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 76 | 76 |
| | | | Column Type | Concrete | concrete |
| | | | Floor to floor height | 4.2 | 4.2 |
| | | | Bay sizes (m) | 4.83 | 4.83 |
| | | | Supported span | 4.83 | 4.83 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| | | 3.1.4 Column_Concrete_SecondFloor_South | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 92 | 92 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.20 | 4.20 |
| | | | Bay sizes (m) | 3.68 | 3.68 |
| | | | Supported span | 3.68 | 3.68 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| | | 3.1.5 Column_Concrete_ThirdFloor_North | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 64 | 64 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.20 | 4.20 |
| | | | Bay sizes (m) | 5.27 | 5.27 |
| | | | Supported span | 5.27 | 5.27 |
| | | | Live load (kPa) | 2.4 | 2.4 |

| | | | | | |
|---|---|---|---|---|---|
| | | 3.1.6 Column_Concrete_ThirdFloor_South | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 91 | 91 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.20 | 4.20 |
| | | | Bay sizes (m) | 4.02 | 4.02 |
| | | | Supported span | 4.02 | 4.02 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| | | 3.1.7 Column_Concrete_FourthFloor_North | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 57 | 57 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.20 | 4.20 |
| | | | Bay sizes (m) | 5.39 | 5.39 |
| | | | Supported span | 5.39 | 5.39 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| | | 3.1.8 Column_Concrete_FourthFloor_South | | | |
| | | | Number of Beams | - | - |
| | | | Beam Type | - | - |
| | | | Number of Columns | 62 | 62 |
| | | | Column Type | Concrete | Concrete |
| | | | Floor to floor height | 4.20 | 4.20 |
| | | | Bay sizes (m) | 4.23 | 4.23 |
| | | | Supported span | 4.23 | 4.23 |
| | | | Live load (kPa) | 2.4 | 2.4 |
| 4.0 Floor | | 4.1.1 Floor | | | |
| | | | Floor Width (m) | 1018.2 | 1018.2 |
| | | | Span (m) | 9.0 | 9.0 |
| | | | Concrete | - | 30 Mpa |
| | | | Concrete flyash % | - | average |
| | | | Live load (kPa) | - | 3.6kPa |
| | | | Category | - | gypsum Board |
| | | | Type | - | Regular 1/2" |
| 5.0 Roof | | 5.1.1 Roof_Concrete | | | |
| | | | Roof Width (m) | 187.0 | 187.0 |
| | | | Span (m) | 9.0 | 9.0 |
| | | | Concrete | - | 20Mpa |
| | | | Concrete flyash % | - | average |
| | | | Live load (kPa) | - | 2.4kPa |
| | | Envelope | Category | - | Expanded Plystyrene |
| | | | Thickness (mm) | - | 150.0 |
| | | 5.1.2 Roof_Metal | | | |
| | | | Roof Width (m) | 181.8 | 181.8 |
| | | | Span (m) | 9.0 | 9.0 |
| | | | With or W/out Conc | - | Included |
| | | | Live load (kPa) | - | 2.4kPa |
| | | | Category | - | Steel Roof system |

| | | | |
|---|---|---|---|
| 6.0 Extra Basic materials | 6.1 XBM_Wood_Beam | | |
| | Glulam Beams (m^3) | 92.8 | 92.8 |
| | 6.2 XBM_Stairs | | |
| | Galvanized Decking (to | 0.008 | 0.008 |

# Appendix B

# IE Input Assumption Document

| Assembly Group | Assembly Type | Assembly Name | Specific Assumptions |
|---|---|---|---|
| 1 Foundation | | | |
| | 1.1 Concrete Slab-on-Grade | | |
| | | 1.1.1 SOG_150mm | The area of this slab had to be adjusted so that the thickness fit into the 100mm thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width inputs for this slab;<br><br>= sqrt[((Measured Slab Area) x (Actual Slab Thickness))/(100/1000) ]<br><br>= sqrt[ (4334 x (150/1000))/(100/1000) ]<br><br>= 80.63 m |
| | 1.2 Footing | | |
| | | For concrete flyash %, "average" is taken as input in IE for all components. | |
| | | 1.2.1 Footing_F01_Basement | Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.2 Footing_F02_Basement | Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.5 Footing_F05_Basement | Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.6 Footing_F06_Basement | Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.7 Footing_F07_Basement | Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.8 Footing_F08_Basement | 1. Due to the limitation of IE, rebar #20 is selected instead of #25. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. |

| | | | |
|---|---|---|---|
| | | | =(Volumn)/(length*0.5m)=2.8*2.8*0.55/(2.8*0.5)=3.1m |
| | | 1.2.9 Footing_F09_Basement | 1. Due to the limitation of IE, rebar #20 is selected instead of #25. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=1.6*1.8*0.55/(1.8*0.5)=1.76m 3. Due to there are only 20 Mpa and 30 Mpa for concrete, the ture value here is 25 Mpa. 20 Mpa is choose to be the input in IE. |
| | | 1.2.10 Footing_F10_Basement | Due to the limitation of IE, rebar #20 is selected instead of #25. |
| | | 1.2.11 Footing_F11_Basement | 1. Due to the limitation of IE, rebar #20 is selected instead of #25. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=1.5*1.5*0.55/(1.5*0.5)=1.8m |
| | | 1.2.12 Footing_F12_Basement | 1. Due to the limitation of IE, Concrete strength #20 is selected instead of #10. 2. Rebar #20 is selected instead of #25. |
| | | 1.2.13 Footing_F13_Basement | 1. Due to the limitation of IE, Concrete strength #20 is selected instead of #15. 2. Rebar #20 is selected instead of #25. |
| | | 1.2.14 Footing_F14_Basement | Since the Concrete Strength and rebar are varied for F14, 20Mpa and #20 are selected. |
| | | 1.2.15 Footing_F15_Basement | 1.Since the concrete strength and rebar are varied for F15, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=3.8*2*0.70/(3.8*0.5)=2.8m |
| | | 1.2.16 Footing_F16_Basement | 1.Since the concrete strength and rebar are varied for F16, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=3.1*1*0.80/(1.6*0.5)=4.96m |

| | | | |
|---|---|---|---|
| | | 1.2.20 Footing_F20_Basement | 1.Since the concrete strength is unknown for F20, 20Mpa is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=9*9*1/(9*0.5)=18 m |
| | | 1.2.21 Footing_F21_Basement | 1.Since the concrete strength is unknown for F20, 20Mpa is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=12*12*1/(12*0.5) =24m |
| | | 1.2.22 Footing_F22_Basement | 1.Since the rebar are varied for F22, #20 is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=7*7*1/(7*0.5)=14 m |
| | | 1.2.23 Footing_F23_Basement | 1.Since the concrete strength and rebar are varied for F23, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=6*11*0.90/(6*0.5) =19.8m |
| | | 1.2.24 Footing_F24_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=4.5*22*1/(4.5*0.5 )=44m |
| | | 1.2.25 Footing_F25_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=20.2*20.2*1/(20.2 *0.5)=40.4m |

| | | | |
|---|---|---|---|
| | | 1.2.26 Footing_F27_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected.<br>2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=8.8*8.8*1/(8.8*0.5)=17.6m |
| | | 1.2.27 Footing_F28_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected.<br>2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=13*7*1/(13*0.5)= 14m |
| | | 1.2.28 Footing_F29_Basement | 1.Since the concrete strength and rebar are varied for F29, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=4*13*1.20/(4*0.5)=31.2m |
| | | 1.2.30 Footing_F31_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected.<br>2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=77*3*1/(77*0.5)= 6m |
| | | 1.2.31 Footing_F32_Basement | 1.Since the concrete strength and rebar are varied for F32, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=3.1*1*0.80/(3.1*0.5)=1.6m |
| | | 1.2.32 Footing_F33_Basement | 1.Since the rebar are varied for F33, #20 is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width.<br>=(Volumn)/(length*0.5m)=14*4*1/(14*0.5)= 8m |
| | | 1.2.33 Footing_F34_Basement | 1. Due to the limitation of IE, Concrete strength #20 is selected instead of #25. 2. Rebar #20 is selected.. |

| | | | |
|---|---|---|---|
| | | 1.2.34 Footing_Concrete CF1_Basement | 1.Since the concrete strength and rebar are varied for CF1, 20Mpa and #20 are selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=2.4*2.4*1.20/(2.4*0.5)=5.8m |
| | | 1.2.35 Footing_Concrete CF2_Basement | 1.Since the rebar are varied for F35, #20 is selected. 2. The maximum thickness is 500mm, thus following calculation is carried out to get the proper width. =(Volumn)/(length*0.5m)=1.8*0.9*0.9/(1.8*0.5)=1.6m 3. For concrete strength 20Mpa is selected instead of 15Mpa |
| | | 1.2.36 Footing_Concrete strip F30_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. |
| | | 1.2.37 Footing_Concrete Strip SF1_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. |
| | | 1.2.38 Footing_Concrete Strip SF2_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. |
| | | 1.2.39 Footing_Concrete Strip SF3_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. |
| | | 1.2.40 Footing_Conrete Wall CF1_Basement | 1.Instead of 25 Mpa for concrete strength, 20 Mpa is selected. Also Rebar #20 is selected. |
| 2.0 Walls | | | |
| | 2.1 Cast in Place | 2.1.1 Wall_CastInPlace_W01 | 1. The concrete strength is 25Mpa, due to the limitation of IE input selection, 30Mpa is taken as input. 2. Type of the door is assumed as steel interior door.3. Envelope is assumed as vapour barrier and the material is plyethylene 6 mil. |
| | | 2.1.2 Wall_CastInPlace_W02 | 1. The concrete strength is 25Mpa, due to the limitation of IE input selection, 30Mpa is taken as input. 2. Type of the door is assumed as steel interior door.3. Envelope is assumed as Brick-modular of Cladding. 4.The thickness is varied for this wall, thus 200 mm is taken. |
| | | 2.1.3 Wall_CastInPlace_W03 | 1. The concrete strength is 25Mpa, due to the limitation of IE input selection, 30Mpa is taken as input. 2. Type of the door is assumed as steel interior door.3. Envelope is assumed as Plyethylene 6 mil of Vapour Barrier. 4.The thickness is varied for this wall, thus 300 mm is taken. |

| | | | |
|---|---|---|---|
| | | 2.1.4 Wall_CastInPlace_W04 | 1. The concrete strength is 25Mpa, due to the limitation of IE input selection, 30Mpa is taken as input. 2. Type of the door is assumed as steel exteriordoor.3. Envelope is assumed as Plyethylene 6 mil of Vapour Barrier, 88.9mm fiberglass batt of insulation, polyethylene 3mil of vapour barrier, 5/8" regular gyspum board. 4.The thickness is varied for this wall, thus 200 mm is taken. |
| | 2.2 Steel Stud | 2.2.1 Wall_Cast-In-Place_SteelStud_W05 | 1. The concrete strength is 25Mpa, due to the limitation of IE input selection, 30Mpa is taken as input. 2. Type of the door is assumed as solic wood door.3. Envelope is assumed as Plyethylene 6 mil of Vapour Barrier, 88.9mm fiberglass batt of insulation and 5/8" regular gyspum board. 4.The thickness is varied for this wall, thus 300 mm is taken.5. sheathing type is None, stud weight is light, stud spacing is 600 o.c. and the thickness is 39x92 |
| | | 2.2.2 Wall_SteelStud_W06 | 1. In this wall, two layers of steel stud are applied. One is Heavy, 600oc, with 29x152 thickness, and the other one is light, 400 oc with 39x152 of thickness.2. Envelope is assumed as Plyethylene 3 mil of Vapour Barrier, 88.9mm fiberglass batt of insulation, two layers of 5/8" regular gyspum board, and brick-split faced of cladding. |
| | | 2.2.3 Wall_SteelStud_W07 | Envelope is assumed as 88.9mm fiberglass batt of insulation and 5/8" regular gyspum board. |
| | | 2.2.4 Wall_SteelStud_W08 | 1. Door is assumed as solid wood door. .2. Envelope is assumed as Plyethylene 3 mil of Vapour Barrier, 88.9mm fiberglass batt of insulation, and 5/8" regular gyspum board. |
| | 2.3 Curtain Wall | 2.3.1 Wall_Curtain Wall_W10 | 1. door type is aluminum Exterior door with 80% glazing |
| | | 2.3.2 Wall_Curtain Wall - W11 | 1. door type is Steel interior door |
| | 2.4 Roof | 2.4.1 Roof_Curtain | 1. Linear condition is used here. |
| 3 Columns and Beams | | | |
| | 3.1 Concrete Column | | |

| | | | |
|---|---|---|---|
| | | 3.1.1 Column_conrete_basement | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured SOG of basement) / (Counted Number of Columns)]<br><br>= sqrt[(4334 m^2) / (45)]<br><br>= 9.81 m |
| | | 3.1.2 Column_Concrete_GroundFloor | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(3887 m^2) / (112)]<br><br>= 5.89 m |
| | | 3.1.3 Column_Concrete_SecondFloor_North | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>=sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1770 m^2) / (9+3+64)]<br><br>= 4.83 m |
| | | 3.1.4 Column_Concrete_SecondFloor_South | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1385 m^2) / (43+59)]<br><br>= 3.68 m |

| | | | |
|---|---|---|---|
| | | 3.1.5<br>Column_Concrete_ThirdFloor_North | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1779 m^2) / (64)]<br><br>= 5.27 m |
| | | 3.1.6<br>Column_Concrete_ThirdFloor_South | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1472 m^2) / (91)]<br><br>= 4.02 m |
| | | 3.1.7<br>Column_Concrete_fourthFloor_North | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1653 m^2) / (57)]<br><br>= 5.39 m |
| | | 3.1.8<br>Column_Concrete_FourthFloor_South | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(1108 m^2) / (62)]<br><br>= 4.23 m |

<table>
<tr><td></td><td></td><td>3.1.9<br>Column_Parralam_GroundFloor</td><td>1.Total Support area is roof area: 880+1683+1636=4199 m^2; 2. Total column length: 4.2*4=16.8 m; 3.Because of the variability of bay and span sizes, they were calculated using the following calculation;<br><br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br><br>= sqrt[(4199 m^2) / (32)]<br><br>= 11.45 m</td></tr>
<tr><td>4.0 Floor</td><td></td><td>4.1.1 Floor</td><td>1. Total Floor aera: 1653 + 1108+1770+1385+1779+1472 = 9164 m^2; 2. Due to the limitation of the IE, that the maximum span could not exceed 9.75 m, we use 9 m as span. The following calculation is used to get the width of the floor. = 9164/9= 1018.2 m</td></tr>
<tr><td>5.0 Roof</td><td colspan="3">Due to the limitation of IE, the maximum Span can not exceed 9.75m, in this section, 9 m is taken as span. Except for Roof, the span is 5 m</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td>5.1.1 Roof_Conrete</td><td>The calculation is used to get the Roof width. = Measured Roof Area / span = 1683 m^2 / 9m=187 m</td></tr>
<tr><td>5.1.2 Roof_Metal</td><td>The calculation is used to get the Roof width. = Measured Roof Area / span = 1636 m^2 / 9m=181.78 m</td></tr>
<tr><td colspan="2">6.0 Extra_Materials</td><td>XBM_Wood_Beam &<br>XBM_Stairs</td><td><table><tr><th></th><th>Measured Length (m)</th><th>Volumn (m^3)</th><th>Tone</th></tr><tr><td>Wood</td><td>368.0</td><td>92.8</td><td>46.4</td></tr><tr><td>Steel</td><td>169.0</td><td>1.0</td><td>0.0079599</td></tr></table></td></tr>
</table>