# Life Cycle Analysis: The Richmond Olympic Oval
## Vancouver, British Columbia

**Clare Zemcov**

**Radu Postole**

**Darren Thomas**

**University of British Columbia**

**CIVL 498C**

**March 29, 2011**

# 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:
# THE RICHMOND OLYMPIC OVAL
## VANCOUVER, BRITISH COLUMBIA

Prepared By: Clare Zemcov, Radu Postole and Darren Thomas

For: Civil 498C, UBC Engineering

Date: March 29, 2011

# ABSTRACT

This report is the result of a Life Cycle Assessment study performed on the Richmond Olympic Oval skating rink in Richmond, British Columbia. This study has been completed in conjunction with one other Olympic venue skating rink located at the University of British Columbia, and encompasses the building envelope and structure from cradle to gate. The ultimate goal of this study is to act as a benchmark for future LCA studies conducted on Olympic venues of similar function, as well as to contribute to the general body of knowledge for LCA studies conducted on structures and envelopes. With the use of two computer programs, environmental impacts have been determined through the measurement and quantification of materials consumed in the construction of the rink. From the bill of materials, the five largest quantities were 30 MPa concrete, ballast (aggregate stone), softwood lumber, rebar (rod and light sections) and Rockwool Batt insulation.

The resulting summary measures table by life cycle stage was then used for sensitivity analyses and building performance. A sensitivity analysis was conducted on five building materials, and illustrated how the building's overall impact on the environment changed as the quantity of each material increased by 10%. The results demonstrate that the impact categories are consistently most sensitive to a 10% increase in concrete. Rebar caused the second highest change overall; and other materials considered generally created minimal relative change in the sensitivity analysis.

## Table of Contents

# List of Tables

# List of Figures

# 1.0 INTRODUCTION

The Richmond Olympic Oval (the Oval) is located at 6111 River Road in Richmond, B.C. Construction began on November 17, 2006, shortly after site preparation, and the venue officially opened on December 12, 2008. During the Olympics, nearly the entire second floor of the 3-floor building maintained a 400 m skating surface. The building can accommodate 8,000 spectators, and was built to qualify for the Leadership in Energy and Environmental Design Scale Silver certification. Most of the second and third floors are open, displaying the uniquely designed "WoodWave" roof. The total cost of the project was $178 million.

**Figure 1 - The Richmond Olympic Oval[1]**

The main structural materials used in the construction of the Oval were concrete and steel. Concrete was used primarily in the foundation, slab on grade, basement walls and basement columns, while steel was used primarily as rebar reinforcement for the concrete in columns, beams and floors, and as structural steel in the roof. The building's exterior appearance on the North and South faces are non-glazed aluminum-framed curtain walls, and the East and West faces are concrete with an overlay of metal cladding. Specific building characteristics can be found in Table 1.

Following the conclusion of the Olympics, the Richmond Oval now serves in its legacy phase with space designed for athletics, child minding, meetings, retail, washrooms/changing rooms and a large parking lot. Other spaces are used for maintenance, administration and to-be-developed areas.

**Table 1 - Building Characteristics**

| **Building System** | **Specific Building Characteristics** |
|---|---|
| ***Structure*** | Concrete and Steel. Concrete columns support concrete suspended slabs and concrete buttresses. Steel is used to reinforce all of the concrete columns, slabs and buttresses. |
| ***Exterior Walls*** | North and South sides: fixed curtain wall with no glazing and aluminum frame. On the third floor of the South side, polycarbonate cladding overlays the glass.<br>East and West sides: A small portion fixed curtain wall with no glazing and aluminum frame. Another portion concrete, and the rest a steel stud wall with metal cladding. |
| ***Interior Walls*** | Mainly steel stud walls with various amounts and types of gypsum board. Also concrete block walls with no envelope material and concrete cast-in-place walls. |
| ***Roof*** | Composite beams composed of Glulam and structural steel support the main span of the roof and contain building HVAC, sprinkler and lighting services. WoodWave engineered structural panels composed mainly of softwood lumber span between the composite beams and are filled with fibrous mineral wool insulation. The envelope is a PVC membrane system with isocyanurate boards for insulation. |
| ***Floors*** | Floors are a concrete slab and slab band system, with hollow core concrete panels supporting a significant portion of the activities deck. |
| ***Openings*** | Interior doors are either solid wood or hollow metal. Exterior doors are either hollow metal or sliding glass. |

# 2.0 GOAL AND SCOPE

When performing a life cycle assessment on any system, a goal and scope have to be well defined. The goal and scope of this report as it fits within the CIVL 498-C course at UBC and within the LCA community is defined in this section.

## 2.1 Goal of Study

The life cycle analysis (LCA) of the Richmond Olympic Oval was carried out as an exploratory study to determine the environmental impact of its design. This LCA of the Richmond Oval is also part of an additional study being carried out simultaneously on the U.B.C Thunderbird Arena in Vancouver 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 Oval. An exemplary application of these references is the establishment of a benchmark for evaluating the relative performance of future Olympic venues. When this study is considered in conjunction with the UBC Thunderbird Arena LCA study, further applications include the possibility of carrying out environmental performance comparisons across Olympic level skating venues as well as renovations versus new structures. Furthermore, as demonstrated through these potential applications, the Oval 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 Olympic venues.

The intended core audience of this LCA study are the International Olympic Committee (IOC) and future host cities. Other potential audiences include governments, private industry and other universities whom may want to learn more or become engaged in performing similar LCA studies on Olympic venues, the legacy of Olympic events, and within their organizations.

## 2.2 Scope of the Study

The product systems being studied in this LCA are the structure and envelope of the Richmond Oval. 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 Oval, 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; OnCentre 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. The engineering and architectural drawings that contain this information are provided for this study. To accomplish the materials quantity takeoff, 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 Appendices A and B respectively.

Using the formatted takeoff data, version 4.1.12 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 Richmond Oval in the Vancouver region as a sporting event 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 and transportation of materials and their installation into the initial structure and envelope assemblies. Some LCI profiles include concrete, brick, Glulam, and other basic building materials. The system also has truck and train LCI profiles for the transportation of materials model. As this study is a cradle-to-gate assessment, the expected service life of the Oval building 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). In order to generate a complete environmental impact profile for the Richmond Oval, 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
- Fossil fuel 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 Richmond Oval.

The primary sources of data for this LCA are the original architectural and structural drawings from when the Richmond Oval was initially constructed in 2006. The assemblies of the building that are modeled include the foundation, columns and beams, floors, walls and roofs, as well as the associated envelope and openings (ie. doors and windows) within each of these assemblies. The decision to omit other building components, such as flooring, electrical aspects, HVAC system, ice rink and ice rink cooling equipment, finishing and detailing, etc., are associated with the limitations of available data and of 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 the energy in the Building Model section and, as previously mentioned, all specific input related assumptions are contained in the "Impact Estimator Input Assumptions" document in Appendix B.

# 3.0 BUILDING MODEL

This section covers the modeling tools and techniques used by the LCA practitioners and the assumptions that were made when modeling. Modeling and assumptions are covered by building assembly type, including earthworks, foundations, walls, columns, floors and beams, and roofs.

## 3.1 Quantity Takeoffs

OnCenter's On-Screen Takeoff 3 was the software selected for performing building modeling for this LCA study. The software allows a user to upload image files or PDF files of architectural and structural drawings. These images can be scaled to determine the appropriate dimensions represented in the drawings and several conditions may be used to acquire quantity takeoffs from the selected drawings in both plan and elevation/section views. Three conditions can be used to acquire quantities. These include area conditions, linear conditions, and count conditions.

Area conditions were used to determine functional areas, floor areas, and for determining volumes of materials. In addition to providing a measured area, these conditions can also output a different quantity, such as volume as long as another parameter is inserted. For example, when measuring the area of a floor, if the output quantity selected is volume (m^3), then a thickness is required as an input. After contouring an area on an image, the condition multiplies this by the thickness specified and outputs a volume (m^3) instead of an area measure. This value can then be used directly as an input for Impact Estimator or multiplied by a density to provide a weight of used material.

Linear conditions allow the user to acquire the length of selected building components. This function was very useful for this project as it allowed the team to easily measure the length of beams, columns and structural members used in the Olympic Oval.

Additionally, the output function, similar to the area condition was used to provide a quantity takeoff in other metrics such as area (m^2) and volume (m^3) by specifying known parameters into the condition.

Count conditions allow a user to count the number of items in a building. This is a very useful function for counting large quantities, like columns and piles. The option of specifying other dimensions with the count function also allows the program to output different quantities like area and volume. For example, if a height, width and thickness are specified for a component, it can simply be counted and OnScreen will provide a total volume of these components within the building (the multiplication of the three dimensions and number of times this appears in the assembly).

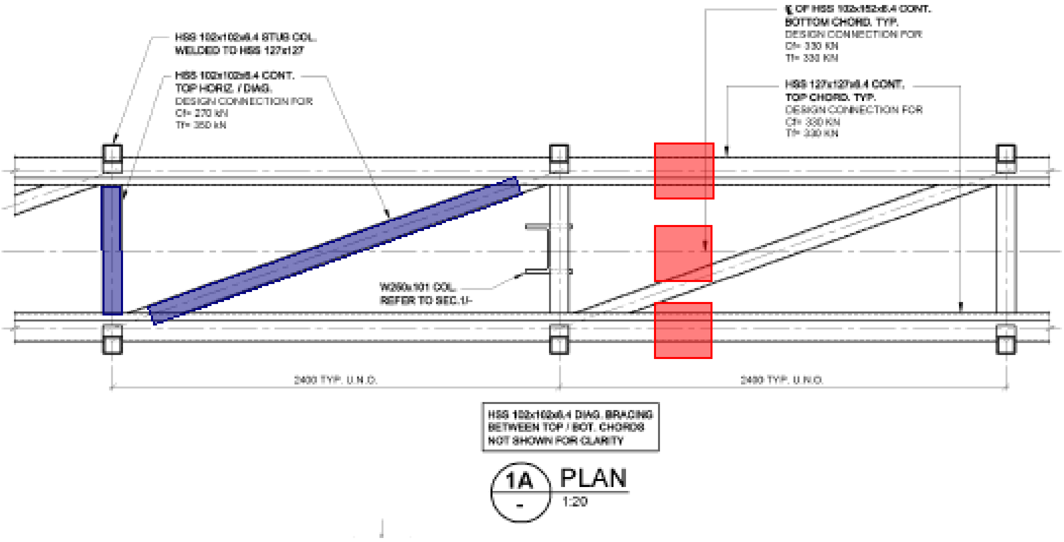


**Figure 2 - Using Linear and Count Conditions in OnScreen**

A nomenclature system was used in On-Screen to label conditions. This maintained organization and ease of cross-referencing quantities for inputting into the Inputs and Assumptions Document (see Appendix A), and finally into the Athena Impact Estimator program. This system relied on the assembly group as a primary label, followed by the location and type of material/assembly, all separated by "underscore" characters. A sample of this referencing technique for walls was provided in the CIVL 498-C course lectures and a sample nomenclature technique for a wall would look like this: “Wall_(*insert wall type, ie. cast-in-place, tilt-up, etc.)_(insert wall name, ie. W1, W2 etc.)_(insert whatever other descriptor that aids in identification and distinction from similar components).*

Some challenges were faced during modeling. When using the linear or area conditions, it was hard to determine a technique for using these tools for objects that were not positioned fully in the plane of view. In this case, either another view of these assemblies were used, or correction factors were applied. Another difficulty was to determine a single value for the height of a sloped edge. In this case, an average value was used. It was also difficult to prevent double counting features when switching between drawings since many drawings over-lap. Another difficulty encountered was unspecified features or materials. In the case of the walls, there were some walls that were not detailed on the drawings. In this case, assumptions were made about the type of wall used at these locations.  All the methods, justifications, assumptions and calculations for each assembly type can be found in Appendix A – Impact Estimator Inputs document.

## 3.2 Modeling Assumptions

To model the Oval in the Athena Impact Estimator, assembly groups were created and building components fell into five major categories including: foundation, walls, columns, floors and beams, and roof. The choices for assembly groups and the building components associated with these groups were selected to accommodate the Impact Estimator's input options.

### 3.2.1 Earthworks

Due to site conditions there was little to no excavation of material at the site and the Richmond Oval has no below ground facilities. In order to prepare the site, a series of in-ground compacted stone columns were installed to prevent seismically induced liquefaction. The site was also pre-loaded to consolidate the soil. The locations of the pilings are noted in structural drawing S201. Insufficient data was available to estimate the material amounts and impacts of the compacted stone columns and they were ignored in this report.

***Preloading***

Prior to construction the entire site was pre-loaded with fill to consolidate the soil. The volumes were extrapolated from pre-loading diagrams provided by Delcan (see Appendix C). From construction photos, the pre-load material was assumed to be crushed aggregate. The density of loose, dry gravel was taken from the "Life Cycle Assessment of Road" by the Swedish Environmental Research Institute, and used as an input into the Impact Estimator. Dry gravel was used to avoid considering mass of water as aggregate in the IE. It should be noted that the total life cycle of the pre-loading materials and manufacturing through to end-of-life takes place prior to the rest of the construction of the Richmond Oval.

## 3.2.2 Foundations

The Richmond oval rests on a raft slab thickened at its intersection with columns and elongated pile caps that run the length of the north and south sides of the building. The slab on grade, apron slab, and buttress pile caps of the atrium are also included in this section. The pile caps were 25 MPa and the rafts slab was 35 MPa concrete, both were modeled as 30 MPa concrete of average fly ash content; the nearest IE alternative. The pile caps are supported by pre-cast concrete piles of varying depths, as noted in structural drawings S201 and S211.

### *Concrete Footings*

The thickening of the raft slab at columns was modeled as a footing in IE. While the slab thickened into a frustum-pyramidal shape (see Figure 3) IE only accepts rectangular footings thus an equivalent length and width were used to maintain the same volume at the maximum footing thickness. All footings were identical and were modeled as an equivalent strip footing of the same width.

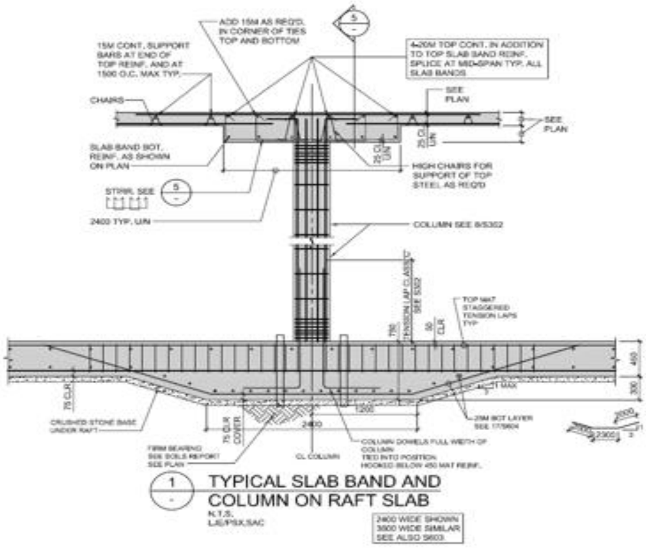


Figure 3 - Typical Thickening of Raft Slab at Column

### *Raft Slab/Slab on Grade*

The raft slab was modeled as a slab on grade in the IE. The IE is limited to slab thicknesses of 100 mm or 200 mm; where the raft slab or atrium slab on grade did not meet this parameter the area was adjusted to maintain the overall volume at the nearest thickness.

**Figure 4 - Parkade Raft Slab**

### *Pile Caps*

Pile caps were also modeled as footings. The total area of the north and south elongated pile caps were measured and modeled in IE as one continuous square footing. Where the caps exceeded the maximum footing thickness in IE of 500 mm they were modeled as a square footing with expanded area to have the same volume at 500 mm thickness.

### *Pilings*

The pre-cast and pre-stressed concrete pilings were also modeled as footings. Concrete strength was unavailable and 60 MPa was assumed. The pilings were cylinders with a diameter of 510 mm and were modeled as equivalent 452 mm x 452 mm square pilings. According to the geotechnical report, the piling depth varied from 0.14 m to 7.85 m; lacking more specific data on actual depths of installation for each piling an average depth of 4 m for each piling was assumed. All 479 pilings were modeled as a single strip footing with a width of 452 mm and equivalent length. Given the thickness constraint of the IE of 500 mm the pilings were modeled as if they were on their side; the depth becoming the length, and diameter becoming the width and thickness.

### *Stairs*

Stairs were modeled as footings of the same length, width, and throat. The landings on the atrium stairwells were considered as a part of the floor system. Where no information was available the stair length was assumed to be the slope of the stairwell length scaled from the structural drawings and the height of the floor traversed from the architectural drawings. For the purpose of modeling, the stairs were assumed to be of uniform thickness and the volume of the steps was neglected. The IE requires a minimum footing thickness of 190 mm and where the stairs had a throat of 175 mm they were modeled as being 190 mm thick; the extra volume is assumed to contribute to the neglected step volume.

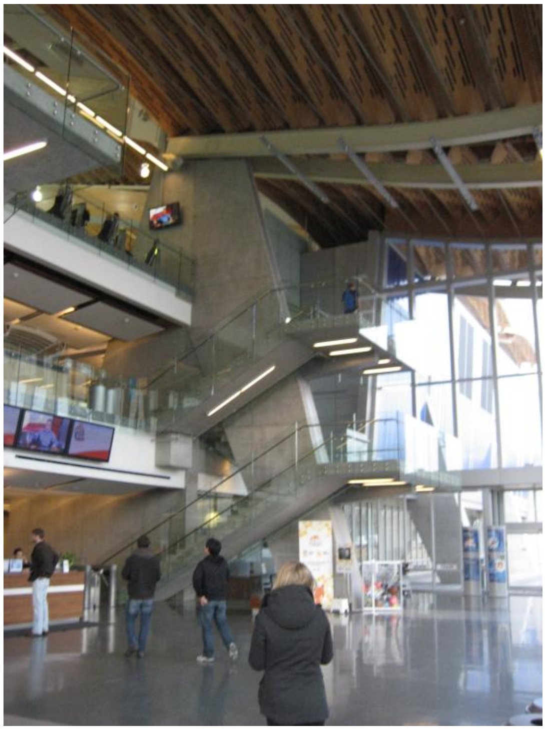


**Figure 5 - Atrium Stairwell Surrounding Roof Buttress**

## 3.2.3 Walls

The walls of the Richmond Oval were one of four types: cast in place (2.1.1-2.1.10), concrete block (2.2.1-2.2.5), curtain wall (2.3.1-2.3.8) or steel stud (2.4.1-2.4.26). Wall assemblies were modeled in IE as exterior or interior walls.

### ***Cast in Place Walls***

Cast in place walls were used as the East and West ground level exterior walls, as well as at necessary locations on the South side interior of the building on Level 1 and 2. Cast in place walls are modeled as load-bearing walls, and are primarily located around the stairwells, but they can also be found at various other locations on each floor. The length and width of the walls were measured in OST and input into IE with a thickness of either 200 or 300 mm. The walls that did not fit either of these widths were scaled so that their actual width was accounted for. The rebar in all cast in place walls was selected as #20 in IE because walls the closest to the actual rebar #4 gauge used in the walls. The average value of concrete flyash ( 9% ) was used in IE since a value was not specified in the general notes or wall plans. Concrete strength was required to be 25 MPa, so assumed as 30 MPa. All of these assumptions have been shown in Appendix A.

### ***Concrete Block Walls***

Concrete block walls are used mostly on Level 1, surrounding the washrooms and change-rooms and are specified as non-load bearing walls. Concrete blocks in the Impact Estimator are a standard size of 200 mm x 200 mm x 400 mm, as well as being hollow concrete. However, the actual walls used in the Oval are concrete masonry unit (CMU) walls that vary in height compared to a standard concrete block. In addition, the CMUs are not necessarily as hollow as a standard concrete block. However, it is not specified in the any of the architectural drawings provided to us, so an assumption of similar volume to a standard concrete block has been made. Due to the difficulty in accounting for differences in height and fill of the blocks, all CMU walls have been modeled as concrete block walls in IE. Interior concrete block walls that specified aluminum cladding had steel commercial cladding added to their envelope in IE. The door openings in the walls were either solid wood or hollow metal. Some doors have a small window, which was not modeled in the IE's inputs because doors with windows are unavailable.

### *Steel Stud*

The majority of the interior walls of the Oval are steel stud walls with varying envelope constituents and number of openings. Most walls had no information regarding stud weight or spacing, so the weight was assumed to be light (25 Ga), and the spacing assumed to be 400 o.c. unless otherwise specified. In some cases, the stud thickness was a value not offered in IE, so the length of the wall was changed in order to account for the difference in stud thicknesses. For walls specifying abuse resistant board, regular gypsum board was used instead. Information on wall insulation type was unavailable for most walls requiring insulation. One wall did specify the use of mineral wool insulation. Since mineral wool is not an option in the IE, and is similar to rockwool batt, this was used in IE for all walls requiring insulation. The exterior steel stud walls on the East and West faces of the Oval require an unspecified metal cladding, so commercial steel cladding was used as an input in IE. Another exterior steel stud wall on the East and West faces of the Oval require a polycarbonate cladding, which was modeled in the IE as a vinyl cladding since they are both types of plastic. For the interior steel stud walls that require type 'x' gypsum wall board, gypsum fire rated type x drywall was used as an input in the IE. The door openings in the interior walls are either solid wood or hollow steel.

### *Curtain Walls*

All curtain walls are exterior walls. The North and South sides as well as small sections of the West and East sides of the building are curtain wall (Figure 6). In the IE, the glass panels are assumed to be double glazed units of two 6 mm glazing panes with total thickness of 12 mm. The curtain wall glass on the Oval is assumed to be between 95-

100% viewable glazing. The glass on Level 2 of the South side of the building has a polycarbonate coating on it, giving it a bluish color. Since polycarbonate is not an option in the IE, vinyl cladding was used instead. No insulation was modeled to be in the spandrels because it was not specified in any of the documents.

**Figure 6 - Curtain Wall System**

## 3.2.4 Columns

The columns (3.1.1) are composed of concrete and steel. Beams were modeled in the floor section since they are slab bands integrated into the second-level floor slabs. All columns are assumed to be the same dimensions because the differences between each column type could not be modeled accurately in the IE. In addition, many of the building's peripheral columns did not have a standard span or bay size, making it difficult to model them individually.

The method used to measure column sizing was completely dependent upon the metrics built into the Impact Estimator. The IE calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. No beams were considered associated with the columns, so the total number of concrete columns were used with the total floor area to determine the appropriate bay size. Since most of the second and third floors are open, and the South section of the building has its load carried by buttresses, no columns were modeled for the second or third floors.

### ***Buttresses***

The input fields for Columns in the IE were limited to average spans and column widths. Therefore, since the Olympic Oval spans nearly one hundred meters and the buttresses supporting the roof and parts of the floors are up to 1.2 meters thick, the buttresses of the building were modeled as extra basic materials in OnScreen. Although the buttresses have a complicated geometry, a mean thickness was assumed based on a constant slope. The face area of the buttresses (see Figure 7) was determined and a thickness was specified to output a volume of the buttress. This volume was then used as an input for the Impact Estimator as concrete. Rebar was also input as an extra basic material and the volume of rebar in each buttress was determined to estimate the weight (tons of rebar) used in the construction. For this, a plan view of a cross section of the buttress was used to determine the area ratio of rebar to concrete, which was determined to be 3% (including vertical and horizontal rebar). This area ratio was assumed throughout the buttress and thus provided a volume of rebar per buttress, which was multiplied by the number of buttresses and the density of steel to determine the total weight of rebar used as an input to the Impact Estimator.

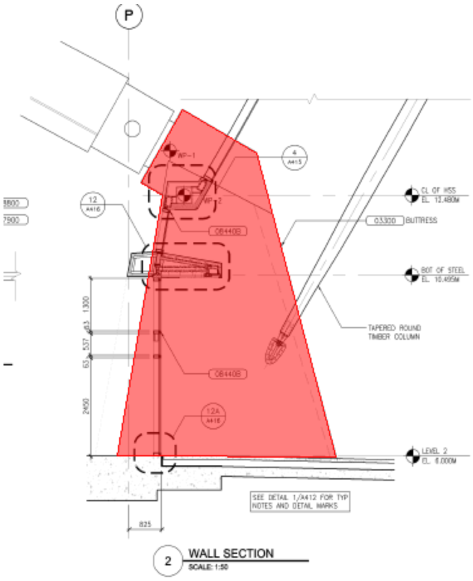


**Figure 7 – Sample Area Measurement for Buttress using OnScreen**

### 3.2.5 Floors and Beams

The floor system in the Richmond Oval was a complex slab-slab band system with concrete hollow core panels along the 2nd floor activity deck as detailed in structural drawings S224 to S238. The thickness of the floor slabs and slab bands varied drastically across the asymmetrical floor plan and the IE floor modeling algorithms; using only span, width, and live load as inputs, were determined to be inappropriate for the structure. Using On Screen Takeoff a total volume of concrete was determined for every slab and the average rebar content estimated as detailed in Appendix B. These were added as extra basic materials.

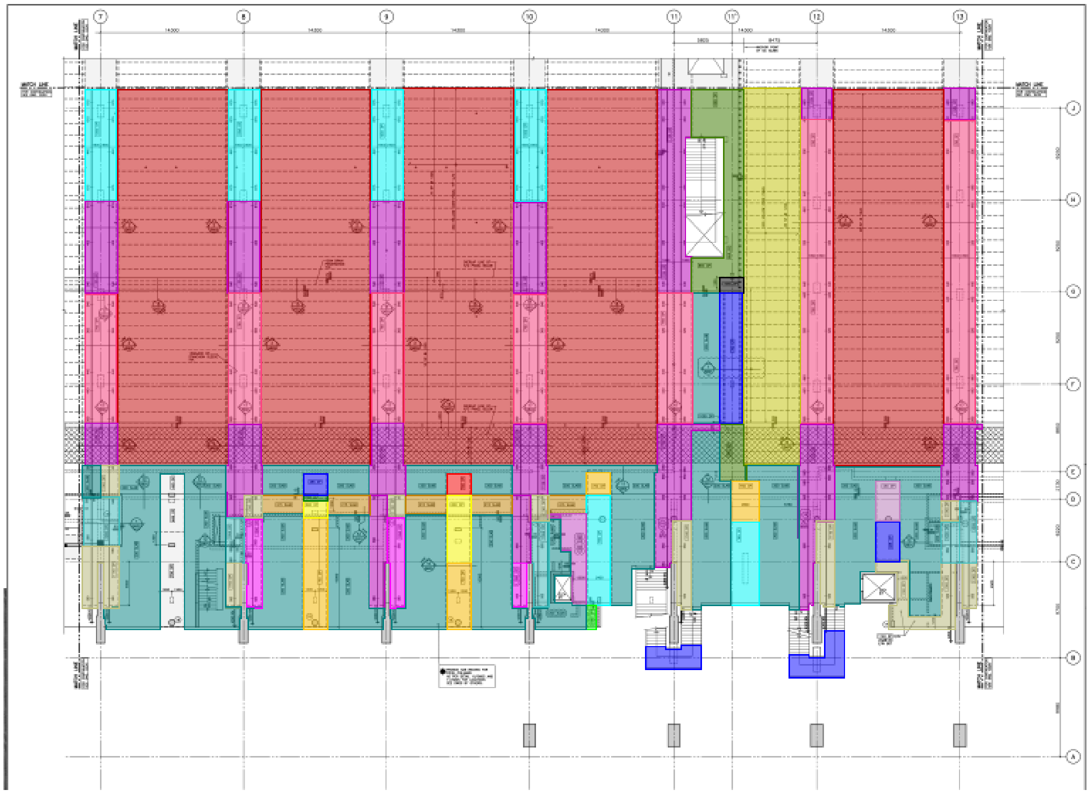


Figure 8 - OnScreen Take-off: Complexity of Second Floor Slab and Slab Bands

### *Suspended Concrete Slabs*

The suspended slabs on the 2nd floor activity deck were constructed of 30 MPa concrete and the 3rd floor mezzanine of 25 MPa concrete. Both were modeled as 30 MPa concrete with average flyash content, the nearest alternative available in the IE. A typical rebar reinforcement scheme was chosen to determine a mass of rebar per area of slab as detailed in Appendix B.

### *Slab Bands*

The suspended slabs and slab bands varied in depth throughout the structure and often the length of the beam. A typical beam that crosses the activity deck was chosen and scrutinized to determine a total rebar content within the length of the beam. This value was then used to determine an average mass of rebar per area of slab band as shown in Appendix B.

***Concrete Hollow Core Panels***

The spans between slab bands on the activity deck were filled with concrete hollow core panels (HCP). These panels were 350 mm thick with the exception of two narrow bands at a depth of 200 mm. The IE takes as inputs the span of the HCP bays, the width of the bays, and total number of bays. Given no other details, the bay size was scaled from the details and sections on structural drawings S600 to S608 to be 300 mm. No live load details were available; to account for the presumed high load of sports activities and the supported ice rink a live load of 4.8 kPa was assumed.

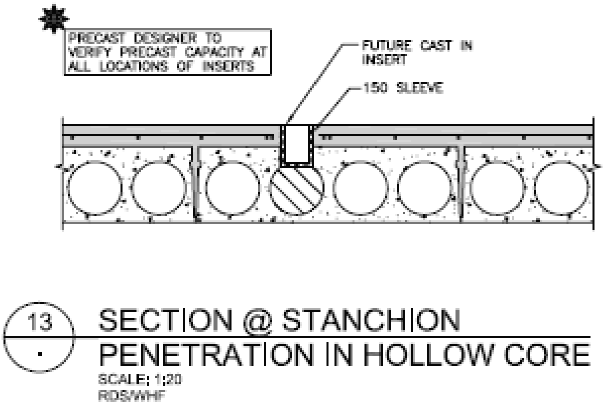


**Figure 9 - Example HCP detail**

## 3.2.6 Roofs

The roof of the Richmond Olympic Oval is a complicated, yet effective design that utilizes composite beams, insulation, and integrated sprinkler systems in an innovative fashion. Based on information gathered from the tour the group was provided, this roof creates one of the largest free-spanning areas in North America. Due to the limitations in the IE for inputting standard roof constructions for typical roof spans (up to a maximum of only 9.14 m), the roof was modeled using mainly Extra Basic Materials. Quantities were measured in OnScreen and weight, area, and volume of materials were further calculated in Excel to provide inputs for the Impact Estimator.

### *Composite Beams*

Composite beams that contain HVAC, sprinklers and lighting services span the roof, utilizing Glulam and structural steel in a V-formation (see Figure 10). These beams are attached to steel-reinforced concrete buttresses on the North and South side of the building.

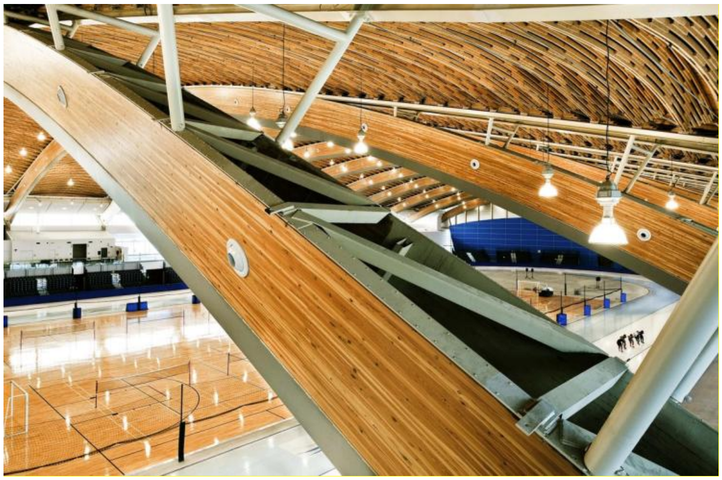


**Figure 10 - Composite V-Beam[2]**

To acquire quantities of materials used in the composite beams, several structural drawings were used in OnScreen to provide quantity takeoffs. Most of the materials were Hollow Structural Steel, Wide Flange Steel Sections, and Glulam Sections. A sample takeoff using the linear condition to determine the length of Wide Flange Steel Sections and beams used in the building is provided in Figure 11. The colored lines on the drawing indicate the conditions used. Section drawings of the beams were used to determine cross sectional areas and perimeter lengths, in conjunction to plan and elevation drawings that provided beam lengths and counts. The output tools in OnScreen were also utilized, with several of these parameters determined, to provide volumes and counts for use as inputs into the IE.

There were several limitations in determining the quantities of materials used in the beams and other support stemming from the beams (struts, braces, etc.). Due to the complexity of the roof, bolts and connecters were not quantified and only large structural members were included. To simplify the quantity takeoffs, where patterns of structural members were continuous, but with minimal changes in dimensions (ie. members with a few millimeters different thickness), a standard dimension was assumed for the pattern. In addition, to simplify the takeoff process, some conditions were set in plan mode assuming sloping out the plane was minimal. More information on these assumptions can be found in the Assumptions document in Appendix B.

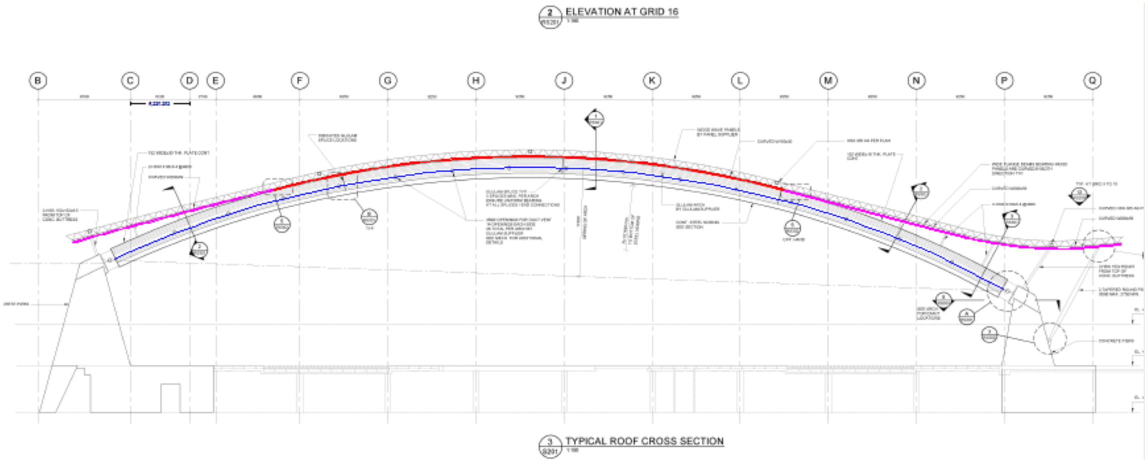


**Figure 11 - Roof: Linear Condition used in OnScreen**

### *WoodWave Panels*

Spanning the composite V-beams are approximately 450 WoodWave panels specially prefabricated by StructureCraft Builders in Delta, BC. This engineered wood product utilizes small dimension softwood lumber in a strand fashion to create a product that not only provides structural stability for the roofs but also acoustic attenuation for the building interior. The WoodWave panels are sheathed with two layers of plywood and are filled with mineral wool insulation to provide insulation for the building and for the water sprinkler systems enclosed. Figure 12 shows a schematic of the WoodWave panels.[3]

**Figure 12 - Woodwave Panels Installed Between Composite V-Beams[3]**

To determine the quantities of materials used in the WoodWave panels, information provided by the Canadian Wood Council (CWC) in a document titled "The Richmond Olympic Oval" was used.[3] Since the construction of the WoodWave panels was so complex and many different panel types were used in the roof, figures provided by the CWC for total softwood lumber and plywood used in the Richmond Olympic Oval roof were utilized as inputs into the IE. The quantity of insulation used within the panels was calculated based on a cross sectional area of insulation per panel, multiplied by the total number of panels used in the roof.

### *Roof Envelope*

The roof envelope of the Oval is a PVC membrane system built on 1/4'' DensDeck material. In most areas, four inches of isocyanurate boards are used for insulation on top of the plywood sheathing assembled onto the WoodWave panels and other areas of the roof. Since the IE has no input for DensDeck, the material was assumed to be Type X Fire Rated Gypsum board due to relatively similar properties. DensDeck. Isocyanurate boards were also not available as a material type in the IE, so extruded polystyrene insulation was assumed instead. To determine the weight of PVC used in the roof, a sample the IE file was created with PVC roofing. An area measuring 1 m x 1 m was used to determine the weight of PVC per meter squared of roofing (a 1 year building life expectancy was used for this to avoid double counting impacts in the IE). This ratio was consistent with other roof dimensions as well and was used to calculate the total weight of PVC used in the roof once the roof area was determined. To acquire the quantities of materials used in the roof envelope, the areas of the roof utilizing the different envelope types were measured in OnScreen in plan view (see Figure 13). Other assumptions made for the roof envelope can be found in section “5 Roof Envelope” of Appendix B.

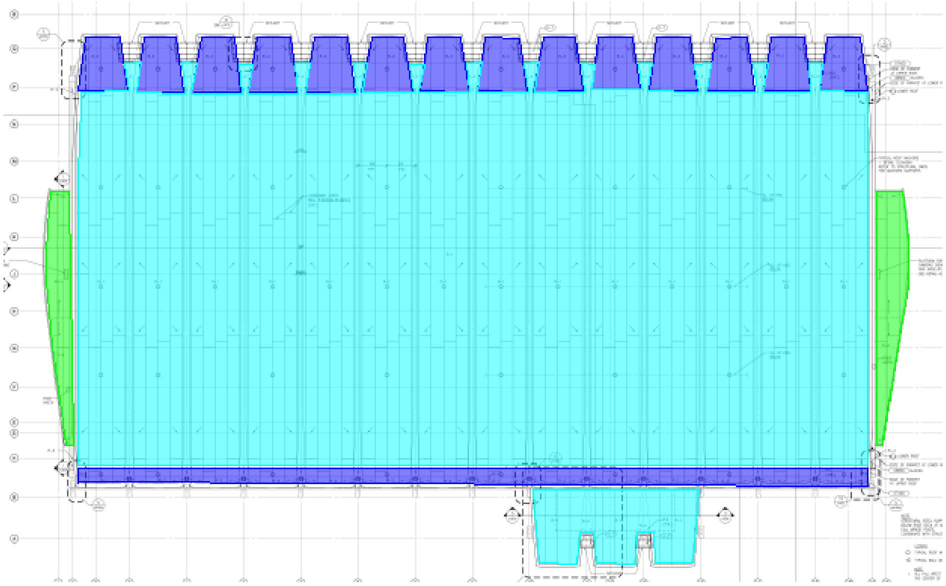


Figure 13 - Roof Envelope Area Measurements

# 4.0 SUMMARY MEASURES

This section provides a bill of materials (BoM) for all individual assembly groups in the building, as well as a total building BoM as generated after inputting the quantity takeoffs into the Athena Impact Estimator. In addition, tables and graphs of summary measures are provided to show the potential impacts each assembly group, and the entire building are expected to have on the environment.

## 4.1 Bill of Materials

After completing the building model and inputting all information about the assembly groups, the Impact Estimator generated a bill of materials for the manufacturing and construction of the Richmond Oval. The BoM shows the total quantities of construction materials used in the building. These bills are generated based on the takeoff inputs into the IE.

### 4.1.1 Earthworks

The only earthworks considered was the volume of preload material, thus there is only one material in the earthworks bill of materials: aggregate stone. Due to the need to pre-load the entire building footprint to a total fill of up to 8 m in height, this amounts to a large quantity of ballast as shown in Table 2.

**Table 2 - Bill of Materials for Earthworks**

| Material | Quantity | Unit |
|---|---|---|
| Ballast (aggregate stone) | 402659784.5 | kg |

### 4.1.2 Foundation

As noted in the assumptions, with the exception of the concrete pilings all the foundations were modeled as 30 MPa concrete, unsurprisingly this is the largest quantity on the bill of materials at 15,914 cubic meters. From the volume of concrete the IE estimated appropriate quantities of rebar and wire mesh reinforcement. the IE does not explicitly provide its modeling assumptions in this regard; thus, determining the accuracy of this estimate is difficult. The values are summarized in Table 3.

**Table 3 - Bill of Materials for Foundation**

| Material | Quantity | Unit |
|---|---|---|
| Concrete 30 MPa (flyash av) | 15991.5274 | m3 |
| Concrete 60 MPa (flyash av) | 411.0188 | m3 |
| Rebar, Rod, Light Sections | 22.5887 | Tonnes |
| Welded Wire Mesh / Ladder Wire | 44.248 | Tonnes |

### 4.1.3 Walls

Based on Table 4, concrete blocks are the largest quantity of material used in the construction of the walls. They are one of the main constituents of the interior walls on the second floor. The estimated quantity of blocks is 133,689 blocks. Many of the concrete block walls were not in fact concrete blocks, but blocks made of a mixture of concrete and gravel. The blocks were specified to be of differing heights and widths than a standard concrete block, but were modeled in the IE as a standard concrete block with a height and width of 200 mm. The actual heights ranged between 90 – 300 mm and the widths ranged between 90 – 290 mm. It is difficult to specify if these differences in dimension result in an under or overestimate of quantity. However, since most blocks seem to be approximately 200 mm in height but for the most part slightly less than 200 mm in width, this quantity is most likely a slight underestimate of the real quantity used.

**Table 4 - Bill of Materials for Walls**

| Material | Quantity | Unit |
|---|---|---|
| #15 Organic Felt | 11967.7384 | m2 |
| 5/8" Fire-Rated Type X Gypsum Board | 9440.1513 | m2 |
| 5/8" Regular Gypsum Board | 4513.4631 | m2 |
| 6 mil Polyethylene | 634.1462 | m2 |
| Aluminum | 91.3222 | Tonnes |
| Batt. Rockwool | 3264.3241 | m2 (25mm) |

| | | |
|---|---|---|
| Commercial(26 ga.) Steel Cladding | 4065.2753 | m2 |
| Concrete 30 MPa (flyash av) | 1651.3938 | m3 |
| Concrete Blocks | 133688.5874 | Blocks |
| EPDM membrane (black, 60 mil) | 6020.5254 | kg |
| Galvanized Sheet | 16.2036 | Tonnes |
| Galvanized Studs | 21.5283 | Tonnes |
| Glazing Panel | 694.7774 | Tonnes |
| Joint Compound | 13.926 | Tonnes |
| Mortar | 2549.529 | m3 |
| Nails | 1.0487 | Tonnes |
| Paper Tape | 0.1598 | Tonnes |
| Rebar, Rod, Light Sections | 1022.3853 | Tonnes |
| Screws Nuts & Bolts | 3.6675 | Tonnes |
| Small Dimension Softwood Lumber, kiln-dried | 2.4883 | m3 |
| Softwood Plywood | 82.1142 | m2 (9mm) |
| Solvent Based Alkyd Paint | 55.1239 | L |
| Vinyl Siding | 7835.828 | m2 |
| Water Based Latex Paint | 1694.354 | L |

### 4.1.4 Columns

The BoM of the columns indicate that there is a significant amount of both concrete and rebar used in their construction. Buttresses that support the roof of the structure and some of the floors on the south side of the building are included in columns because they have a similar purpose and composition. All columns are located within the first level of the building, and are assumed to be the same due to the input methods of the IE. For example, the way that rebar is tied together within a column varies between column type, but because the Impact Estimator determines the amount of rebar necessary by calculating the load requirement on a column, rebar configuration is not able to be specified.

**Table 5 - Bill of Materials for Columns**

| Material | Quantity | Unit |
|---|---|---|
| Concrete 30 MPa (flyash av) | 3240.7027 | m3 |
| Rebar, Rod, Light Sections | 1013.7633 | Tonnes |

### 4.1.5 Floors and Beams

Due to the complex nature of the floor and beam system, with the exception of the concrete hollow core panels, the floors and beams were all added as extra basic materials. The resulting materials are shown in Table 6. That the floors an beams were mostly modeled as pure materials and not assemblies is apparent in the quantity of welded wire mesh in the bill of materials; as this volume was estimated by the IE for only the hollow core panels. No wire mesh was specified in the structural drawings thus it was not estimated in the extra basic materials calculations; leading to a ratio of welded wire mesh to rebar rod sections much different than that found in the foundations bill of materials. Again, at 8,233 cubic meters, the volume of 30 MPa concrete is the most significant material.

**Table 6 - Bill of Materials for Floors and Beams**

| Material | Quantity | Unit |
|---|---:|---|
| Concrete 20 MPa (flyash av) | 597.683 | m3 |
| Concrete 30 MPa (flyash av) | 8232.5838 | m3 |
| Concrete 60 MPa (flyash av) | 1677.9672 | m3 |
| Rebar, Rod, Light Sections | 6912.3274 | Tonnes |
| Welded Wire Mesh / Ladder Wire | 17.4182 | Tonnes |

### 4.1.6 Roof

Since the roof of the Olympic Oval spans nearly 100 m, the area required for structural and building envelope systems is great. Table 7 provides the bill of materials for the roof. Some of the significant material quantities used in the structural components of the roof include hollow structural steel at 427.6 tonnes and 933 cubic meters of GluLam sections. These materials are found mainly in the fifteen composite V-beams that span the structure. A large quantity of plywood and small dimension lumber is also present in the structure of the roof, mainly due to the WoodWave Panels. In addition, since the WoodWave panels are filled with insulation, this results in the use of 264,010 square meters of 25 mm Rockwool Batt insulation. For the building envelope, PVC membrane at 114,338 kg and extruded polystyrene at 88,104 square meters (25 mm basis) constitute the largest material quantities. These materials are found above the plywood sheathing of the entire roof area. Since these materials were measured and calculated and input as Extra Basic Materials into the IE, the resulting BOM is as accurate as the approximations and assumptions made in modeling.

**Table 7 - Bill of Materials for Roof**

| Material | Quantity | Unit |
|---|---:|---|
| 1/2"  Fire-Rated Type X Gypsum Board | 11732.05 | m2 |
| 5/8"  Fire-Rated Type X Gypsum Board | 730.18 | m2 |
| Batt. Rockwool | 264009.9 | m2 (25mm) |
| Extruded Polystyrene | 88104.0405 | m2 (25mm) |
| Galvanized Sheet | 170.185 | Tonnes |
| GluLam Sections | 933.2047 | m3 |
| Hollow Structural Steel | 427.5956 | Tonnes |
| PVC membrane | 114337.9774 | kg |
| Small Dimension Softwood Lumber, kiln-dried | 2592 | m3 |
| Softwood Plywood | 125575.8338 | m2 (9mm) |
| Wide Flange Sections | 187.6994 | Tonnes |

### 4.1.7 Building Total

A complete bill of materials was generated after all the assemblies were combined in the Impact Estimator. The complete bill of materials for the building can be found in Table 8, followed by a discussion indicating the largest quantities used.

**Table 8 - Complete Bill of Materials for Richmond Oval**

| Material | Quantity | Unit |
|---|---|---|
| #15 Organic Felt | 2991.9346 | m2 |
| 1/2" Fire-Rated Type X Gypsum Board | 11732.05 | m2 |
| 5/8" Fire-Rated Type X Gypsum Board | 10170.3313 | m2 |
| 5/8" Regular Gypsum Board | 4513.4631 | m2 |
| 6 mil Polyethylene | 634.1462 | m2 |
| Aluminum | 88.0242 | Tonnes |
| Ballast (aggregate stone) | 402659784.5 | kg |
| Batt. Rockwool | 267274.2241 | m2 (25mm) |
| Commercial(26 ga.) Steel Cladding | 1195.6692 | m2 |
| Concrete 20 MPa (flyash av) | 597.683 | m3 |
| Concrete 30 MPa (flyash av) | 29116.2182 | m3 |
| Concrete 60 MPa (flyash av) | 2088.986 | m3 |
| Concrete Blocks | 133688.5874 | Blocks |
| EPDM membrane (black, 60 mil) | 1204.1051 | kg |
| Extruded Polystyrene | 88104.0405 | m2 (25mm) |
| Galvanized Sheet | 186.3886 | Tonnes |
| Galvanized Studs | 21.5283 | Tonnes |
| Glazing Panel | 247.5806 | Tonnes |
| GluLam Sections | 933.2047 | m3 |
| Hollow Structural Steel | 427.5956 | Tonnes |
| Joint Compound | 13.926 | Tonnes |
| Mortar | 2549.529 | m3 |
| Nails | 0.86 | Tonnes |
| Paper Tape | 0.1598 | Tonnes |
| PVC membrane | 114337.9774 | kg |
| Rebar, Rod, Light Sections | 8971.0647 | Tonnes |
| Screws Nuts & Bolts | 3.6675 | Tonnes |
| Small Dimension Softwood Lumber, kiln-dried | 2594.4883 | m3 |
| Softwood Plywood | 125657.948 | m2 (9mm) |
| Solvent Based Alkyd Paint | 55.1239 | L |
| Vinyl Siding | 2886.884 | m2 |
| Water Based Latex Paint | 151.0277 | L |
| Welded Wire Mesh / Ladder Wire | 61.6661 | Tonnes |

The values generated by the Athena Impact Estimator in the bill of materials are material quantities that were used to construct the building. Some quantities are adjusted in the IE to take into account the effect of scrap or wasted material. Therefore, some materials, like wood, will generate a larger quantity in the bill of materials than were input into the Impact Estimator. It is difficult to identify the largest material quantities in the building as the bill of materials presents varying units of measure. However, by considering the assemblies that certain materials are attributed to and contrasting similar material types it is possible to identify some of the largest material quantities resulting from the bill of materials. Based on Table 8, the five largest material quantities selected include:

1. 30 MPa Concrete (average flyash)
    - Used throughout the building: concrete footings, buttresses, floor slabs and columns

2. Ballast (aggregate stone)
    - Used in the earthworks stage of the building to compact the soil prior to construction of the building

3. Softwood Lumber
    - Used in the approximately 450 WoodWave panels that span the composite V-beams of the roof

4. Rebar, Rod and Light Sections
    - Used as reinforcement for concrete throughout the building

5. Rockwool Batt Insulation
    - Used in each WoodWave panel to provide insulation for the building and for the piping system within the panels

## 4.2 Impact Assessment

After providing a bill of materials based on the inputs to the IE, the program utilizes the Athena Life Cycle Inventory Database to generate a cradle-to-grave profile for the building. These are presented as “Summary Measure” tables. These summary measures display quantitative environmental impacts that can be attributed to a specific assembly group, or the total building at different life cycle stages. For this study, only the manufacturing and construction stage of the building is considered, which are further broken down into materials and transportation segments. The Impact Estimator utilizes characterization factors to attribute emissions to 8 impact categories. These categories include like global warming potential, weighted resource use, and acidification potential. The summary measures are presented by impact category and assembly group in this section.

### 4.2.1 Fossil Fuel Consumption

Energy consumption includes both direct and indirect energy that is used in the manufacture and transport of building materials. The manufacturing process includes the energy required to transport and use the raw materials in the building construction. In addition, the Impact Estimator takes into account the indirect energy use associated with processing, transporting, converting and delivering fuel and energy. Fossil fuel consumption is expressed in MJ.

**Table 9 - Impacts by Assembly Group: Fossil Fuel Consumption**

| Life Cycle Stage | Process | Fossil Fuel Consumption (GJ) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 250,138 | 27,255 | 33,770 | 20,722 | 45,008 | 123,382 |
| | Transportation | 6,842 | 1,785 | 728 | 582 | 1019 | 2,728 |
| Construction | Material | 3,239 | 2,555 | 536 | 0 | 0 | 148 |
| | Transportation | 9,007 | 2,692 | 1,240 | 594 | 2,277 | 2,204 |
| | Earthworks | 49,950 | - | - | - | - | - |

## 4.2.2 Global Warming Potential

Global Warming Potential is expressed in terms of $CO_2$ equivalence by weight. $CO_2$ is chosen as a category indicator because it is commonly recognized as a greenhouse gas. Other greenhouse gases are referred to on a scale of their "$CO_2$ equivalence" (a characterization factor) that accounts for the difference between a substance's contribution to global warming and that of $CO_2$. The sources of greenhouse gases include energy production by combustion and processing of raw resources such as concrete.[1] Based on the results in Table 10, floors and beams account for the largest impact, follows by foundations. This is due to the energy and material intensive process of creating concrete for floors and beams, and foundations. It is also evident that the majority of impacts result from the material manufacturing of these products.

**Table 10 - Impacts by Assembly Group: Global Warming Potential**

| Life Cycle Stage | Process | Global Warming Potential (kg $CO_2$ equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 18,048,929 | 4,617,313 | 3,016,784 | 1,474,895 | 2,691,531 | 6,869,770 |
| | Transportation | 512,299 | 134,327 | 55,390 | 43,797 | 77,425 | 205,348 |
| Construction | Material | 220,538 | 172,694 | 37,443 | 0 | 0 | 10,401 |
| | Transportation | 558,153 | 198,883 | 89,805 | 44,444 | 123,952 | 163,954 |
| | Earthworks | 3,665,078 | - | - | - | - | - |

## 4.2.3 Acidification Potential

Acidification is a regional concern, which has the potential to impact human health if $NO_x$ or $SO_2$ reach high concentrations.[1] It is expressed as a hydrogen ion equivalency based on a substances potential to produce hydrogen ion. Acidification potential is once again mainly attributed to the material manufacturing of the foundations and floors and beams of the Olympic Oval as seen in Table 11.

Table 11 - Impacts by Assembly Group: Acidification Potential

| Life Cycle Stage | Process | Acidification Potential (moles of H+ equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 8,766,891 | 1,843,112 | 2,034,884 | 610,105 | 1,797,641 | 2,886,670 |
| | Transportation | 196,777 | 57,331 | 21,802 | 16,933 | 26,867 | 75,542 |
| Construction | Material | 204,568 | 89,857 | 18,896 | 0 | 0 | 95,815 |
| | Transportation | 189,927 | 63,411 | 29,115 | 14,017 | 51,237 | 51,980 |
| | Earthworks | 1,052,186 | - | - | - | - | - |

## 4.2.4 Eutrophication Potential

Eutrophication is the addition, or 'fertilization' of nutrients (mainly Nitrogen and Phosphorus) to an aquatic system. The addition of previously growth-limiting nutrients can result in excessive growth of algae or other photosynthetic plants. Due to oxygen depletion, aquatic life such as fish may suffer or die. Eutrophication potential is expressed in terms of mass equivalence of nitrogen.[1] The impacts of each assembly group for this category are displayed in Table 12.

Table 12 - Impacts by Assembly Group: Eutrophication Potential

| Life Cycle Stage | Process | Eutrophication Potential (kg N equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 16,777 | 1,189 | 2,119 | 1,602 | 1,803 | 10,169 |
| | Transportation | 206 | 60 | 23 | 18 | 28 | 79 |
| Construction | Material | 209 | 85 | 19 | 0 | 0 | 105 |
| | Transportation | 198 | 66 | 30 | 15 | 54 | 54 |
| | Earthworks | 969 | - | - | - | - | - |

## 4.2.5 Ozone Depletion Potential

Ozone depletion has been a global concern in the past and accounts for impacts related to the reduction of the protective ozone layer within the stratosphere caused by emissions of ozone depleting substances. Ozone depletion potential is expressed relative to CFC-11 mass equivalence. [1] The largest quantity of CFC-11 equivalence is 0.0093 kg, attributed to the material manufacturing for the foundations of the Olympic Oval.

**Table 13 - Impacts by Assembly Group: Ozone Depletion Potential**

| Life Cycle Stage | Process | Ozone Depletion Potential (kg CFC-11 equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 1.96E-02 | 9.30E-03 | 5.55E-03 | 0.00E+00 | 4.77E-03 | 0.00E+00 |
| | Transportation | 1.12E-05 | 5.65E-06 | 2.31E-06 | 0.00E+00 | 3.20E-06 | 0.00E+00 |
| Construction | Material | 3.24E-10 | 0.00E+00 | 3.24E-10 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| | Transportation | 1.69E-05 | 8.15E-06 | 3.68E-06 | 0.00E+00 | 5.12E-06 | 0.00E+00 |
| | Earthworks | 1.50E-04 | - | - | - | - | - |

### 4.2.6 Smog Potential

Smog potential is expressed in units of kilograms NO$_x$ equivalent, and is a measure of photochemical ozone depletion potential. Under certain climatic conditions, emissions from industry and transportation becoming trapped at ground level, resulting in nitrogen oxides reacting with volatile organic compounds (VOCs) in the presence of sunlight. These reactions are what create photochemical smog. [1] Although foundations, floors and beams account for the majority of this impact, the roof of the Olympic Oval also shows a high relative impact (see Table 14).

**Table 14 - Impacts by Assembly Group: Smog Potential**

| Life Cycle Stage | Process | Smog Potential (kg No$_x$ equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 88,932 | 24,609 | 15,669 | 6,117 | 25,852 | 24,468 |
| | Transportation | 4,499 | 1,325 | 500 | 387 | 607 | 1,719 |
| Construction | Material | 5,379 | 2,132 | 490 | 0 | 0 | 2,758 |
| | Transportation | 4,272 | 1,417 | 652 | 313 | 1,172 | 1,161 |
| | Earthworks | 20,845 | - | - | - | - | - |

### 4.2.7 Human Health Respiratory Effects Potential

Human health can be severely impacted by particulates in the air from an activity such as diesel fuel combustion. These particulates are inhaled, and result in respiratory problems such as asthma, bronchitis and acute pulmonary disease. The Impact Estimator uses TRACIs "Human Health Particulates from Mobile Sources" characterization factor to account for the differences in mobility of different particle sizes. This allows for a single particle size equivalent for comparison: PM2.5. [1] This impact category is present in Table 15 for all the assembly groups.

**Table 15 - Impacts by Assembly Group: Human Health Respiratory Effects Potential**

| Life Cycle Stage | Process | H H Respiratory Effects Potential (kg PM2.5 equivalent) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 65,592 | 12,633 | 18,422 | 3,680 | 15,806 | 16,322 |
| | Transportation | 238 | 70 | 26 | 21 | 32 | 91 |
| Construction | Material | 238 | 97 | 21 | 0 | 0 | 119 |
| | Transportation | 229 | 76 | 35 | 17 | 62 | 62 |
| | Earthworks | 634,247 | - | - | - | - | - |

## 4.2.8 Weighted Resource Use

Weighted resource use refers to the "ecologically weighted mass" of resource use. It can be thought of as the sum of the weighted resource requirements for all the products used in each step of the design, where the weights reflect the comparison between different materials producing different relative effects of resource extraction. Most resources, including fossil fuels, are given a weight of 1. However, some materials have larger impacts in extraction, such as wood fibers and coal. The unit of weighted resource use is expressed in tons. [1] As seen in Table 16, the manufacturing of materials for foundations floors and beams contribute to the highest weighted resource use among the assembly groups.

**Table 16 - Impacts by Assembly Group: Weighted Resource Use**

| Life Cycle Stage | Process | Weighted Resource Use (Tonnes) | Assembly Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foundations | Walls | Columns | Roofs | Floors & beams |
| Manufacturing | Material | 112960 | 43198 | 11049 | 9908 | 11422 | 37383 |
| | Transportation | 196 | 56 | 21 | 17 | 28 | 74 |
| Construction | Material | 75 | 59 | 12 | 0 | 0 | 3 |
| | Transportation | 212 | 63 | 29 | 14 | 53 | 52 |
| | Earthworks | 409877 | - | - | - | - | - |

## 4.2.9 Summary Measures by Life Cycle Stage

It is important to contrast environmental impacts resulting from the different life cycle stages of the building. Environmental impacts for the total building are presented in Table 17 for the manufacturing and construction stage of the Olympic Oval.

**Table 17 - Total Building Impacts by Life Cycle Stage**

| | Manufacturing | | | Construction | | | Total Effects |
|---|---|---|---|---|---|---|---|
| | Material | Transportation | **Total** | Material | Transportation | **Total** | |
| Fossil Fuel Consumption (MJ) | 2.63e+08 | 1.61e+07 | **2.79e+08** | 3.24e+06 | 3.72e+07 | **4.05e+07** | 3.20E+08 |
| Weighted Resource Use (kg) | 5.22e+08 | 4.14e+05 | **5.22e+08** | 7.51e+04 | 8.77e+05 | **9.52e+05** | 5.23E+08 |
| Global Warming Potential (kg CO2 eq) | 1.95e+07 | 1.21e+06 | **2.07e+07** | 2.21e+05 | 2.73e+06 | **2.95e+06** | 2.37E+07 |
| Acidification Potential (moles of H+ eq) | 9.34e+06 | 4.17e+05 | **9.76e+06** | 2.05e+05 | 8.76e+05 | **1.08e+06** | 1.08E+07 |
| HH Respiratory Effects Potential (kg PM2.5 eq) | 7.00e+05 | 5.03e+02 | **7.01e+05** | 2.38e+02 | 1.05e+03 | **1.29e+03** | 7.02E+05 |
| Eutrophication Potential (kg N eq) | 1.69e+04 | 4.34e+02 | **1.74e+04** | 2.09e+02 | 9.08e+02 | **1.12e+03** | 1.85E+04 |
| Ozone Depletion Potential (kg CFC-11 eq) | 2.75e-02 | 4.99e-05 | **2.76e-02** | 3.24e-10 | 1.12e-04 | **1.12e-04** | 2.77E-02 |
| Smog Potential (kg NOx eq) | 9.78e+04 | 9.41e+03 | **1.07e+05** | 5.38e+03 | 1.96e+04 | **2.50e+04** | 1.32E+05 |

It is evident that a large proportion of the environmental impacts can be attributed to the material manufacturing of the building. A graphical representation is provided in Figure 14, which displays the fractions of impacts attributed to the various life cycle stages of the Olympic Oval. For all the impact categories, the predominant source of impacts is from the material manufacturing of the building (~90%). This is intuitive as the material manufacture encompasses the extraction and manufacturing of all the individual materials within the building. The second largest contributor occurs in the transportation segment of construction (~6.5%). During this phase, the materials are brought on site from the manufacturing locations or other sources. These impacts are a result of the emissions created during transportation by the burning of fossil fuels. The third highest contributor is transportation during the manufacturing stage (~3.0%) and finally, the materials segment of construction phase (~1.1%).

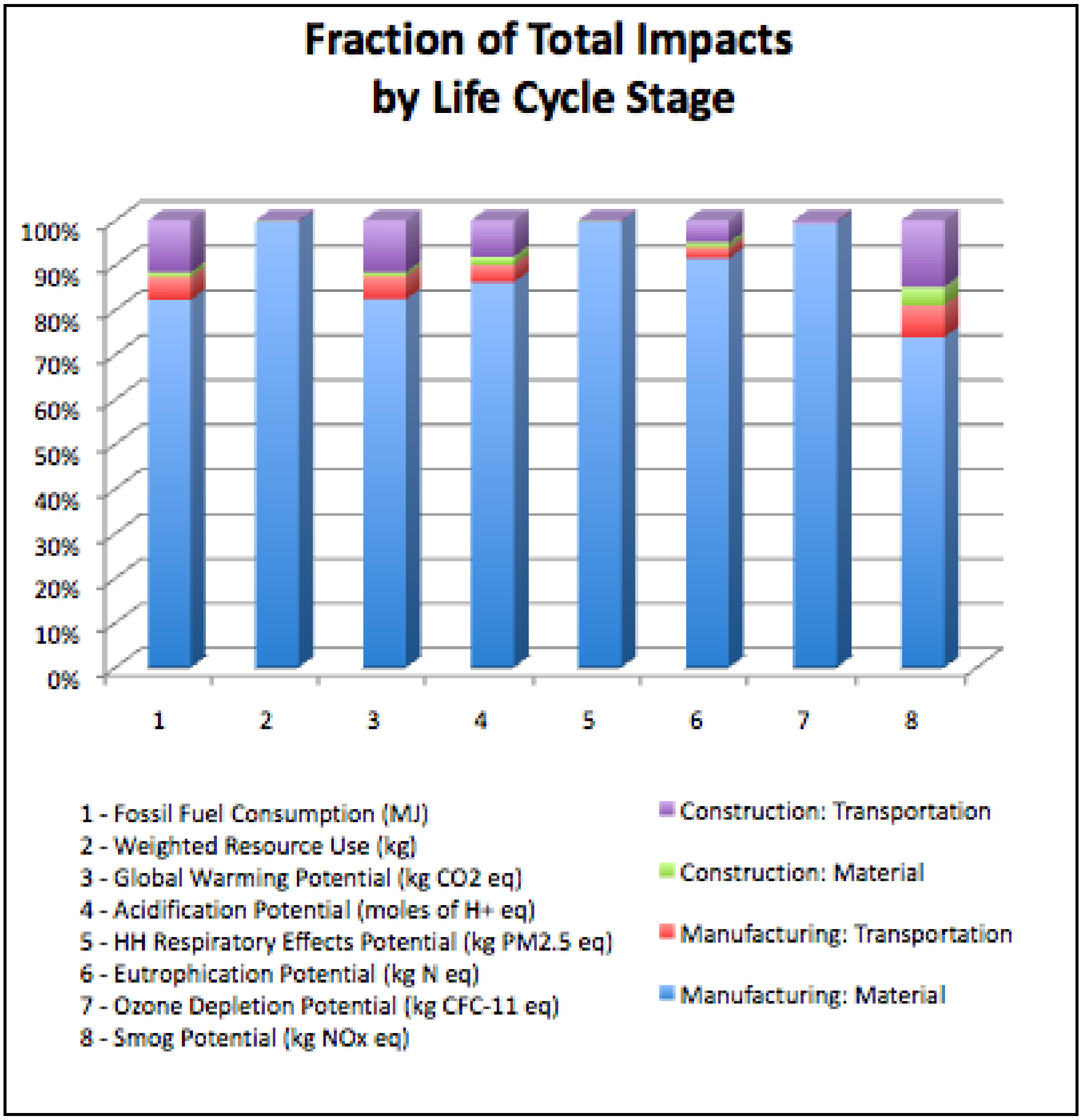


**Figure 14 - Fraction of Total Impacts by Life Cycle Stage**

## 4.3 Sources of Uncertainty

Uncertainty is inherent within any LCA study. Equally as important as attempting to minimize uncertainties, an understanding of what uncertainties and assumptions are present and why aids in interpreting results of an LCA. Since elimination of uncertainty is impossible, a clear statement of assumptions made and how and where they introduce uncertainty in results is necessary to facilitate greater understanding. During the impact assessment phase of an LCA, uncertainty can arise as a consequence of the following: insufficient or inaccurate data, model uncertainty, temporal variability, and spatial variability.

Data uncertainty can arise from the characterization of emissions due to the dynamic nature of various impacts. Impact categories can be affected by factors such as the life-span of compounds or substances, the location and climate of the release site and the ability for compounds to travel in different mediums such as air, water or land. Uncertainties in the characterization of the emissions introduce uncertainty in the LCA.

Model uncertainty is present because characterization factors are important when considering the limitations posed on the model itself. A select few environmental impact potentials are chosen as indicators of how a material, building, etc. may affect the environment, as stated in the goal and scope. Therefore, this LCA is not a complete assessment of all potential issues. In addition, qualitative factors that are difficult to value, such as politics dictating design elements, economics and aesthetics of the Richmond Oval have not been considered in this study.

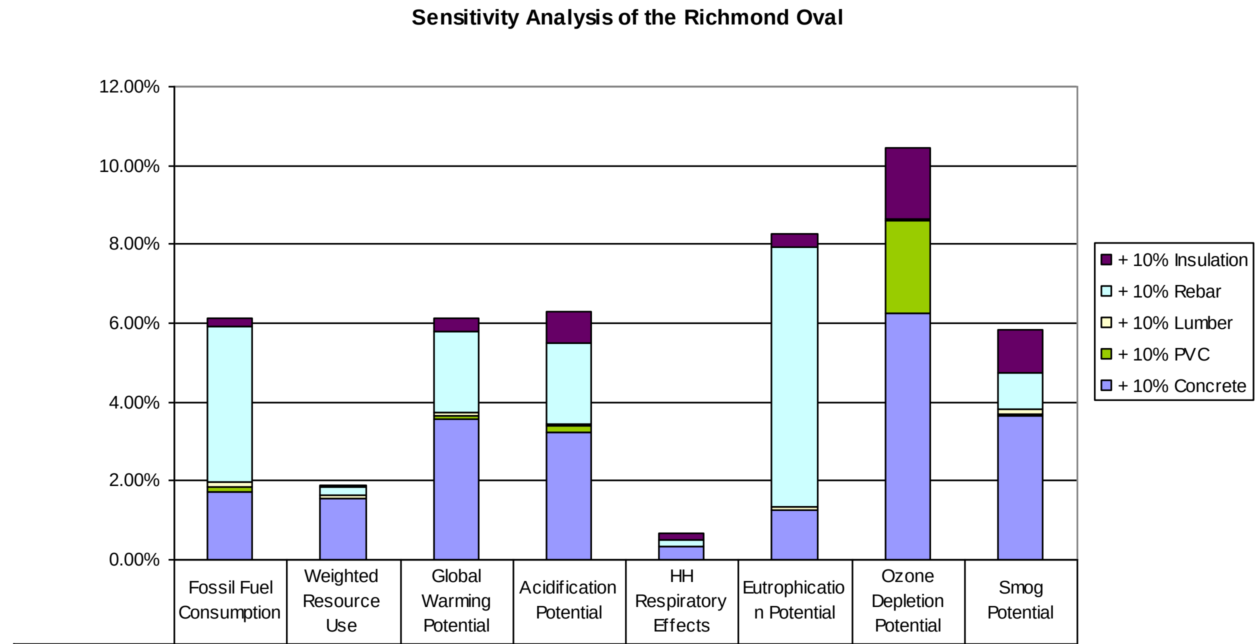
Temporal variability contributes to uncertainty within an LCA because the impacts and interpretations of results are highly variable in time. These are very important factors when it comes to determining the meaning and relation of results to the real world. For instance, ozone potential may not have been considered an impact category before the ozone holes were discovered at the earth's poles in the 1980s. Varying rates of decomposition of chemicals, as well as varying release concentration of chemicals during the lifetime of the building, can affect the impact category results; since this LCA only considers an instant in time.

Spatial variability is also an important consideration that can lead to uncertainty. The sensitivity of specific locations to various impact categories may be different. Some impact categories are considered on a global scale, and some are very localized. The effects of certain impact categories may also depend on the presence of a receptor. Eutrophication potential may not be accurate if there are no water bodies in the surrounding area to pollute. Also, reactions of emission constituents with other compounds or substances after release are not taken into account, although these processes may be significant.

An additional uncertainty in the model is differences in human exposure patterns. It is difficult to define responses to exposure since these can be affected by differences in individuals and groups of individuals within different geographic locations. Also the intensity and duration of exposure can elicit extremely different responses. Therefore, the severity of impacts in these categories are difficult to determine and can produce uncertainty for the model.

## 4.4 Sensitivity Analysis

It is important to emphasize that the results of the Impact Estimator are best estimates based on the information available and the experience of the assessors at the time of compilation of the report. There is a lot of inherent uncertainty and assumptions when modeling a building, especially one such as the Richmond Oval, which has been uniquely engineered and not simply designed to code. The sensitivity analysis is done on five material quantities to better comprehend the effects that different materials have on the overall building's environmental impacts. Sensitivity analyses are of a high significance during the design phase of a building, when it is early enough for decisions to be made regarding material quantities and types. For the sensitivity analysis on the Richmond Oval, the following materials were chosen: 30 MPa average flyash concrete, softwood lumber, rebar rod light sections, rockwool batt insulation and PVC membrane. Figure 15 illustrates the results, which will be discussed in detail below. Concrete, PVC, and rebar consistently generate the highest change in the impact categories.



Sensitivity Analysis of the Richmond Oval

|  | Fossil Fuel Consumption | Weighted Resource Use | Global Warming Potential | Acidification Potential | HH Respiratory Effects | Eutrophication Potential | Ozone Depletion Potential | Smog Potential |
|---|---|---|---|---|---|---|---|---|
| ■ + 10% Insulation | 0.20% | 0.03% | 0.33% | 0.82% | 0.18% | 0.37% | 1.81% | 1.10% |
| □ + 10% Rebar | 3.97% | 0.24% | 2.04% | 2.03% | 0.15% | 6.55% | 0.02% | 0.90% |
| □ + 10% Lumber | 0.09% | 0.08% | 0.08% | 0.08% | 0.01% | 0.08% | 0.00% | 0.14% |
| ■ + 10% PVC | 0.13% | 0.00% | 0.08% | 0.13% | 0.01% | 0.03% | 2.36% | 0.04% |
| ■ + 10% Concrete | 1.74% | 1.54% | 3.58% | 3.24% | 0.34% | 1.25% | 6.26% | 3.64% |

**Figure 15 - Effects of a 10% increase in various materials on over-all impacts**

### 4.4.1 Fossil Fuel Consumption

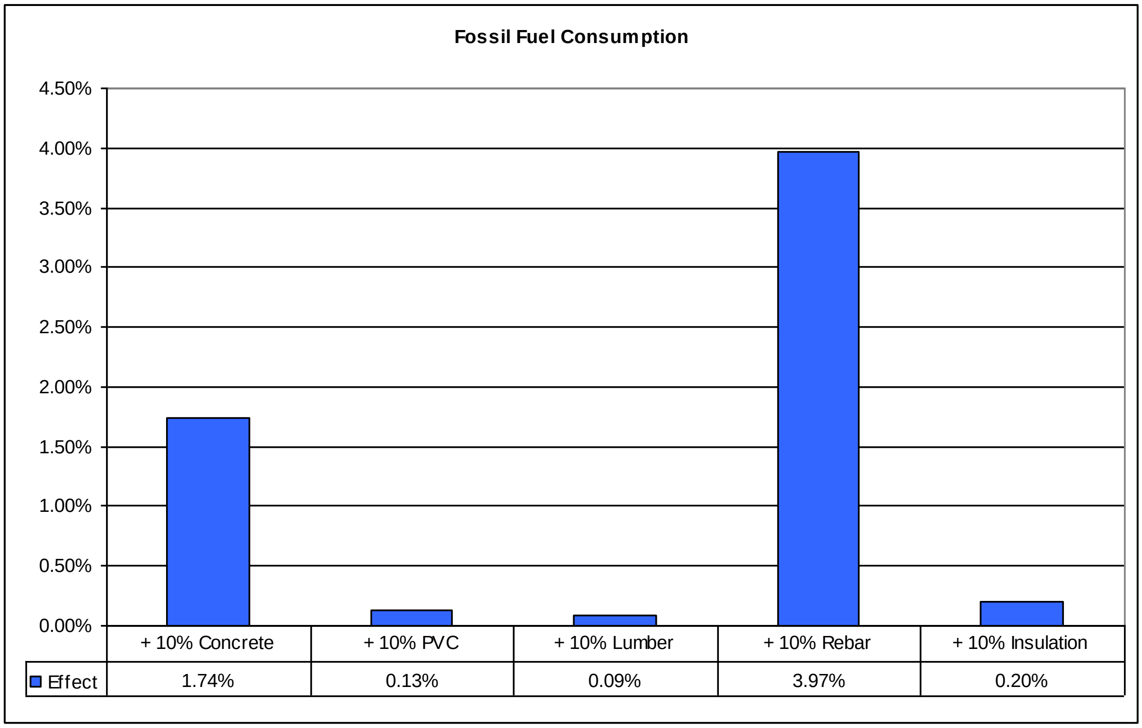


**Figure 16 - Sensitivity analysis of fossil fuel consumption**

All materials require transportation and thus involve the consumption of fossil fuels from resource extraction, to manufacture, to delivery. As shown in Figure 16, of these, an increase in rebar has a significantly higher impact at 3.79% than then next most significant materials; concrete and insulation. The impact of PVC and lumber is minimal.

### 4.4.2 Weighted Resource Use

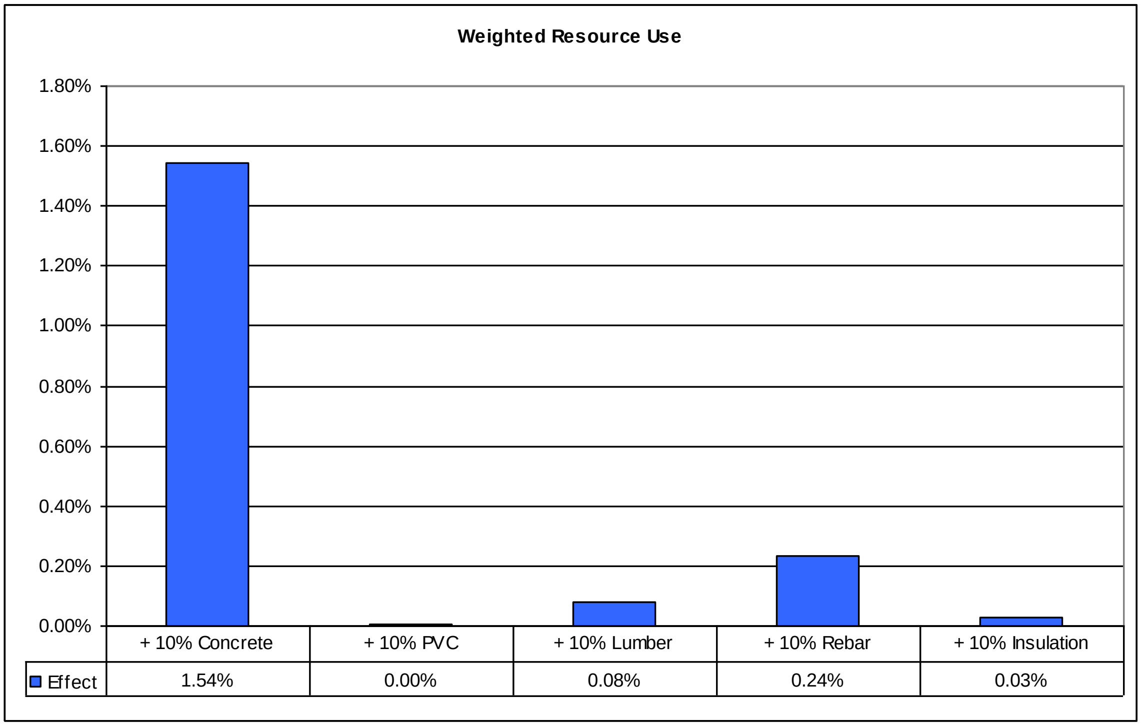


**Figure 17 - Sensitivity analysis of weighted resource use**

Figure 17 shows the impacts of a 10% increase in materials on weighted resource use. This category considers the impact of resource extraction, and is most heavily influenced by an increase in concrete. This can be attributed to the large amount of raw resources required for the manufacture of concrete: aggregate, sand, cement, additives, etc.

## 4.4.3 Global Warming Potential

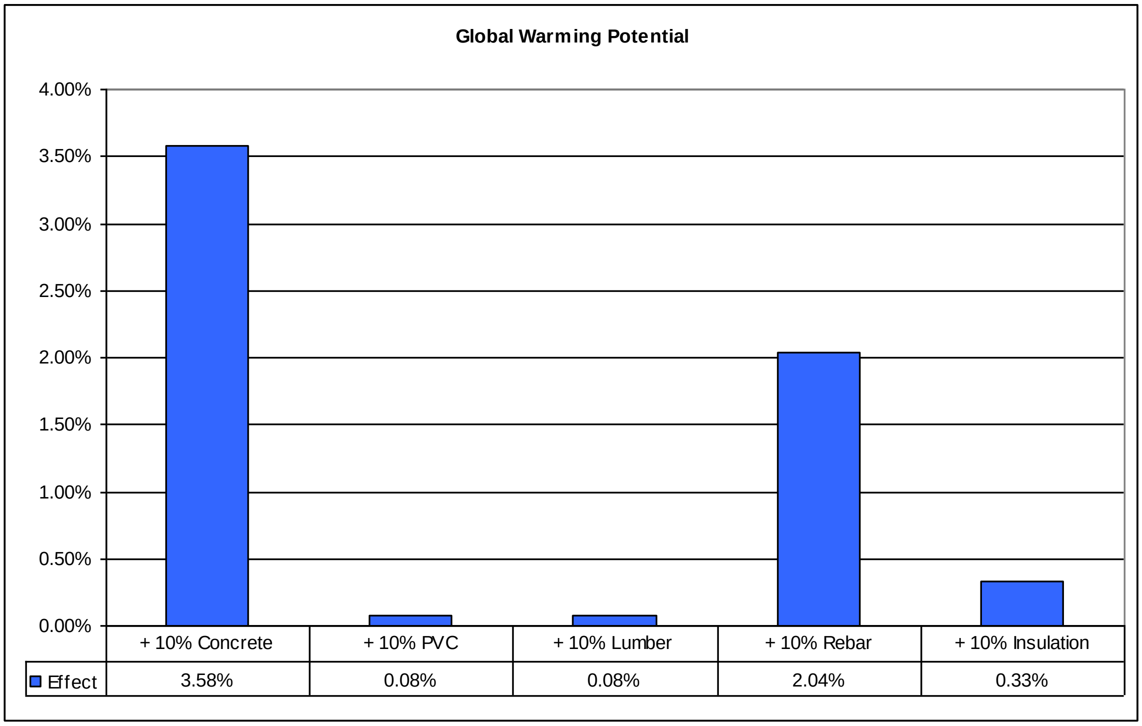


**Figure 18 - Sensitivity analysis of global warming potential**

With respect to global warming potential, an increase in concrete is again the most significant contributor as illustrated in Figure 18. The manufacture of Portland cement creates a significant amount of carbon dioxide from the kiln firing process, explaining the high impact of concrete on this category. Rebar is also a significant contributor, due to the energy intensive smelter required in its manufacture. Many steel plants run off coal power plants or other polluting energy sources. Again lumber and PVC create minimal change. It is also interesting to note that use of lumber can act to sequester carbon, as it prevents the wood from decomposing in the wild, producing methane – a compound that carries 23 times the global warming potential of carbon dioxide by mass.

### 4.4.4 Acidification Potential

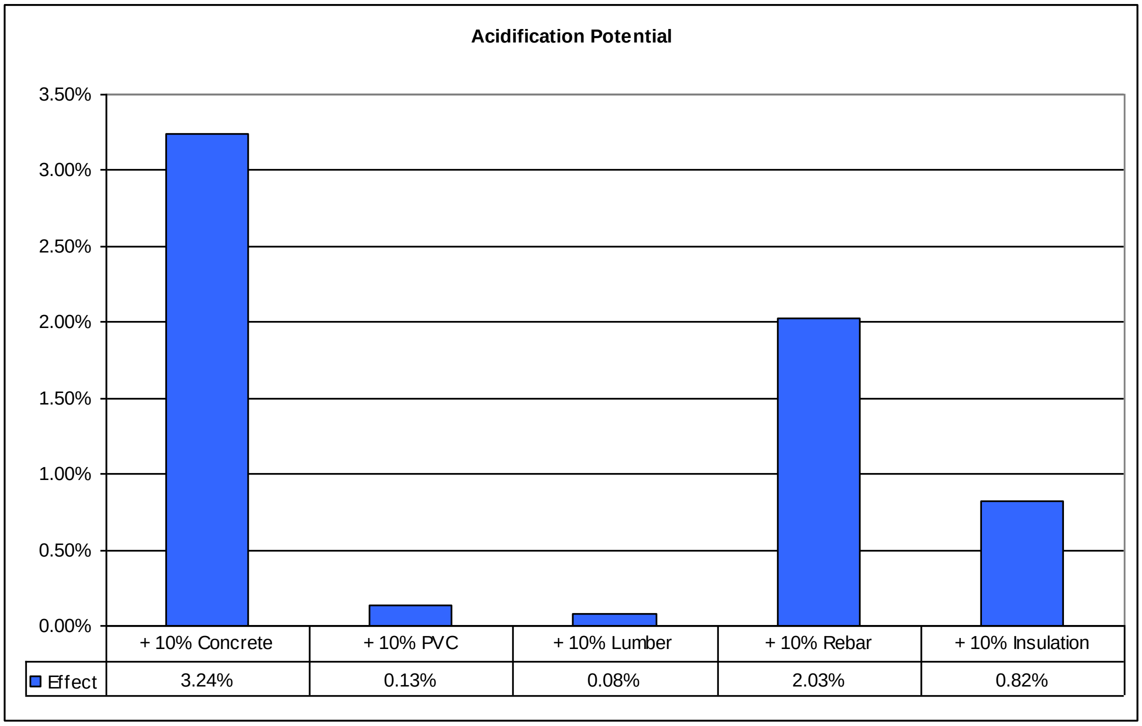


**Figure 19 - Sensitivity analysis of acidification potential**

As shown in Figure 19 all the materials considered, with the exception of lumber and PVC, have a significant impact on the acid rain potential. The reasons for their impacts is closely tied to the emissions in their manufacture processes as noted in the section on their global warming potential. Again the impact of concrete at 3.24% is significantly higher than that of the next two most influential materials (rebar and insulation at 2.03% and 0.82% respectively).

### 4.4.5 HH Respiratory Effects

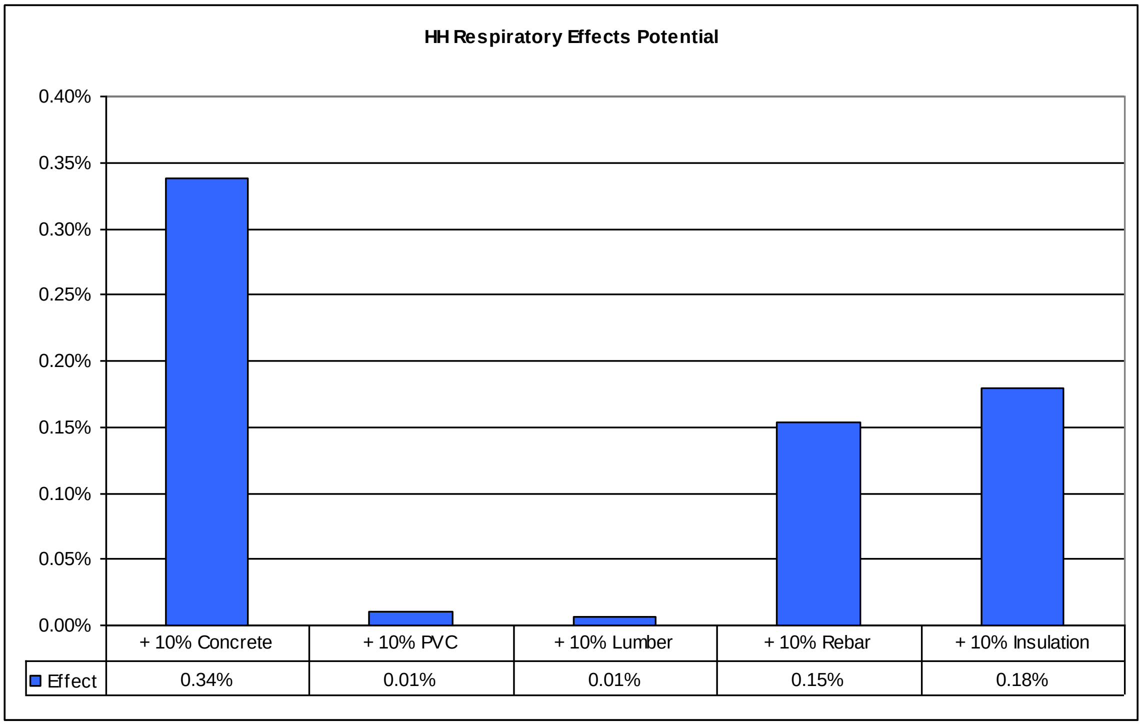


Figure 20: - Sensitivity analysis of HH respiratory effects potential

The abilities of all materials to create a change on the human health respiratory effects potential are actually quite low; with the effects of the largest offender (again concrete) at 0.34% not even causing a half of a percent change. Illustrated in Figure 20, the emission of particulate matter is most significant for concrete, although it is likely this is more due to the larger amount of concrete compared to the other materials considered than any inherent property of concrete.

## 4.4.6 Eutrophication Potential

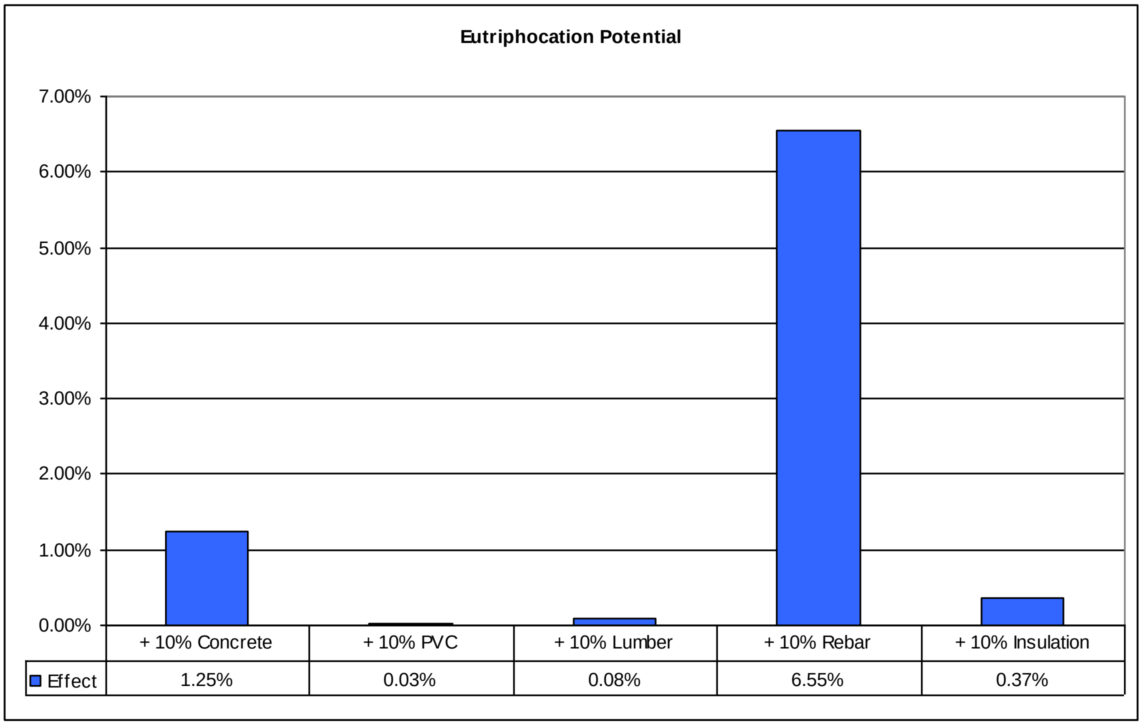


**Figure 21 - Sensitivity analysis of eutriphocation potential**

As Figure 21 demonstrates, an increase in rebar has the greatest impact on eutriphocation potential at 6.55%. Concrete is also a significant impact at 1.25%, however the other materials create minimal change in this category.

### 4.4.7 Ozone Depletion Potential

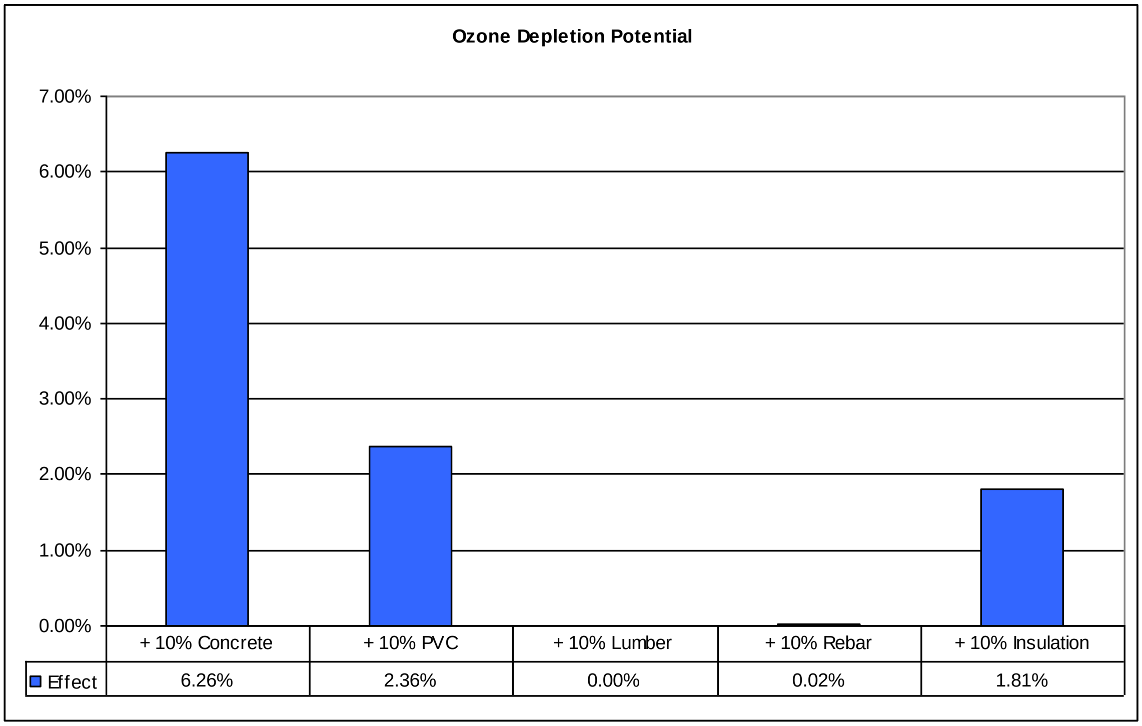


**Figure 22 - Sensitivity analysis of ozone depletion potential**

As in previous impact categories, ozone depletion potential is most sensitive to an increase in concrete (6.26%). PVC and insulation also cause a noticeable increase at 2.36% and 1.18% respectively.

## 4.4.8 Smog Potential

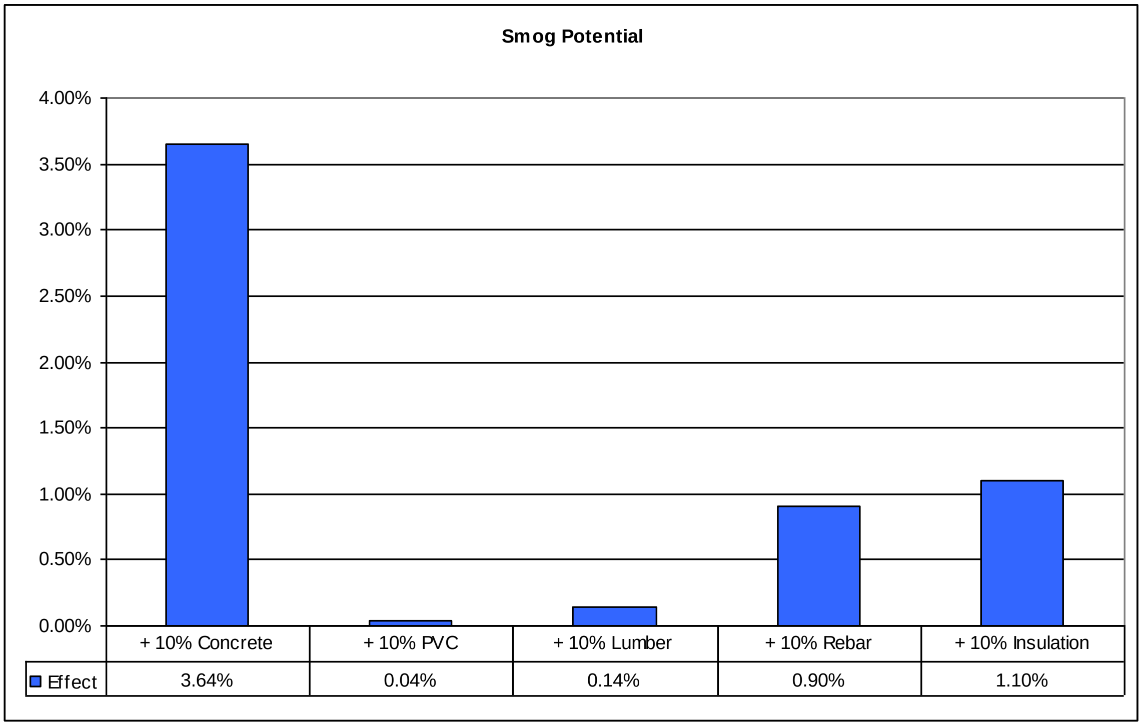


**Figure 23 - Sensitivity analysis of smog potential**

Figure 23 shows that smog potential is most sensitive to an increase in concrete with a 3.64% change. This is likely due to the emissions of the kiln process in Portland cement production. The other materials vary from 0.04% (PVC) to 1.10% (Insulation).

## 4.5 Functions and Impacts

The primary function of the Richmond Oval is to provide an entertainment space for those people watching activities that take place inside of them. Although the main functional areas of the Oval are multipurpose rinks and recreation, there are few other significant areas that are considered. These areas can then be used to measure the performance of the Oval. These measurements can then be used as benchmarks for future Olympic venues.

### 4.5.1 Building Functions

The Richmond Olympic Oval was originally built as a speed-skating facility for the 2010 Winter Olympic Games. Since the Olympics, the building has become a legacy facility allowing for the community of Richmond, and also Vancouver, to continue using it for the duration of its functional life. The table below is a list of the functional areas within the Richmond Oval, including the square footage and percentage of the total building square footage. The total square footage of the Richmond Oval is 499, 481 ft^2.

**Table 18 - Building Function Areas**

| Area Type | Area (sq. ft) | Percent of total building area |
|---|---|---|
| Administration | 9,194 | 1.8% |
| Hallways/Concourses | 37,768 | 7.6% |
| Utilities | 27,758 | 5.6% |
| Multipurpose rinks | 184,117 | 36.9% |
| Multiporpose Recreation | 53,208 | 10.7% |
| Retail/Concession | 3,220 | 0.6% |
| Parking Lot | 156,284 | 31.3% |
| Activity Areas | 5,187 | 1.0% |
| Washroom/Changing Room | 22,745 | 4.6% |
| **Total** | **499,481** | **100.0%** |

The majority of the venue is used as multipurpose rinks and parking lots, a percent of the total building area of 37% and 31% respectively. The third largest area is for multipurpose recreation at 11% of the total. All other building areas are under 10% of the total building area, comprising a significant minority of the building functions.

### 4.5.2 Functional Units

The functional unit of an LCA is used to ensure LCA results reflect the function of the product system being studied and to enable comparisons with other product systems (studied with similar Goal and Scope) on an equal footing. Thus functional units can provide context for the study, as it relates the impacts directly to the functions the building provides. As previously mentioned, the Richmond Oval was built originally as a speed skating facility which then turned into a legacy facility once the Olympics were finished. The main function of the building is to provide a facility for exercise and sport as well as entertainment to spectators watching these activities. The purpose of this LCA study is to determine the impacts associated with an Olympic multi-purpose rink facility, so as to be able to act as a comparison for future multi-purpose Olympic rinks around the world.

Considering the purpose of the building as well as its functions, the functional units can be broken down into a total building impacts by the following units:

- Per generic floor area;
- Per function-specific floor area (as defined in Table 20);
- Per year and per day of service life

The generic floor area is used as a unit in the determination of the impacts associated with each square foot floor. Table 20 is a list of functional areas within the Oval. The functional area that contributes the largest impact to the building can be determined by defining the total building impact based on all of the functional units. The primary function of the building is to provide a place for athletes to compete or participate in various sports including hockey, basketball, table-tennis, volleyball, track, ping-pong, gymnastics and others. The functional unit per year and per day of service life was determined by dividing the total building impacts by the number of service years of the

Oval. The impacts were further broken down to determine the per day impacts of the manufacture and construction of the Oval.

**Table 19 - Maximum number of spectators per multipurpose rink area**

| Area | Number of Spectators |
|---|---|
| Speed skating rink | 8000 |

The following table provides a break-down of the summary measures divided by functional area of the Richmond Oval.

**Table 20 - Impacts per function unit of the Richmond Oval**

| | Total Impact | per generic floor area (/ft^2) | per functional area (/ft^2) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Administration | Hallways/ Concourses | Utilities | Multipurpose rinks | Multipurpose recreation | Retail/ Concession | Parking Lot | Activity Areas | Washroom/ Changing Rooms |
| **Fossil Fuel Consumption (MJ)** | 3.20E+08 | 639.66 | 34,750.92 | 8,459.54 | 11,510.20 | 1,735.31 | 6,004.74 | 99,223.60 | 2,044.36 | 61,596.30 | 14,047.04 |
| **Weighted Resource Use (kg)** | 5.23E+08 | 1,046.99 | 56,879.70 | 13,846.43 | 18,839.69 | 2,840.32 | 9,828.45 | 162,407.45 | 3,346.16 | 100,819.74 | 22,991.95 |
| **Global Warming Potential (kg CO2 eq.)** | 2.37E+07 | 47.35 | 2,572.33 | 626.19 | 852.01 | 128.45 | 444.48 | 7,344.72 | 151.33 | 4,559.48 | 1,039.79 |
| **Acidification Potential (moles H+ eq.)** | 1.08E+07 | 21.70 | 1,179.03 | 287.02 | 390.52 | 58.88 | 203.73 | 3,366.46 | 69.36 | 2,089.84 | 476.59 |
| **HH Respiratory Effects Potential (kg PM 2.5 eq.)** | 7.02E+05 | 1.41 | 76.39 | 18.59 | 25.30 | 3.81 | 13.20 | 218.10 | 4.49 | 135.39 | 30.88 |
| **Eutrophication Potential (kg N eq.)** | 1.85E+04 | 0.04 | 2.01 | 0.49 | 0.67 | 0.10 | 0.35 | 5.75 | 0.12 | 3.57 | 0.81 |
| **Ozone Depletion Potential (kg CFC-11 eq.)** | 2.77E-02 | 5.55E-08 | 3.01E-06 | 7.34E-07 | 9.98E-07 | 1.51E-07 | 5.21E-07 | 8.61E-06 | 1.77E-07 | 5.34E-06 | 1.22E-06 |
| **Smog Potential (kg Nox eq.)** | 1.32E+05 | 0.26 | 14.36 | 3.50 | 4.76 | 0.72 | 2.48 | 40.99 | 0.84 | 25.45 | 5.80 |

Table 21 shows the effects of the measured impact categories split over the 70 year estimated life span of the Richmond Oval. The impacts have been split per year and per day of service life.

**Table 21 - Impacts per Functional Unit of 70 Year Building Service Life**

| | Fossil Fuel Consumption (MJ) | Weighted Resource Use (kg) | Global Warming Potential (kg CO2 eq.) | Acidification Potential (moles H+ eq.) | HH Respiratory Effects Potential (kg PM 2.5 eq.) | Eutrophication Potential (kg N eq.) | Ozone Depletion Potential (kg CFC-11 eq.) | Smog Potential (kg Nox eq.) |
|---|---|---|---|---|---|---|---|---|
| **Total Impact** | 3.20E+08 | 5.23E+08 | 2.37E+07 | 1.08E+07 | 7.02E+05 | 1.85E+04 | 2.77E-02 | 1.32E+05 |
| **Impact per Year of Service Life** | 4.57E+06 | 7.47E+06 | 3.39E+05 | 1.54E+05 | 1.00E+04 | 2.64E+02 | 3.96E-04 | 1.89E+03 |
| **Impact per Day of Service Life** | 12,500 | 20,500 | 927 | 422 | 27.5 | 0.724 | 1.08E-06 | 516 |

# 5.0 CONCLUSION

The life cycle assessment of the Richmond Olympic Oval has resulted in a bill of materials for the building, which identified the quantities of materials used within the manufacturing and construction phase of the Oval. Five of the largest material quantities in the building are concrete, softwood lumber, rebar, Rockwool batt insulation and ballast. Based on this bill of materials, the Athena Impact Estimator was used to generate environmental impacts of the Olympic Oval for the manufacturing and construction phase of its life cycle. Based on the findings, 90% of the impacts were due to the material manufacturing of the building, with some of the biggest impacts related to floors and beams, foundation and earthworks. This is expected for a large building, in which large quantities of concrete and rebar are required for structural support.

The sensitivity analysis on five selected building materials showed how the building's overall impact on the environment changed as the quantity of each material increased by 10%. The result demonstrated that the impact categories are consistently most sensitive to a 10% increase in concrete. Rebar causes the second highest change overall. Other materials generally generated minimal relative change.

By using functional units to represent environmental impacts by building function on an area basis, this provides a method of comparison for future buildings with similar functions. It can also be a tool for comparison with future Olympic venues.

Based on these findings, this study can be used to identify the largest contributors to environmental impacts within the Olympic Oval and can be used in the construction of future sporting venues or buildings.

# WORKS CITED

[1] Matheson, B. (Photographer). (2009). *Richmond oval.* [Web]. Retrieved from http://www.iald.org/media/article.asp?ARTICLE_ID=668&

[2] Kang, H. (Photographer). (2009). *Richmond olypic oval - interior through arches*. [Web]. Retrieved from http://www.openbuildings.com/buildings/richmond-olympic-oval-roof-profile-4152.html

[3] Canadian Wood Council. *The Richmond Olympic Oval*. Retrieved March 21, 2011. <http://www.cwc.ca/NR/rdonlyres/0C368425-CD79-4BB4-BB6F-6A7EE57E2936/0/RichmondOvallow_res.pdf>

[4]The Athena Sustainable Materials Institute's Impact Estimator (IE) for buildings, Software Database on Impact Categories.

# APPENDIX A – IE INPUTS DOCUMENT

| Richmond Oval Inputs Document | | | | | |
|---|---|---|---|---|---|
| **Assembly** | **Assembly Type** | **Assembly Name** | **Input Field** | **Known/ Measured** | **IE Input** |
| 1 Foundation | | | | | |
| | 1.1 Concrete Footing | | | | |
| | | 1.1.1 Footing_F1_Column | | | |
| | | | Length (m) | 2.40 | 323.98 |
| | | | Width (m) | 2.40 | 3.34 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 35 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 25M | 20M |
| | | 1.1.2 Footing_F2_Pile-Cap | | | |
| | | | Length (m) | 4.90 | 19.60 |
| | | | Width (m) | 3.60 | 7.20 |
| | | | Thickness (mm) | 900 | 450 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | - | 20M |
| | | 1.1.3 Footing_F3_Pile-Cap | | | |
| | | | Length (m) | - | 115.60 |
| | | | Width (m) | - | 100.00 |
| | | | Thickness (mm) | 900 | 450 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | - | 20M |
| | | 1.1.4 Piling_TYP | | | |
| | | | Length (m) | - | 1,916.00 |
| | | | Width (m) | - | 0.45 |
| | | | Thickness (mm) | - | 452 |
| | | | Concrete (MPa) | - | 60 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | - | 20M |
| | 1.2 Concrete Slab-on-Grade | | | | |
| | | 1.2.1 RAFT_450 | | | |
| | | | Length (m) | - | 214.40 |
| | | | Width (m) | - | 214.40 |
| | | | Thickness (mm) | 450 | 200 |
| | | | Concrete (MPa) | 35 | 30 |
| | | | Concrete flyash % | - | average |
| | | 1.2.2 Apron_180 | | | |
| | | | Length (m) | - | 47.53 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Width (m) | - | 47.53 |
| | | | Thickness (mm) | 180 | 100 |
| | | | Concrete (MPa) | 32 | 30 |
| | | | Concrete flyash % | - | average |
| | | 1.2.3 SOG_200 | | | |
| | | | Length (m) | - | 13.93 |
| | | | Width (m) | - | 13.93 |
| | | | Thickness (mm) | 200 | 200 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | 1.2.4 SOG_400 | | | |
| | | | Length (m) | - | 8.83 |
| | | | Width (m) | - | 8.83 |
| | | | Thickness (mm) | 400 | 200 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | 1.2.5 RAFT_900 | | | |
| | | | Length (m) | - | 21.53 |
| | | | Width (m) | - | 21.53 |
| | | | Thickness (mm) | 900 | 200 |
| | | | Concrete (MPa) | 35 | 30 |
| | | | Concrete flyash % | - | average |
| | 1.3 Stairs | | | | |
| | | 1.3.1 Stair_#1-1 | | | |
| | | | Length (m) | 10.90 | 10.90 |
| | | | Width (m) | 3.00 | 3.00 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.2 Stair_#1-2 | | | |
| | | | Length (m) | 9.00 | 9.00 |
| | | | Width (m) | 1.90 | 1.90 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.3 Stair_#2-1 | | | |
| | | | Length (m) | 9.00 | 9.00 |
| | | | Width (m) | 1.90 | 1.90 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.4 Stair_#2-2 | | | |
| | | | Length (m) | 9.00 | 9.00 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Width (m) | 1.90 | 1.90 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.5 Stair_#3-1 | | | |
| | | | Length (m) | 9.50 | 9.50 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.6 Stair_#3-2 | | | |
| | | | Length (m) | 9.30 | 9.30 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.7 Stair_#4-1 | | | |
| | | | Length (m) | 10.20 | 10.20 |
| | | | Width (m) | 1.40 | 1.40 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.8 Stair_#5-1 | | | |
| | | | Length (m) | 12.30 | 12.30 |
| | | | Width (m) | 7.10 | 7.10 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.9 Stair_#6-1 | | | |
| | | | Length (m) | 9.40 | 9.40 |
| | | | Width (m) | 1.60 | 1.60 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.10 Stair_#7-1 | | | |
| | | | Length (m) | 9.50 | 9.50 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |

| | | | | | |
|---|---|---|---|---|---|
| | | | Rebar | 15M | 15M |
| | | 1.3.11 Stair_#7-2 | | | |
| | | | Length (m) | 9.30 | 9.30 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.12 Stair_#8-1 | | | |
| | | | Length (m) | 9.50 | 9.50 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.13 Stair_#8-2 | | | |
| | | | Length (m) | 9.30 | 9.30 |
| | | | Width (m) | 1.80 | 1.80 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| | | 1.3.14 Stair_#9-1 | | | |
| | | | Length (m) | 11.10 | 11.10 |
| | | | Width (m) | 3.20 | 3.20 |
| | | | Thickness (mm) | 175 | 190 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | 15M | 15M |
| 2 Walls | | | | | |
| | 2.1 Cast In Place | | | | |
| | | 2.1.1 Wall_Cast-in-Place_200mm_Level 1_Interior | | | |
| | | | Length (m) | 47 | 47.00 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Thickness (mm) | 200 | 200 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #9 | #20 |
| | | 2.1.2 Wall_Cast-in-Place_300mm_Level 1 | | | |
| | | | Length (m) | 227 | 227 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #9 | #20M |
| | | 2.1.3 Wall_Cast-In-Place_600mm_Level 1_Interior | | | |

| | | | |
|---|---|---|---|
| | Length (m) | 133 | 266 |
| | Height (m) | 4.9 | 4.9 |
| | Thickness (mm) | 600 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.4 Wall_Cast-in-Place_315mm_Level 1 | | | |
| | Length (m) | 188 | 197.4 |
| | Height (m) | 4.90 | 4.90 |
| | Thickness (mm) | 315 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.5 Wall_Cast-in-Place_215mm_Level 1 | | | |
| | Length (m) | 217 | 233.275 |
| | Height (m) | 4.9 | 4.9 |
| | Thickness (mm) | 215 | 200 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.6 Wall_Cast-in-Place_250mm_Level 1 | | | |
| | Length (m) | 59 | 49.16666667 |
| | Height (m) | 4.9 | 4.9 |
| | Thickness (mm) | 250 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.7 Wall_Cast-in-Place_400mm_Level 1 | | | |
| | Length (m) | 97 | 129.3333333 |
| | Height (m) | 4.9 | 4.9 |
| | Thickness (mm) | 400 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.8 Wall_Cast-in-Place_1120mm_Level 1 | | | |
| | Length (m) | 5 | 18.66666667 |
| | Height (m) | 4.9 | 4.9 |
| | Thickness (mm) | 1120 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete flyash % | - | average |
| | Rebar | #9 | #20 |
| 2.1.9 Wall_Cast-in-Place_300_Level 2 | | | |
| | Length (m) | 48 | 48 |
| | Height (m) | 4.5 | 4.5 |
| | Thickness (mm) | 300 | 300 |
| | Concrete (MPa) | 25 | 30 |
| | Concrete | - | average |

| | | | | | |
|---|---|---|---|---|---|
| | | | flyash % | | |
| | | | Rebar | #9 | #20 |
| | | 2.1.10 Wall_Cast-in-Place_300_Level 3 | | | |
| | | | Length (m) | 32 | 32 |
| | | | Height (m) | 4.1375 | 4.1375 |
| | | | Thickness (mm) | 300 | 300 |
| | | | Concrete (MPa) | 25 | 30 |
| | | | Concrete flyash % | - | average |
| | | | Rebar | #9 | #20 |
| | 2.2 Concrete Block Wall | | | | |
| | | 2.2.1 Wall_ConcreteBlock_Level 1 | | | |
| | | | Length (m) | 1458 | 1458 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Rebar | - | #15 |
| | | Door Opening | Number of Doors | 74 | 74 |
| | | | Door Type | Hollow Metal Door | Steel Interior Door |
| | | Door Opening | Number of Doors | 4 | 4 |
| | | | Door Type | Solid Wood Door | Solid Wood Door |
| | | | | | |
| | | 2.2.2 Wall_ConcreteBlock_Level 2 | | | |
| | | | Length (m) | 401 | 401 |
| | | | Height (m) | 4.5 | 4.5 |
| | | | Rebar | - | #15 |
| | | Door Opening | Number of Doors | 15 | 15 |
| | | | Door Type | Hollow Metal Door | Steel Interior Door |
| | | Door Opening | Number of Doors | 14 | 14 |
| | | | Door Type | Solid Wood Door | Solid Wood Door |
| | | 2.2.3 Wall_ConcreteBlock_Level 2_with Cladding | | | |
| | | Envelope | Length (m) | 3 | 3 |
| | | | Height (m) | 4.5 | 4.5 |
| | | | Rebar | - | #15 |
| | | | Group Assembly | Walls | Walls |
| | | | Envelope Category | Cladding | Cladding |
| | | | Envelope Material | Aluminum Cladding | Steel Cladding Commercial (26ga) |
| | | 2.2.4 Wall_ConcreteBlock_Level 3 | | | |
| | | | Length (m) | 190 | 190 |
| | | | Height (m) | 4.1375 | 4.1375 |
| | | | Rebar | - | #15 |
| | | Door Opening | Number of Doors | 15 | 15 |
| | | | Door Type | Hollow Metal Door | Steel Interior Door |
| | | 2.2.5 Wall_ConcreteBlock_Level 3_with Cladding | | | |
| | | Envelope | Length (m) | 19 | 19 |
| | | | Height (m) | 4.1375 | 4.1375 |
| | | | Rebar | - | #15 |
| | | | Group Assembly | Walls | Walls |
| | | | Envelope Category | Cladding | Cladding |

| | | | Envelope Material | Aluminum Cladding | Steel Cladding Commercial (26ga) |
|---|---|---|---|---|---|
| | 2.3 Curtain Wall | | | | |
| | | 2.3.1 Wall_CurtainWall_MetalSpandrel_South_Level 1 | | | |
| | | | Length (m) | 290 | 290 |
| | | | Height (m) | 3.6 | 3.6 |
| | | | Percent Viewable Glazing | 95 | 95 |
| | | | Percent Spandrel Panel | 5 | 5 |
| | | | Thickness of Insulation (mm) | - | 0 |
| | | | Spandrel Type (Metal/Glass) | Metal | Metal |
| | | Door Opening | Number of Doors | 12 | 12 |
| | | | Door Type | - | Aluminum Exterior Door, 80% glazing |
| | | 2.3.2 Wall_CurtainWall_MetalSpandrel_Front_Lobby | | | |
| | | | Length (m) | 27 | 27 |
| | | | Height (m) | 11.1 | 11.1 |
| | | | Percent Viewable Glazing | 90 | 90 |
| | | | Percent Spandrel Panel | 10 | 10 |
| | | | Thickness of Insulation (mm) | - | 0 |
| | | | Spandrel Type (Metal/Glass) | Metal | Metal |
| | | 2.3.3 Wall_CurtainWall_MetalSpandrel_Side_Lobby | | | |
| | | | Length (m) | 30 | 30 |
| | | | Height (m) | 12.449 | 12.449 |
| | | | Percent Viewable Glazing | 90 | 90 |
| | | | Percent Spandrel Panel | 10 | 10 |
| | | | Thickness of Insulation (mm) | - | 0 |
| | | | Spandrel Type (Metal/Glass) | Metal | Metal |
| | | Door Opening | Number of Doors | 4 | 4 |
| | | | Door Type | - | Aluminum Exterior Door, 80% glazing |
| | | 2.3.4 Wall_CurtainWall_MetalSpandrel_North_Level 2 | | | |
| | | | Length (m) | 178 | 178 |
| | | | Height (m) | 6.25 | 6.25 |
| | | | Percent | 95 | 95 |

|  |  |  |  |
|---|---|---|---|
|  | Viewable Glazing |  |  |
|  | Percent Spandrel Panel | 5 | 5 |
|  | Thickness of Insulation (mm) | - | 0 |
|  | Spandrel Type (Metal/Glass) | Metal | Metal |
| Door Opening | Number of Doors | 16 | 16 |
|  | Door Type | - | Aluminum Exterior Door, 80% glazing |
| 2.3.5 Wall_CurtainWall_MetalSpandrel_East & West_Level 2 |  |  |  |
|  | Length (m) | 22 | 22 |
|  | Height (m) | 9 | 9 |
|  | Percent Viewable Glazing | 100 | 100 |
|  | Percent Spandrel Panel | 0 | 0 |
|  | Thickness of Insulation (mm) | - | 0 |
|  | Spandrel Type (Metal/Glass) | Metal | Metal |
| 2.3.6 Wall_CurtainWall_MetalSpandrel_South_Level 3 |  |  |  |
|  | Length (m) | 170 | 170 |
|  | Height (m) | 5.9 | 5.9 |
|  | Percent Viewable Glazing | 100 | 100 |
|  | Percent Spandrel Panel | 0 | 0 |
|  | Thickness of Insulation (mm) | - | 0 |
|  | Spandrel Type (Metal/Glass) | Metal | Metal |
| 2.3.7 Wall_CurtainWall_MetalSpandrel_North_Level 3 |  |  |  |
|  | Length (m) | 199 | 199 |
|  | Height (m) | 7.785 | 7.785 |
|  | Percent Viewable Glazing | 100 | 100 |
|  | Percent Spandrel Panel | 0 | 0 |
|  | Thickness of Insulation (mm) | - | 0 |
|  | Spandrel Type (Metal/Glass) | Metal | Metal |
| 2.3.8 Wall_CurtainWall_MetalSpandrel_South_Level 2 |  |  |  |

| | | | | | |
|---|---|---|---|---|---|
| | | | Length (m) | 159 | 159 |
| | | | Height (m) | 9.26 | 9.26 |
| | | | Percent Viewable Glazing | 95 | 95 |
| | | | Percent Spandrel Panel | 5 | 5 |
| | | | Thickness of Insulation (mm) | - | 0 |
| | | | Spandrel Type (Metal/Glass) | Metal | Metal |
| | | | Number of Windows | 34 | 34 |
| | | | Total Window Area (m2) | 34 | 34 |
| | | | Frame Type | Aluminum | Aluminum |
| | | | Glazing Type | - | None |
| | | | Category | Cladding | Cladding |
| | | | Material | Polycarbonate | Vinyl |
| | | | Thickness (mm) | - | - |
| | 2.4 Steel Stud | | | | |
| | | 2.4.1 Wall_SteelStud_A2_Level 1 | | | |
| | | | Length (m) | 23 | 23 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | Envelope | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Insulation | Insulation |
| | | | Material | - | Rockwool Batt |
| | | | Thickness (mm) | 89 | 89 |
| | | 2.4.2 Wall_SteelStud_C1_Level 2 | | | |
| | | | Length (m) | 52 | 52 |
| | | | Height (m) | 4.5 | 4.5 |
| | | | Sheathing Type | None | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | Opening | Number of Doors | 3 | 3 |
| | | | Door Type | Hollow metal | Steel Interior Door |
| | | Envelope | Category | Gypsum Wall | Gypsum Board |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Board | |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | 2.4.3 Wall_SteelStud_C1_Level 3 | | | |
| | | Envelope | Length (m) | 47 | 47 |
| | | | Height (m) | 4.1375 | 4.1375 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | 2.4.4 Wall_SteelStud_C2_Level 2 | | | |
| | | | Length (m) | 5 | 5 |
| | | | Height (m) | 4.5 | 4.5 |
| | | | Sheathing | - | None |

| | | | |
|---|---|---|---|
| | Type | | |
| | Stud Spacing | - | 400 oc |
| | Stud Weight | - | Light (25Ga) |
| | Stud Thickness (mm) | 92 | 39 x 92 |
| Envelope | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Insulation | Insulation |
| | Material | - | Rockwool Batt |
| | Thickness | 89 | 89 |
| 2.4.5 Wall_SteelStud_G3_Level 2_Exterior | | | |
| | Length (m) | 17 | 17 |
| | Height (m) | 4.5 | 4.5 |
| | Sheathing Type | - | None |
| | Stud Spacing | - | 400 oc |
| | Stud Weight | - | Heavy (20Ga) |
| | Stud Thickness (mm) | 102 | 39 x 92 |
| Envelope | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Gypsum Wall Board | Gypsum Board |
| | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| | Category | Gypsum Wall Board | Gypsum Board |
| | Material | Fire resistive gypsum liner panels | Gypsum Fire Rated Type X 5/8" |
| | Thickness (mm) | 16 | - |
| 2.4.6 Wall_SteelStud_G3 with metal | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | cladding_Level 2_Exterior | | | |
| | | Envelope | Length (m) | 55 | 55 |
| | | | Height (m) | 9 | 9 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Heavy (20Ga) |
| | | | Stud Thickness (mm) | 102 | 39 x 92 |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | Fire resistive gypsum liner panels | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Cladding | Cladding |
| | | | Material | Composite metal | Steel Cladding Commercial (26Ga) |
| | | | Thickness (mm) | - | - |
| | | 2.4.7 Wall_SteelStud_G3 with polycarbonate_Level 2_Exterior | | | |
| | | Envelope | Length (m) | 116 | 116 |
| | | | Height (m) | 10.225 | 10.225 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Heavy (20Ga) |
| | | | Stud Thickness (mm) | 102 | 39 x 92 |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | Fire resistive gypsum liner panels | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |

| | | | | | |
|---|---|---|---|---|---|
| | | | Category | Cladding | Cladding |
| | | | Material | Polycarbonate | Vinyl Cladding |
| | | | Thickness (mm) | - | - |
| | | 2.4.8 Wall_SteelStud_G3 with metal cladding_Level 3_Exterior Above Polycarbonate | | | |
| | | Envelope | Length (m) | 92 | 92 |
| | | | Height (m) | 4.35 | 4.35 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Heavy (20Ga) |
| | | | Stud Thickness (mm) | 102 | 39 x 92 |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | Fire resistive gypsum liner panels | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Cladding | Cladding |
| | | | Material | Metal Cladding | Steel Cladding Commercial (26Ga) |
| | | | Thickness | - | - |
| | | 2.4.9 Wall_SteelStud_G3 with metal cladding_Level 3_Exterior Beside Polycarbonate | | | |
| | | Envelope | Length (m) | 12 | 12 |
| | | | Height (m) | 2.781 | 2.781 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Heavy (20Ga) |
| | | | Stud Thickness (mm) | 102 | 92 |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall Board | Gypsum Board |
| | | | Material | 16 type 'x' gypsum wall board | Gypsum Fire Rated Type X 5/8" |
| | | | Thickness (mm) | 16 | - |
| | | | Category | Gypsum Wall | Gypsum Board |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  |  |  | Material | Board<br>Fire resistive gypsum liner panels | Gypsum Fire Rated Type X 5/8" |
|  |  |  | Thickness (mm) | 16 | - |
|  |  |  | Category | Cladding | Cladding |
|  |  |  | Material | Metal Cladding | Steel Cladding Commercial (26Ga) |
|  |  |  | Thickness | - | - |
|  |  | 2.4.10 Wall_SteelStud_H2_Level 1 |  |  |  |
|  |  |  | Length (m) | 48 | 6.782608696 |
|  |  |  | Height (m) | 4.9 | 4.9 |
|  |  |  | Sheathing Type | - | None |
|  |  |  | Stud Spacing | - | 400 oc |
|  |  |  | Stud Weight | - | Light (25Ga) |
|  |  |  | Stud Thickness (mm) | 13 | 92 |
|  |  | Envelope | Category | Gypsum Board | Gypsum Board |
|  |  |  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  |  |  | Thickness | - | - |
|  |  | 2.4.11 Wall_SteelStud_H2_Level 2 |  |  |  |
|  |  |  | Length (m) | 58 | 8.195652174 |
|  |  |  | Height (m) | 4.5 | 4.5 |
|  |  |  | Sheathing Type | - | None |
|  |  |  | Stud Spacing | - | 400 oc |
|  |  |  | Stud Weight | - | Light (25Ga) |
|  |  |  | Stud Thickness (mm) | 13 | 92 |
|  |  | Door Opening | Number of Doors | 1 | 1 |
|  |  |  | Door Type | Hollow metal | Steel Interior Door |
|  |  |  | Number of Doors | 4 | 4 |
|  |  |  | Door Type | Wood | Solid Wood Door |
|  |  | Envelope | Category | Gypsum Board | Gypsum Board |
|  |  |  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  |  |  | Thickness | - | - |
|  |  | 2.4.12 Wall_SteelStud_H2_Level 3 |  |  |  |
|  |  |  | Length (m) | 38 | 5.369565217 |
|  |  |  | Height (m) | 4.1375 | 4.1375 |
|  |  |  | Sheathing Type | - | None |
|  |  |  | Stud Spacing | - | 400 oc |
|  |  |  | Stud Weight | - | Light (25Ga) |
|  |  |  | Stud Thickness (mm) | 13 | 92 |
|  |  | Door Opening | Number of Doors | 4 | 4 |
|  |  |  | Door Type | Hollow Metal | Steel Interior Door |
|  |  | Envelope | Category | Gypsum Board | Gypsum Board |
|  |  |  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  |  |  | Thickness | - | - |
|  |  | 2.4.13 Wall_SteelStud_K1_Level 1 |  |  |  |
|  |  |  | Length (m) | 281 | 195.4782609 |
|  |  |  | Height (m) | 4.9 | 4.9 |
|  |  |  | Sheathing Type | - | None |
|  |  |  | Stud Spacing | - | 400 oc |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Stud Weight | - | Light (25Ga) |
| | | | | Stud Thickness (mm) | 64 | 39 x 92 |
| | | | Door Opening | Number of Doors | 10 | 10 |
| | | | | Door Type | Hollow Metal | Steel Interior Door |
| | | | | Number of Doors | 4 | 4 |
| | | | | Door Type | Wood | Solid Wood Door |
| | | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | | Thickness | - | - |
| | | | 2.4.14 Wall_SteelStud_K1_Level 2 | | | |
| | | | | Length (m) | 106 | 73.73913043 |
| | | | | Height (m) | 4.5 | 4.5 |
| | | | | Sheathing Type | - | None |
| | | | | Stud Spacing | - | 400 oc |
| | | | | Stud Weight | - | Light (25Ga) |
| | | | | Stud Thickness (mm) | 64 | 39 x 92 |
| | | | Door Opening | Number of Doors | 4 | 4 |
| | | | | Door Type | Hollow Metal | Steel Interior Door |
| | | | | Number of Doors | 3 | 3 |
| | | | | Door Type | Wood | Solid Wood Door |
| | | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | | Thickness | - | - |
| | | | 2.4.15 Wall_SteelStud_K1_Level 3 | | | |
| | | | | Length (m) | 49 | 34.08695652 |
| | | | | Height (m) | 4.1375 | 4.1375 |
| | | | | Sheathing Type | - | None |
| | | | | Stud Spacing | - | 400 oc |
| | | | | Stud Weight | - | Light (25Ga) |
| | | | | Stud Thickness (mm) | 64 | 39 x 92 |
| | | | Door Opening | Number of Doors | 1 | 1 |
| | | | | Door Type | Hollow Metal | Steel Interior Door |
| | | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | | Thickness (mm) | - | - |
| | | | 2.4.16 Wall_SteelStud_K2_Level 1 | | | |
| | | | | Length (m) | 8 | 5.565217391 |
| | | | | Height (m) | 4.9 | 4.9 |
| | | | | Sheathing Type | - | None |
| | | | | Stud Spacing | - | 400 oc |
| | | | | Stud Weight | - | Light (25Ga) |
| | | | | Stud Thickness (mm) | 64 | 39 x 92 |
| | | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | | Thickness (mm) | - | - |
| | | | | Category | Insulation | Insulation |

| | | | | | |
|---|---|---|---|---|---|
| | | | Material | Mineral Wool | Rockwool Batt |
| | | | Thickness (mm) | 60 | 60 |
| | | 2.4.17 Wall_SteelStud_K3_Level 2 | | | |
| | | | Length (m) | 225 | 225 |
| | | | Height (m) | 4.5 | 4.5 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | Door Opening | Number of Doors | 53 | 53 |
| | | | Door Type | Hollow metal | Steel Interior Door |
| | | | Number of Doors | 1 | 1 |
| | | | Door Type | Wood | Solid Wood Door |
| | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | 2.4.18 Wall_SteelStud_K5_Level 1 | | | |
| | | | Length (m) | 122 | 122 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | | Category | Insulation | Insulation |
| | | | Material | Mineral Wool | Rockwool Batt |
| | | | Thickness (mm) | 89 | 89 |
| | | | Category | Vapor Barrier | Vapor & Air Barrier |
| | | | Material | - | Polyethylene 6 mil |
| | | | Thickness (mm) | - | - |
| | | 2.4.19 Wall_SteelStud_M1_Level 1 | | | |
| | | | Length (m) | 12 | 12 |
| | | | Height (m) | 4.9 | 4.9 |
| | | | Sheathing Type | - | None |
| | | | Stud Spacing | - | 400 oc |
| | | | Stud Weight | - | Light (25Ga) |
| | | | Stud Thickness (mm) | 92 | 39 x 92 |
| | | Envelope | Category | Gypsum Board | Gypsum Board |
| | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | Thickness (mm) | - | - |
| | | | Category | Gypsum Board | Gypsum Board |
| | | | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
| | | | Thickness (mm) | - | - |

|  |  |  |  |
|---|---|---|---|
| 2.4.20 Wall_SteelStud_M1_Level 2 |  |  |  |
| Envelope | Length (m) | 9 | 9 |
|  | Height (m) | 4.5 | 4.5 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | - | 400 oc |
|  | Stud Weight | - | Light (25Ga) |
|  | Stud Thickness (mm) | 92 | 92 |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
| 2.4.21 Wall_SteelStud_M2_Level 1 |  |  |  |
| Envelope | Length (m) | 29 | 29 |
|  | Height (m) | 4.9 | 4.9 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | - | 400 oc |
|  | Stud Weight | - | Light (25Ga) |
|  | Stud Thickness (mm) | 92 | 92 |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
|  | Category | Insulation | Insulation |
|  | Material | Mineral Wool | Rockwool Batt |
|  | Thickness (mm) | 89 | 89 |
| 2.4.22 Wall_SteelStud_M3_Level 2 |  |  |  |
|  | Length (m) | 26 | 26 |
|  | Height (m) | 4.5 | 4.5 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | - | 400 oc |
|  | Stud Weight | - | Light (25Ga) |
|  | Stud Thickness (mm) | 152 | 152 |
| Door Opening | Number of Doors | 1 | 1 |
|  | Door Type | Wood | Solid Wood Door |
| Envelope | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | Gypsum Regular 5/8" | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
| 2.4.23 Wall_SteelStud_U1_Level 2 |  |  |  |

|  |  |  |  |
|---|---|---|---|
|  | Length (m) | 18 | 18 |
|  | Height (m) | 4.5 | 4.5 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | 600 | 600 oc |
|  | Stud Weight | 20 Ga | Heavy (20Ga) |
|  | Stud Thickness (mm) | 92 | 92 |
| Door Opening | Number of Doors | 2 | 2 |
|  | Door Type | Hollow metal | Steel Interior Door |
| Envelope | Category | Gypsum Board | Gypsum Board |
|  | Material | 16 mm abuse resistant board | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
|  | Category | Gypsum Board | Gypsum Board |
|  | Material | 16 mm abuse resistant board | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
| 2.4.24 Wall_SteelStud_V1_Level 1 |  |  |  |
|  | Length (m) | 14 | 14 |
|  | Height (m) | 4.9 | 4.9 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | 600 | 600 oc |
|  | Stud Weight | 20 Ga | Heavy (20 Ga) |
|  | Stud Thickness (mm) | 92 | 92 |
| Envelope | Category | Gypsum Board | Gypsum Board |
|  | Material | 16 mm abuse resistant board | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
| 2.4.25 Wall_SteelStud_V2_Level 2 |  |  |  |
|  | Length (m) | 139 | 33.23913043 |
|  | Height (m) | 4.5 | 4.5 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | 600 | 600 oc |
|  | Stud Weight | 20 Ga | Heavy (20 Ga) |
|  | Stud Thickness (mm) | 22 | 92 |
| Door Opening | Number of Doors | 5 | 5 |
|  | Door Type | Hollow metal | Steel Interior Door |
|  | Number of Doors | 2 | 2 |
|  | Door Type | Wood | Solid Wood Door |
| Envelope | Category | Gypsum Board | Gypsum Board |
|  | Material | 16 mm abuse resistant board | Gypsum Regular 5/8" |
|  | Thickness (mm) | - | - |
| 2.4.26 Wall_SteelStud_V2_Level 3 |  |  |  |
|  | Length (m) | 14 | 3.347826087 |
|  | Height (m) | 4.1375 | 4.1375 |
|  | Sheathing Type | - | None |
|  | Stud Spacing | 600 | 600 oc |
|  | Stud Weight | 20 Ga | Heavy (20 Ga) |
|  | Stud Thickness (mm) | 22 | 92 |

|  |  | Envelope | Category | Gypsum Board | Gypsum Board |
|---|---|---|---|---|---|
|  |  |  | Material | 16 mm abuse resistant board | Gypsum Regular 5/8" |
|  |  |  | Thickness (mm) | - | - |
| 3 Columns | 3.1 Concrete Column | 3.1.1 Column_Concrete_Level 1 |  |  |  |
|  |  |  | Number of Beams | 0 | 0 |
|  |  |  | Number of Columns | 213 | 213 |
|  |  |  | Floor to floor height (m) | 4.9 | 4.9 |
|  |  |  | Bay sizes (m) | 10.99 | 10.99 |
|  |  |  | Supported span (m) | 9.25 | 9.25 |
|  |  |  | Live load (kPa) | 3.6 | 3.6 |
|  | 3.2 Butresses |  |  |  |  |
|  |  | 3.2.1 - XBM_Butress_Roof Support_Concrete_North Elevation |  |  |  |
|  |  |  | Concrete 30 MPa Average Flyash (m^3) | - | 419.670 |
|  |  | 3.2.2 - XBM_Butress_Roof Support_Concrete_South Elevation |  |  |  |
|  |  |  | Concrete 30 MPa Average Flyash (m^3) | - | 1748.100 |
|  |  | 3.2.3 - XBM_Butress_Roof Support_Rebar_Total |  |  |  |
|  |  |  | Rebar Rod Light Sections (tonnes) | - | 544.544 |
|  |  |  |  |  |  |
| 4 Floors |  |  |  |  |  |
|  | 4.1 Concrete Slab |  |  |  |  |
|  |  | 4.1.1 - Slab_200 |  |  |  |
|  |  |  | Area (m^2) | 3,926 | 3,926 |
|  |  |  | Thickness (mm) | 200 | 200.000 |
|  |  |  | Volume Concrete (m^3) | 785.200 | 785.200 |
|  |  |  | Steel (Tonnes) | 61.638 | 61.638 |
|  |  | 4.1.2 - Slab_215 |  |  |  |
|  |  |  | Area (m^2) | 55 | 55 |
|  |  |  | Thickness (mm) | 215 | 215.000 |
|  |  |  | Volume Concrete (m^3) | 11.825 | 11.825 |
|  |  |  | Steel (Tonnes) | 0.864 | 0.864 |
|  |  | 4.1.3 - Slab_235 |  |  |  |
|  |  |  | Area (m^2) | 125 | 125 |
|  |  |  | Thickness (mm) | 235 | 235.000 |
|  |  |  | Volume Concrete (m^3) | 29.375 | 29.375 |
|  |  |  | Steel (Tonnes) | 1.963 | 1.963 |
|  |  | 4.1.4 - Slab_250 |  |  |  |

| | | | | | |
|---|---|---|---|---|---|
| | | | Area (m^2) | 2,361 | 2,361 |
| | | | Thickness (mm) | 250 | 250.000 |
| | | | Volume Concrete (m^3) | 590.250 | 590.250 |
| | | | Steel (Tonnes) | 37.068 | 37.068 |
| | | 4.1.5 - Slab_285 | | | |
| | | | Area (m^2) | 40 | 40 |
| | | | Thickness (mm) | 285 | 285.000 |
| | | | Volume Concrete (m^3) | 11.400 | 11.400 |
| | | | Steel (Tonnes) | 0.628 | 0.628 |
| | | 4.1.6 - Slab_300 | | | |
| | | | Area (m^2) | 42 | 42 |
| | | | Thickness (mm) | 300 | 300.000 |
| | | | Volume Concrete (m^3) | 12.600 | 12.600 |
| | | | Steel (Tonnes) | 0.659 | 0.659 |
| | | 4.1.7 - Slab_350 | | | |
| | | | Area (m^2) | 123 | 123 |
| | | | Thickness (mm) | 350 | 350.000 |
| | | | Volume Concrete (m^3) | 43.050 | 43.050 |
| | | | Steel (Tonnes) | 1.931 | 1.931 |
| | | 4.1.8 - Slab_900 | | | |
| | | | Area (m^2) | 79 | 79 |
| | | | Thickness (mm) | 900 | 900.000 |
| | | | Volume Concrete (m^3) | 71.100 | 71.100 |
| | | | Steel (Tonnes) | 1.240 | 1.240 |
| | 4.2 Concrete Slab Band | | | | |
| | | 4.2.1 - SlabBand_1050DP | | | |
| | | | Area (m^2) | 537 | 537 |
| | | | Thickness (mm) | 1050 | 1050.000 |
| | | | Volume Concrete (m^3) | 563.850 | 563.850 |
| | | | Steel (Tonnes) | 23.957 | 23.957 |
| | | 4.2.2 - SlabBand_1055DP | | | |
| | | | Area (m^2) | 94 | 94 |
| | | | Thickness (mm) | 1055 | 1055.000 |
| | | | Volume Concrete (m^3) | 99.170 | 99.170 |
| | | | Steel (Tonnes) | 4.194 | 4.194 |
| | | 4.2.3 - SlabBand_1065DP | | | |
| | | | Area (m^2) | 10 | 10 |
| | | | Thickness | 1065 | 1065.000 |

| | | | | | |
|---|---|---|---|---|---|
| | | | (mm) | | |
| | | | Volume Concrete (m^3) | 10.650 | 10.650 |
| | | | Steel (Tonnes) | 0.446 | 0.446 |
| | | 4.2.4 - SlabBand_1090DP | | | |
| | | | Area (m^2) | 36 | 36 |
| | | | Thickness (mm) | 1090 | 1090.000 |
| | | | Volume Concrete (m^3) | 39.240 | 39.240 |
| | | | Steel (Tonnes) | 1.606 | 1.606 |
| | | 4.2.5 - SlabBand_1125DP | | | |
| | | | Area (m^2) | 1,654 | 1,654 |
| | | | Thickness (mm) | 1125 | 1125.000 |
| | | | Volume Concrete (m^3) | 1860.750 | 1860.750 |
| | | | Steel (Tonnes) | 73.789 | 73.789 |
| | | 4.2.6 - SlabBand_1130DP | | | |
| | | | Area (m^2) | 37 | 37 |
| | | | Thickness (mm) | 1130 | 1130.000 |
| | | | Volume Concrete (m^3) | 41.810 | 41.810 |
| | | | Steel (Tonnes) | 1.651 | 1.651 |
| | | 4.2.7 - SlabBand_1140DP | | | |
| | | | Area (m^2) | 185 | 185 |
| | | | Thickness (mm) | 1140 | 1140.000 |
| | | | Volume Concrete (m^3) | 210.900 | 210.900 |
| | | | Steel (Tonnes) | 8.253 | 8.253 |
| | | 4.2.8 - SlabBand_450DP | | | |
| | | | Area (m^2) | 122 | 122 |
| | | | Thickness (mm) | 450 | 450.000 |
| | | | Volume Concrete (m^3) | 54.900 | 54.900 |
| | | | Steel (Tonnes) | 5.443 | 5.443 |
| | | 4.2.9 - SlabBand_465DP | | | |
| | | | Area (m^2) | 19 | 19 |
| | | | Thickness (mm) | 465 | 465.000 |
| | | | Volume Concrete (m^3) | 8.835 | 8.835 |
| | | | Steel (Tonnes) | 0.848 | 0.848 |
| | | 4.2.10 - SlabBand_485DP | | | |
| | | | Area (m^2) | 5 | 5 |
| | | | Thickness (mm) | 485 | 485.000 |
| | | | Volume Concrete (m^3) | 2.425 | 2.425 |
| | | | Steel | 0.223 | 0.223 |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  |  |  | (Tonnes) |  |  |
|  |  | 4.2.11 - SlabBand_500DP |  |  |  |
|  |  |  | Area (m^2) | 886 | 886 |
|  |  |  | Thickness (mm) | 500 | 500.000 |
|  |  |  | Volume Concrete (m^3) | 443.000 | 443.000 |
|  |  |  | Steel (Tonnes) | 39.527 | 39.527 |
|  |  | 4.2.12 - SlabBand_520DP |  |  |  |
|  |  |  | Area (m^2) | 5 | 5 |
|  |  |  | Thickness (mm) | 520 | 520.000 |
|  |  |  | Volume Concrete (m^3) | 2.600 | 2.600 |
|  |  |  | Steel (Tonnes) | 0.223 | 0.223 |
|  |  | 4.2.13 - SlabBand_600DP |  |  |  |
|  |  |  | Area (m^2) | 1,552 | 1,552 |
|  |  |  | Thickness (mm) | 600 | 600.000 |
|  |  |  | Volume Concrete (m^3) | 931.200 | 931.200 |
|  |  |  | Steel (Tonnes) | 69.238 | 69.238 |
|  |  | 4.2.14 - SlabBand_605DP |  |  |  |
|  |  |  | Area (m^2) | 18 | 18 |
|  |  |  | Thickness (mm) | 605 | 605.000 |
|  |  |  | Volume Concrete (m^3) | 10.890 | 10.890 |
|  |  |  | Steel (Tonnes) | 0.803 | 0.803 |
|  |  | 4.2.15 - SlabBand_680DP |  |  |  |
|  |  |  | Area (m^2) | 2 | 2 |
|  |  |  | Thickness (mm) | 680 | 680.000 |
|  |  |  | Volume Concrete (m^3) | 1.360 | 1.360 |
|  |  |  | Steel (Tonnes) | 0.089 | 0.089 |
|  |  | 4.2.16 - SlabBand_700DP |  |  |  |
|  |  |  | Area (m^2) | 63 | 63 |
|  |  |  | Thickness (mm) | 700 | 700.000 |
|  |  |  | Volume Concrete (m^3) | 44.100 | 44.100 |
|  |  |  | Steel (Tonnes) | 2.811 | 2.811 |
|  |  | 4.2.17 - SlabBand_745DP |  |  |  |
|  |  |  | Area (m^2) | 3 | 3 |
|  |  |  | Thickness (mm) | 745 | 745.000 |
|  |  |  | Volume Concrete (m^3) | 2.235 | 2.235 |
|  |  |  | Steel (Tonnes) | 0.134 | 0.134 |
|  |  | 4.2.18 - SlabBand_750DP |  |  |  |
|  |  |  | Area (m^2) | 162 | 162 |
|  |  |  | Thickness (mm) | 750 | 750.000 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Volume Concrete (m^3) | 121.500 | 121.500 |
| | | | Steel (Tonnes) | 7.227 | 7.227 |
| | | 4.2.19 - SlabBand_760DP | | | |
| | | | Area (m^2) | 1,701 | 1,701 |
| | | | Thickness (mm) | 760 | 760.000 |
| | | | Volume Concrete (m^3) | 1292.760 | 1292.760 |
| | | | Steel (Tonnes) | 75.886 | 75.886 |
| | | 4.2.20 - SlabBand_765DP | | | |
| | | | Area (m^2) | 112 | 112 |
| | | | Thickness (mm) | 765 | 765.000 |
| | | | Volume Concrete (m^3) | 85.680 | 85.680 |
| | | | Steel (Tonnes) | 4.997 | 4.997 |
| | | 4.2.21 - SlabBand_785DP | | | |
| | | | Area (m^2) | 5 | 5 |
| | | | Thickness (mm) | 785 | 785.000 |
| | | | Volume Concrete (m^3) | 3.925 | 3.925 |
| | | | Steel (Tonnes) | 0.223 | 0.223 |
| | | 4.2.22 - SlabBand_800DP | | | |
| | | | Area (m^2) | 21 | 21 |
| | | | Thickness (mm) | 800 | 800.000 |
| | | | Volume Concrete (m^3) | 16.800 | 16.800 |
| | | | Steel (Tonnes) | 0.937 | 0.937 |
| | | 4.2.23 - SlabBand_835DP | | | |
| | | | Area (m^2) | 47 | 47 |
| | | | Thickness (mm) | 835 | 835.000 |
| | | | Volume Concrete (m^3) | 39.245 | 39.245 |
| | | | Steel (Tonnes) | 2.097 | 2.097 |
| | | 4.2.24 - SlabBand_845DP | | | |
| | | | Area (m^2) | 4 | 4 |
| | | | Thickness (mm) | 845 | 845.000 |
| | | | Volume Concrete (m^3) | 3.380 | 3.380 |
| | | | Steel (Tonnes) | 0.178 | 0.178 |
| | | 4.2.25 - SlabBand_865DP | | | |
| | | | Area (m^2) | 358 | 358 |
| | | | Thickness (mm) | 845 | 845.000 |
| | | | Volume Concrete (m^3) | 302.510 | 302.510 |
| | | | Steel (Tonnes) | 15.971 | 15.971 |

| | | | | | |
|---|---|---|---|---|---|
| | | 4.2.26 - SlabBand_890DP | | | |
| | | | Area (m^2) | 454 | 454 |
| | | | Thickness (mm) | 890 | 890.000 |
| | | | Volume Concrete (m^3) | 404.060 | 404.060 |
| | | | Steel (Tonnes) | 20.254 | 20.254 |
| | 4.3 Concrete Hollow Core Panels | | | | |
| | | 4.3.1 - HCP_200 | | | |
| | | | Number of Bays | 271 | 271 |
| | | | Bay Size (m) | 0.300 | 0.300 |
| | | | Span (m) | 5.830 | 5.830 |
| | | | Live load (KPa) | - | 4.8 |
| | | 4.3.2 - HCP_350 | | | |
| | | | Number of Bays | 271 | 271 |
| | | | Bay Size (m) | 0.300 | 0.300 |
| | | | Span (m) | 11.140 | 11.140 |
| | | | Live load (KPa) | - | 4.8 |
| | | 4.3.3 - Cover Slab | | | |
| | | | Area (m^2) | 11,368 | 11,368 |
| | | | Thickness (mm) | 100 | 100.000 |
| | | | Volume Concrete (m^3) | 1136.800 | 1136.800 |
| | | | Steel (Tonnes) | 59.489 | 59.489 |
| 5 Roofs | | | | | |
| | 5.1 Composite V-Beam | | | | |
| | | 5.1.1 - XBM_Composite Beams_Roof_Glulam | | | |
| | | | Glulam Beams (m^3) | 864.386 | 864.386 |
| | | 5.1.2 - XBM_Composite Beams_Roof_Nosing | | | |
| | | | Galvanized Steel Sheet (tonnes) | 168.500 | 168.500 |
| | | 5.1.3 - XBM_Composite Beams_Roof_I-beams W200x59_Above Glulam | | | |
| | | | Wide Flange Sections (tonnes) W200 x 59 | 102.547 | 102.547 |
| | | 5.1.4 - XBM_Composite Beams_Roof_I-beams W150x30_Above Glulam | | | |
| | | | Wide Flange Sections (tonnes) W150 x 30 | 48.728 | 48.728 |
| | | 5.1.5 - XBM_Composite Beams_Roof_HSS102x102x6.4 Struts_Between Glulam | | | |
| | | | Hollow Structural Steel (tonnes) | 107.440 | 107.440 |
| | | 5.1.6 - XBM_Composite Beams_Roof_HSS127x127x6.4 Struts_At Tops of Glulam | | | |
| | | | Hollow Structural Steel (tonnes) | 55.892 | 111.403 |
| | 5.2 | | | | |

| | | | | |
|---|---|---|---|---|
| WoodWave Panels | | | | |
| | 5.2.1 - XBM_WoodWave Panels_Roof_SPF Lumber | | | |
| | | Softwood Lumber, small dim, kiln dried (m^3) | - | 2400.000 |
| | 5.2.2 - XBM_WoodWave Panels_Roof_Plywood | | | |
| | | Softwood Plywood (m^2) (9mm basis) | - | 119596.032 |
| | 5.2.3 - XBM_WoodWave Panels_Roof_Insulation | | | |
| | | Batt Rockwool (m^2) (25mm basis) | - | 251438.000 |
| 5.3 Glulam Posts | | | | |
| | 5.3.1 - XBM_Glulam Columns_Roof Posts_Glulam_North Elevation | | | |
| | | Glulam Beams (m^3) | - | 49.404 |
| | 5.3.2 - XBM_Glulam Columns_Roof Posts_Glulam_South Entrance | | | |
| | | Glulam Beams (m^3) | - | 10.175 |
| 5.5 Other Roof Supports | | | | |
| | 5.5.1 - XBM_Horizontal HSS_Roof_HSS 305x305x13_Between Composite Beams | | | |
| | | Hollow Structural Steel (tonnes) | 127.955 | 127.955 |
| | 5.5.2 - XBM_Horizontal HSS_Roof_HSS 305x305x13_Butress to Butress North Elev | | | |
| | | Hollow Structural Steel (tonnes) | 30.366 | 30.366 |
| | 5.5.3 - XBM_Horizontal I-Beams_Roof_W610x82_Between Butresses South Elev | | | |
| | | Wide Flange Sections (tonnes) | 12.816 | 12.816 |
| | 5.5.4 - XBM_Roof Supports_Roof_HS273o11 _Beams to Butress | | | |
| | | Hollow Structural Steel (tonnes) | 17.772 | 17.772 |
| | 5.5.5 - XBM_Cross Supports_Roof_HS141o6.4 _Beams to WoodWave | | | |
| | | Hollow Structural Steel (tonnes) | 6.676 | 6.676 |
| | 5.5.6 - XBM_Horizontal I-beams_Roof_I-beams W610x174_At entrance | | | |
| | | Wide Flange Sections (tonnes) | 21.750 | 21.750 |
| 5.6 Envelope | | | | |
| | 5.6.1 - XBM_Envelope Materials_Roof_R1/R2 | | | |
| | | Extruded Polystyrene (m^2, 25 mm basis)<br>PVC Membrane (kg)<br>1/2" Fire-rated Type X Gypum Board (m^2) | 75732.640<br>94050.845<br>9317.500 | 75732.640<br>94050.845<br>9317.500 |
| | 5.6.2 - XBM_Envelope Materials_Roof_R3 | | | |
| | | Extruded Polystyrene | 5478.270 | 5478.270 |

| | | | | | |
|---|---|---|---|---|---|
| | | | (m^2, 25 mm basis) | | |
| | | | PVC Membrane (kg) | 13606.700 | 13606.700 |
| | | | 1/2" Fire-rated Type X Gypsum Board (m^2) | 1348.000 | 1348.000 |
| | | 5.6.3 - XBM_Envelope Materials_Roof_R4 | | | |
| | | | Extruded Polystyrene (m^2, 25 mm basis) | 2697.700 | 2697.700 |
| | | | PVC Membrane (kg) | 3350.200 | 3350.200 |
| | | | 5/8" Fire-rated Type X Gypsum Board (m^2) | 663.800 | 663.800 |
| 6 Earthworks | | | | | |
| | 6.1 Pre-Loading | | | | |
| | | 6.1.1 - Site Pre-load material | | | |
| | | | Ballast (aggregate stone) (kg) | 383485509.000 | 383485509.000 |

# APPENDIX B – IE INPUTS ASSUMPTIONS DOCUMENT

| Assembly | Assembly Type | Assembly Name | Modeling Assumptions |
|---|---|---|---|
| 1 Foundation | | | |
| | 1.1 Concrete Footing | 25 and 35 MPa footings were both modeled as 30MPa footings, the nearest Athena Impact Estimator equivalent. | |
| | | 1.1.1 Footing_F1_Column | Pyramidal shaped thickening of raft slab to 4.2m x 4.2m from 2.4m x 2.4m. To maintain volume of footing, 3.34m x 3.34m average used. Model 97 identical footings at 3.34m = 323.98m length. |
| | | 1.1.2 Footing_F2_Pile-Cap | Max thickness in the IE is 500mm, modeled 900mm pile cap as 900mm/2 = 450mm thick with double width. 4 pile caps at 4.90m length = 19.6m |
| | | 1.1.3 Footing_F3_Pile-Cap | Max thickness in the IE is 500mm, modeled 900mm pile cap as 450mm thick with double area. Irregular shape, area take-off = 5780 square meters. Double area = 11560 square meters. Modeled as rectangles: 100m x 115.6m |
| | | 1.1.4 Piling_TYP | Pilings are 510 diameter cylindrical columns and were modeled as equivalent rectangles (0.452m x 0.452m). Piling height varies from 0.14m to 7.85m; assumed varied uniformly to an average height of 4m. Modeled sideways (height = length). 479 pilings x 4m = 1916m. Precast concrete assumed to be 60MPa |
| | 1.2 Concrete Slab-on-Grade | Where concrete slab-on-grades were not 100 or 200mm (as limited by the Impact Estimator) they were modeled as the closest depth with the area adjusted to maintain the overall volume by the formula:<br>(adjusted area) = (measured area)*(cited thickness)/(Impact Estimator thickness)<br>Square slab assumed for sake of Impact Estimator modeling by the formula:<br>Length = sqrt(adjusted area) | |
| | | 1.2.1 RAFT_450 | 20,459 square meters @ 450mm = 45,965 square meters @ 200mm |
| | | 1.2.2 Apron_180 | 1,225 square meters @ 180mm = 2,259 square meters @ 100mm |
| | | 1.2.4 SOG_400 | 39 square meters @ 400mm = 78 square meters @ 200mm |
| | | 1.2.5 RAFT_900 | Represents a thickening of the 450 Raft Slab at 900mm step down. 103 square meters @ 900mm = 464 square meters @ 200mm |
| | 1.3 Stairs | Stairs were modeled as footings of equivalent length, width, and throat (thickness). Due to a minimum thickness constraint, 175mm thick stairs were modeled as 190mm thick. Stairs labeled as [(Stairwell #) - (Floor)] | |
| 2 Walls | The length of the concrete cast-in-place walls needed adjusting to accommodate the wall thickness limitation in the Impact Estimator. It was assumed that interior steel stud walls were light gauge (25Ga) and exterior steel stud walls were heavy gauge (20Ga).All Cast in Place walls have an actual concrete strength of 25MPa, but only 20 and 30MPa are options in the IE, so 30MPa will be used as a conservative estimate. All Cast in Place walls use #9 gauge rebar, but only #15M and #20M are options in the IE. Since #9 gauge is closest to #20M, #20M is used as the value input into the IE. All Cast in Place walls do not specify flyash % in the concrete. Therefore, an average flyash % is chosen. All curtain walls were assumed to have aluminum exterior doors with 80% glazing as the closest door estimation in the IE. All hollow metal doors are assumed to be steel interior doors in the IE since hollow metal is not an option. All wood doors are considered solid wood doors. | | |
| | 2.1 Cast In Place | | |
| | | 2.1.3 Wall_Cast-in-Place_Level 1_600mm | This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/300mm]<br>=133m* [(600mm) / (300mm)]<br>= 266 meters |
| | | 2.1.4 Wall_Cast-in-Place_Level 1_315mm | This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/300mm]<br>=188m* [(315mm) / (300mm)]<br>= 197.4 meters |

| | | |
|---|---|---|
| | 2.1.5 Wall_Cast-In-Place_Level 1_215mm | This wall was increased by a factor in order to fit the 200mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/200mm]<br>=217m* [(215mm) / (200mm)]<br>= 233.3 meters |
| | 2.1.6 Wall_Cast-in-Place_Level 1_250mm | This wall was reduced by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/300mm]<br>=59m* [(250mm) / (300mm)]<br>= 49.2 meters |
| | 2.1.7 Wall_Cast-in-Place_Level 1_400mm | This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;= (Measured Length) * [(Cited Thickness)/300mm]=97m* [(400mm) / (300mm)]= 183 meters |
| | 2.1.8 Wall_Cast-in-Place_Level 1_1120mm | This wall was increased by a factor in order to fit the 300mm thickness limitation of the Impact Estimator. This was done by increasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/300mm]<br>=5m* [(1120mm) / (300mm)]<br>= 18.7 meters |
| 2.2 Concrete Block Wall | | |
| | 2.2.1 Wall_ConcreteBlock_13_Level 1 | There are 7 doors with a 15% window area where the window area has not been taken into account.<br>There are 13 double doors, which are modeled as 26 single doors, thereby overestimating the framing material necessary. |
| | 2.2.1 Wall_ConcreteBlock_18_Level 1 | 1 set of double hollow metal doors, and 1 set of double solid wood doors are modeled as 2 single hollow metal doors and 2 single double solid. |
| | 2.2.1 Wall_ConcreteBlock_22_Level 1 | 2 sets of double hollow metal doors.<br>3 single doors that are isothermally insulated, but have not taken this into account. |
| | 2.2.2 Wall_ConcreteBlock_13_Level 2 | There are 5 doors with a 15% window area where the window area has not been taken into account.<br>There is 1 set of double doors being modeled as 2 single doors. |
| | 2.2.2 Wall_ConcreteBlock_22_Level 2 | There are 9 doors with a 25% window area where the window area has not been taken into account.<br>There is 1 door with a 15% window area where the window area has not been taken into account.<br>There are 5 sets of double doors being modeled as 10 single doors. |
| | 2.2.3 Wall_ConcreteBlock_22_Level 2_with Cladding | Commercial steel cladding is being used to model Aluminum cladding because aluminum is not an option in the IE. |
| | 2.2.4 Wall_ConcreteBlock_13_Level 3 | There are 5 hollow metal doors with a 15% window area where the window area has not been taken into account.<br>There is 1 set of double doors being modeled as 2 single doors. |
| | 2.2.4 Wall_ConcreteBlock_19_Level 3 | There is 1 hollow metal door with a 15% window area which is not being modeled. |
| | 2.2.4 Wall_ConcreteBlock_22_Level 3 | 1 set of double hollow metal doors are being modeled as 2 single doors. |
| | 2.2.5 Wall_ConcreteBlock_13_Level 3_with Cladding | Commercial steel cladding is being used to model Aluminum cladding because aluminum is not an option in the IE. |
| 2.3 Curtain Wall | | |
| | 2.3.3 Wall_CurtainWall_MetalSpandrel_Side Lobby | The side lobby walls sloped, so an average height was used.<br>2 sets of double sliding doors are modeled as 4 single aluminum door with 80% glazing. |
| | 2.3.4 Wall_CurtainWall_MetalSpandrel_North_Level 2 | 8 double sliding glass doors were modeled as 16 single doors with 80% viewable glazing. |
| | 2.3.8 Wall_CurtainWall_MetalSpandrel_South_Level 2 | This wall is a curtain wall covered in polycarbonate cladding. At random spots, the polycarbonate has been taken away, and a regular window is present. This wall has been modeled as a curtain wall with vinyl cladding over-top since vinyl is the closest to polycarbonate in the IE. Windows without cladding have been considered as window openings in the IE. |
| 2.4 Steel Stud | | |

| | |
|---|---|
| 2.4.1 Wall_SteelStud_A2_Level 1 | Since this was an interior wall, no sheathing was considered. The gypsum is on both sides of the wall. Rockwall Batt was used as the insulation type since mineral wool insulation was specified and is not an option in the IE. |
| 2.4.2 Wall_SteelStud_C1_Level 2 | 6 m of this wall was assumed since the architectural drawings did not specify the wall type.<br>2 single hollow metal doors have been modeled as an overhead motorized door. |
| 2.4.3 Wall_SteelStud_C1_Level 3 | Each side of the wall has 2 layers of gypsum wall board. |
| 2.4.4 Wall_SteelStud_C2_Level 2 | Research shows that Mineral Wool is a similar material to Rockwool Batt. Since mineral wool is not an option in the IE, rockwool batt is used instead.<br>Each side of the wall has 2 layers of gypsum wall board. |
| 2.4.5 Wall_SteelStud_G3_Level 2_Exterior | Stud size is 102 mm, but 92 mm is used with a heavier stud weight (20Ga instead of 25Ga), to account for the difference in stud size. Gypsum fire resistant board is used in the IE instead of the actual 25 fire resistive gypsum liner panels. 2 layers of gypsum board on the interior of the wall is required. |
| 2.4.6 Wall_SteelStud_G3 with metal cladding_Level 2 | Stud size is 102 mm, but 92 mm is used with a heavier stud weight (20Ga instead of 25Ga), to account for the difference in stud size. Gypsum fire resistant board is used in the IE instead of the actual 25 fire resistive gypsum liner panels required.<br>2 layers of gypsum board on the interior of the wall is required.<br>Composite metal cladding on the exterior of the building is entered into the IE as a steel cladding of commercial grade since it is the closest equivalent. |
| 2.4.7 Wall_SteelStud_G3 with polycarbonate_Level 2_Exterior | Stud size is 102 mm, but 92 mm is used with a heavier stud weight (20Ga instead of 25Ga), to account for the difference in stud size. Gypsum fire resistant board is used in the IE instead of the actual fire resistive gypsum liner panels required.<br>2 layers of gypsum board on the interior of the wall is required.<br>Polycarbonate cladding is used on the exterior of the building, but since it is not an option in the IE, vinyl cladding is used as an equivalent since polycarbonate and vinyl are both types of plastic. |
| 2.4.8 Wall_SteelStud_G3 with metal cladding_Level 3_Exterior Above Polycarbonate | Stud size is 102 mm, but 92 mm is used with a heavier stud weight (20Ga instead of 25Ga), to account for the difference in stud size. Gypsum fire resistant board is used in the IE instead of the actual 25 fire resistive gypsum liner panels required.<br>2 layers of gypsum board on the interior of the wall is required.<br>Composite metal cladding on the exterior of the building is entered into the IE as a steel cladding of commercial grade since it is the closest equivalent.<br>The height of this wall is the average height above the polycarbonate cladding found on the East and West exterior walls. |
| 2.4.9 Wall_SteelStud_G3 with metal cladding_Level 3_Exterior Beside Polycarbonate | Stud size is 102 mm, but 92 mm is used with a heavier stud weight (20Ga instead of 25Ga), to account for the difference in stud size. Gypsum fire resistant board is used in the IE instead of the actual 25 fire resistive gypsum liner panels required.<br>2 layers of gypsum board on the interior of the wall is required.<br>Composite metal cladding on the exterior of the building is entered into the IE as a steel cladding of commercial grade since it is the closest equivalent.<br>The height of this wall is the average height beside the polycarbonate cladding found on the East and West exterior walls. |
| 2.4.10 Wall_SteelStud_H2_Level 1 | This is not a true steel stud wall, instead of full steel studs, this wall has a 13 mm resilient channel. This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=48 m* [(13mm) / (92mm)]<br>= 6.8 meters<br>However, this will underestimate the material of the gypsum wall board. |

| | |
|---|---|
| 2.4.11 Wall_SteelStud_H2_Level 2 | This is not a true steel stud wall, instead of full steel studs, this wall has a 13 mm resilient channel. This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=58 m* [(13mm) / (92mm)]<br>= 8.2 meters<br>However, this will underestimate the material of the gypsum wall board.<br>There are 2 sets of double wooden doors that are modeled in the IE as 4 single wooden doors. This will over-estimate the material of the door frames.<br>2 m of this wall is assumed because one wall was not specified in the architectural drawings. |
| 2.4.12 Wall_SteelStud_H2_Level 3 | This is not a true steel stud wall, instead of full steel studs, this wall has a 13 mm resilient channel. This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=48 m* [(13mm) / (92mm)]<br>= 6.8 meters<br>However, this will underestimate the material of the gypsum wall board.<br>There are 2 doors with a 15% area of window that is not taken into account. There is 1 set of double doors, therefore overestimating framing material. |
| 2.4.13 Wall_SteelStud_K1_Level 1 | This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;= (Measured Length) * [(Cited Thickness)/92mm]=281 m* [(64mm) / (92mm)]= 195 metersHowever, this will underestimate the material of the gypsum wall board.4 of the hollow metal doors have a 15% area of window that is not taken into account. There are 2 sets of double doors entered as 4 single doors, resulting in an overestimation of framing material. |
| 2.4.14 Wall_SteelStud_K1_Level 2 | This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=106 m* [(64mm) / (92mm)]<br>= 74 meters<br>However, this will underestimate the material of the gypsum wall board.<br>There are 1 set of hollow metal double doors, being modeled as 2 single steel interior doors. There is 1 door with a 15% window area that will not be modeled.<br>There is 1 set of wood double doors being modeled as 2 single doors. In addition, these double doors each have a 15% window area that will not be modeled. |
| 2.4.15 Wall_SteelStud_K1_Level 3 | This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=49 m* [(64mm) / (92mm)]<br>= 34 meters<br>However, this will underestimate the material of the gypsum wall board.<br>There is 1 hollow metal door with a 15% window area that will not take the window area into account. |
| 2.4.16 Wall_SteelStud_K2_Level 1 | This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=8 m* [(64mm) / (92mm)]<br>= 5.6 meters<br>However, this will underestimate the material of the gypsum wall board.<br>The insulation type calls for mineral wool, but since this isn't an option in the IE, the closest estimate is Rockwool Batt. |

|  |  |  |  |
|---|---|---|---|
|  |  | 2.4.17 Wall_SteelStud_K3_Level 2 | A total of 22 single hollow metal doors have been added to model overhead motorized doors. Each overhead door is the equivalent of 2 single doors in the IE.<br>2 metal doors have 20% window area where the window area which has not been taken into account.<br>4 metal doors have 15% window area where the window area which has not been taken into account.<br>There is 1 set of double hollow metal doors being modeled as 2 single hollow metal doors.<br>1 wooden door has a 15% window area in which the window area is not being modeled. |
|  |  | 2.4.18 Wall_SteelStud_K5_Level 1 | The insulation type calls for mineral wool, but since this isn't an option in the IE, the closest estimate is Rockwool Batt.<br>This wall requires a vapor barrier, but does not specify the thickness. Polyethylene 10 mil is a common barrier thickness in commercial buildings, so 6 mil shall be used as a best estimate in the IE for this wall. |
|  |  | 2.4.21 Wall_SteelStud_M2_Level 1 | The insulation type calls for mineral wool, but since this isn't an option in the IE, the closest estimate is Rockwool Batt. |
|  |  | 2.4.23 Wall_SteelStud_U1_Level 2 | This wall requires 1 layer of abuse resistant board on each side of the wall, but since abuse resistant board is not an option in the IE, it is being modeled as regular gypsum board.<br>The 2 single hollow metal doors are modeling 1 set of double hollow metal doors. |
|  |  | 2.4.24 Wall_SteelStud_V1_Level 1 | This wall requires 1 layer of abuse resistant board, but since abuse resistant board is not an option in the IE, it is being modeled as regular gypsum board. |
|  |  | 2.4.25 Wall_SteelStud_V2_Level 2 | This is not a true steel stud wall, instead of full steel studs, this wall has a 22 mm furring channels. This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;= (Measured Length) * [(Cited Thickness)/92mm]=139 m* [(22mm) / (92mm)]= 33 metersHowever, this will underestimate the material of the gypsum wall board.This wall requires 1 layer of abuse resistant board, but since abuse resistant board is not an option in the IE, it is being modeled as regular gypsum board. 1 hollow metal and 1 solid wood door have a 15% window area in which the window area is not being modeled. There is 1 set of double hollow metal doors being modeled as 2 single metal doors, and 1 set of double wood doors being modeled as 2 single wood doors. |
|  |  | 2.4.26 Wall_SteelStud_V2_Level 3 | This is not a true steel stud wall, instead of full steel studs, this wall has a 22 mm furring channels. This wall was decreased by a factor in order to fit the 92 mm stud size limitation of the Impact Estimator. This was done by decreasing the length of the wall using the following equation;<br>= (Measured Length) * [(Cited Thickness)/92mm]<br>=14 m* [(22mm) / (92mm)]<br>= 3.3 meters<br>However, this will underestimate the material of the gypsum wall board.<br>This wall requires 1 layer of abuse resistant board, but since abuse resistant board is not an option in the IE, it is being modeled as regular gypsum board. |
| 3<br>Columns | The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. This being the case, in OnScreen, since no beams were present in the AERL building, concrete columns were accounted for on each floor, while each floor's area was measured. The number of beams supporting each floor were assigned an average bay and span size in order to cover the measured area, as seen assumption details below for each input. Since the live loading was not located within the provided building information, a live load of 75psf on all four floors and the basement level were assumed. The hollow structural steel (HSS) columns in the AERL building were modeled in the Extra Basic Materials, where their associated assumptions and calculations are documented. |  |  |
|  | 3.1 Concrete Column |  |  |
|  |  | 3.1.1 Column_Concrete_Level 1 | Because of the variability of bay and span sizes, they were calculated using the following calculation;<br>= sqrt[(Measured Supported Floor Area) / (Counted Number of Columns)]<br>= sqrt[(25728 m2) / (213)]<br>= 10.99 meters<br>The live loads of the columns change over the area of the building. Therefore, the middle value of 3.6 kPa is used to encompass the 2.4 |

| | | | |
|---|---|---|---|
| | | | and 4.8KPa live loads necessary for different sections of the building. |
| | 3.2 Butresses | | |
| | | 3.2.1 - XBM_Butress_Roof Support_Concrete_North Elevation | Volume per buttress for buttresses on North Elevation calculated by measuring cross sectional area of buttress and multiplying by an average thickness of 0.9 m. Thickness at bottom of buttress is 1.2 m and 0.6 m at the top, therefore assume average thickness of 0.9 m. Concrete 35 MPa from General Notes in drawings, however closest input in the IE is 30 MPa. Flyash content not specified, assume average. Total count of 15 buttresses on North Elevation, therefore use this as multiplicant. Volume of rebar assumed negligible and not subtracted |
| | | 3.2.2 - XBM_Butress_Roof Support_Concrete_South Elevation | Volume per buttress for buttresses on South Elevation calculated by measuring cross sectional area of buttress and multiplying by an average thickness of 0.9 m. Thickness at bottom of buttress is 1.2 m and 0.6 m at the top, therefore assume average thickness of 0.9 m. Concrete 35 MPa from General Notes in drawings, however closest input in the IE is 30 MPa. Flyash content not specified, assume average. Total count of 15 buttresses on South Elevation, therefore use this as multiplicant. Column of rebar assumed negligible and not subtracted. |
| | | 3.2.3 - XBM_Butress_Roof Support_Rebar_Total | To estimate the volume ratio of rebar used in the buttresses, the area of rebar at a typical cross section was measured in OTF. Vertical rebar area was approximately 0.053 m^2, while horizontal area was approx. 0.742 m^2. By assuming intervals between horizontal rebar of approximately 5 equivalent rebar thicknesses, we can divide 0.742 m^2 by 5 to get an average area throughout the buttress of about 0.148 m^2. This gives a total cross sectional area of rebar in the typical buttress cross section of 0.2 m^2. Dividing this by the cross sectional area of the buttress at this typical section (0.2/6.322) gives a volume ratio of 3.2%. This assumes constant area ratio of rebar to concrete throughout buttress. Now 3.2% of the total volume of concrete in the buttresses is 0.032*(419.67+1748.1) = 69.4 m^3 of total rebar used in buttresses. Multiply this by density of steel, 69.4*7850 kg/m^3 = 544544 kg of rebar |
| 4 Floors | Athena Impact Estimator has no tool for modeling complex and varying slab and slab-band systems; as such the most accurate model was determined to be by volume of concrete and steel as extra basic materials. The concrete on the activity deck is 30MPa and the Mezzanine is 25MPa, both were modeled as 30MPa; the nearest available equivalent. | | |
| | 4.1 Concrete Slab | Typical rebar reinforcement is 15M bars @ 100mm spacing = 0.0157 tonnes per square meter (see sheet "Typ Slab") | |
| | 4.2 Concrete Slab Band | Typical rebar reinforcement for a slab band is 0.0446 tonnes per square meter (see sheet "Typ Slab Band") | |
| | 4.3 Concrete Hollow Core Panels | Assumed a live load of 4.8kPa to account for additional dead load of ice rink and additional live load of activities. Bay size scaled from detailed drawings, 8 bays in 2420mm = 300mm per bay. Length covered by HCP = 81.3m (all sections) @ 0.3m per bay = 271 bays. | |
| | | 4.3.1 - HCP_200 | 3 sections @ 271 bays = 813 bays total |
| | | 4.3.2 - HCP_350 | 11 sections @ 271 bays = 2981 bays total |
| | | 4.3.3 - Cover Slab | 10M bars @ 300mm spacing either way = 0.00523 tonnes per square meter (see sheet "Typ Slab") |
| 5 Roofs | | | |
| | 5.1 Composite V-Beam | | |
| | | 5.1.1 - XBM_Composite Beams_Roof_Glulam | Measured beam width, height and length and multiplied by number of beams to get volume in On Screen |
| | | 5.1.2 - XBM_Composite Beams_Roof_Nosing | Wall Thickness = 9.5 mm<br>Height = Length of beam = 97m<br>Volume = volume of steel nosing per composite v-beam in m^3<br>Assume material to be galvanized sheet steel as only steel is provided as a material.<br>Volume is thickness*length*height = 1.431m^3. Multiply by 15 beams and density for weight in tonnes.<br>Density of steel is roughly 7850kg/m^3 < http://www.engineeringtoolbox.com/> |
| | | 5.1.3 - XBM_Composite Beams_Roof_I-beams W200x59_Above Glulam | Wide Flange W200x59<br>Weight is 59 kg/m - second number in specification |

| | | | |
|---|---|---|---|
| | | | <http://www.huntersteel.ca/><br>Total weight is length of beams multiplied by weight/meter of the specific I-beam. Multiply this by 30 glulam beams above which these I-beams are positioned. |
| | | 5.1.4 - XBM_Composite Beams_Roof_I-beams W150x30_Above Glulam | Wide Flange W150x30<br>Weight is 30 kg/m - second number in specification<br><http://www.huntersteel.ca/><br>Total weight is length of beams multiplied by weight/meter of the specific I-beam. Multiply this by 30 glulam beams above which these I-beams are positioned. |
| | | 5.1.5 - XBM_Composite Beams_Roof_HSS102x102x6.4 Struts_Between Tops of Glulam | Measured length of steel struts between glulam beams. This is a repeated pattern through the entire beam at 2400mm intervals. Divide 97m beam length by 2.4m intervals to get 40 sections per beam. Multiply by 15 composite V-beams to get 600 sections of hollow structural steel (HSS102x102x6.4) of the length measured in OST (8.736 m of HSS per section - diagonal, vertical and horizontal (web of steel)).<br>600 sections of 8.736 meters of HSS102x102x6.4 will give 5241.6 m of this steel.<br>To get volume:<br>perimeter is .102 m * 4, with a thickness of 0.0064 m, and a length of 5241.6 m<br>Volume = .102*4*0.0064*5241.6 = 13.69 m^3 of HSS<br>Multiply by density... 13.69 m^3 * 7850 kg/m^3 * 1 tonne/ 1000 kg = 107.44 tonnes HSS<br>(Diagonal struts measured in RS203) |
| | | 5.1.6 - XBM_Composite Beams_Roof_HSS127x127x6.4 Struts_At Tops of Glulam | Steel members on inner face of glulam beams are HSS127x127x6.4. These run the length of the beams and are connected to each glulam beam. Therefore, with 97 meter beams and 30 glulam beams, we can determine the volume and then weight of this type of hollow structural steel used in this assemble. Steel member along bottom of V-shape web of steel is HSS 102x152x6.4. To simplify, we can assume this is a HSS 127x127x6.4 running parallel with the other two members (as indicated in cross section).<br>97 m of 45 (added 15 more for bottom of V - HSS 127x127x6.4) beams gives 4365 m of this steel in total.<br>To get volume:<br>perimeter is .127 m * 4, with a thickness of 0.0064 m, and a length of 4365 m<br>Volume = .127*4*0.0064*4365 = 14.19 m^3 of HSS<br>Multiply by density... 14.19 m^3 * 7850 kg/m^3 * 1 tonne/ 1000 kg = 111.403 tonnes HSS |
| | 5.2 WoodWave Panels | | |
| | | 5.2.1 - XBM_WoodWave Panels_Roof_SPF Lumber | Based on Richmond Olympic Oval brochure from WoodWorks and the Canadian Wood Council, "2400m^3 of SPF construction grade dimension lumber" used in WoodWave Roof. Asume kiln dried. |
| | | 5.2.2 - XBM_WoodWave Panels_Roof_Plywood | Based on Olympic Oval brochure from WoodWorks and the Canadian Wood Council, "1900 sheets of exterior grade Douglas Fir plywood" used in WoodWave Roof. Based on brochure, two layers (5/8 in. and 1/2 in. thick) were used. Using the construction images of the roof, estimate 30% of plywood membrane is 5/8". Therefore, the following equation will convert to total plywood area on a 9 mm basis.<br>Therefore, 0.7*19000*(1.27/0.9)*(1.44*2.88) + 0.3*19000*(1.59/0.9)*(1.44*2.88) = 119596 m^2<br>Assume sheet of plywood measures 1.44 m x 2.88 m |
| | | 5.2.3 - XBM_WoodWave Panels_Roof_Insulation | Based on Richmond Olympic Oval brochure from WoodWorks and the Canadian Wood Council, 450 WoodWave panels span between the glulam beams, each comprising 3 hollow triangular sections. This gives 1350 hollow triangular sections. Based on drawings in brochure, each section measures approx. 1.2 m wide by 0.66 m deep by 12.5 m long. This cavity is lined with "fibrous mineral wool insulation batts" approximately 0.15 m thick (based on drawings provided). Therefore, on a 25mm basis of Rockwool insulation (required input format for the IE) there total area of insulation in the WoodWave panels is calculated as follows: |

| | | |
|---|---|---|
| | | Outer length of cross section (1.2 m + .89 +.89) = 2.98 m. Mutiply this by the depth of cross section (2.98 m * 12.5 m) to get surface area = 37.25 m^2. For 25mm basis, multiply this area by 5 since the insulation is 150 mm thick in construction = 186.25 m^2 of insulation per section. Multiply this by 1350 WoodWave triangular sections to get total insulation on 25 mm basis for the WoodWave panels = 251438 m^2 |
| 5.3 Glulam Posts | | |
| | 5.3.1 - XBM_Glulam Columns_Roof Posts_Glulam_North Elevation | Assumptions: Based on WoodWorks brochure, glulam posts on North elevation constructed from stock 335mm x 458 mm glulam beams 11.5 m in length. Assume this to represent the volume of glulam wood used in construction as posts were lathed to their final oval shape. Count function used to count number of beams on North Elevation and input the 3 parameters to get total volume. |
| | 5.3.2 - XBM_Glulam Columns_Roof Posts_Glulam_South Entrance | Assumptions: Based on WoodWorks brochure, glulam posts at South entrance constructed from stock 350mm x 570 mm glulam beams 8.5 m in length. Assume this to represent the volume of glulam wood used in construction as posts were lathed to their final oval shape. Count function used to count number of beams on North Elevation and input the 3 parameters to get a volume using the count function. |
| 5.4 Other Roof Supports | | |
| | 5.5.1 - XBM_Horizontal HSS_Roof_HSS 305x305x13_Between Composite Beams | This is hollow rectangular steel with a wall thickness of 13 mm<br>Measured Beam lengths to be approx. 13.347 m = Height input<br>Width of beams = wall thickness = 13 mm (last number in 00x00x00 sequence)<br>Depth of beams = perimeter of wall segment = 4*305 mm = 1220 mm (wall segment is 305 mm long)<br>Therefore, use count function but output volume based on these parameters.<br><br>Weight is volume * density = 16.3 m^3 * 7850 kg/m^3 / 1000kg/tonne = 127.955 tonnes |
| | 5.5.2 - XBM_Horizontal HSS_Roof_HSS 305x305x13_Butress to Butress North Elev | This is hollow rectangular steel with a wall thickness of 12 mm spanning between buttresses on North Elevation.<br>Measured Beam lengths of beams to be approx. 14.225 m = Height input<br>Width of beams = wall thickness = 12 mm (last number in 00x00x00 sequence)<br>Depth of beams = length of wall segment = 4*406 mm = 1624 mm (wall segment is 406 mm long)<br>Therefore, use count function but output volume based on these parameters.<br><br>Weight is volume * density = 3.881m^3 * 7850 kg/m^3 / 1000kg/tonne = 30.366 tonnes |
| | 5.5.3 - XBM_Horizontal I-Beams_Roof_W610x82_Between Butresses South Elev | Wide Flange W610x82<br>Weight is 82 kg/m - second number in specification http://www.huntersteel.ca/<br>Therefore, find total length of this I-beam used and multiply by 82 kg/<br><br>156.29 m * 82 kg/m / 1000kg/tonne = 12.816 tonnes wide flange sections |
| | 5.5.4 - XBM_Roof Supports_Roof_HS273o11 _Beams to Butress | Cross sectional area is diameter multiplied by Pi multiplied by wall thickness. Thus 273*3.14159 = 857.75mm (circumference), 11 mm is the thickness, and 10.116m is the length of each member. Assume member is in plane of view and thus length can be measured off these drawings as the angle of inclination is minimal. Assume other counted members to be of similar lengths. Use count function with input parameters to measure total volume of hollow structural steel for these supports.<br><br>Multiply volume by density to get tonnes of hollow structural steel.<br><br>2.264 m^3 * 7850 kg/m^3 / 1000kg/tonne = 17.772 tonnes |
| | 5.5.5 - XBM_Cross Supports_Roof_HS141o6.4 _Beams to WoodWave | Measured lengths of HS141o6.4 used to support WoodWave panels from Composite V-Beams at Grid 2 of the drawings. Cross Sectional area of these beams is 141 * Pi * 6.4, which when multiplied by the total length of supports provides the volume of hollow steel used at Grid 2. These supports are the same for each V-Beam span, therefore, count 30 total (2 per beam) for the roof.<br><br>Total Volume = 0.141*3.14159*0.064*30 = 0.851 m^3 |

| | | | |
|---|---|---|---|
| | | | 0.851 m^3 * 7850 kg/m^3 / 1000kg/tonne = 6.676 tonnes |
| | | 5.5.6 - XBM_Horizontal I-beams_Roof_I-beams W610x174_At entrance | Measured total length of W610x174 I-beams at entrance roof.<br>Weight is 174 kg/m - second number in specification http://www.huntersteel.ca/<br>174 kg/m * 125.09 m * 1tonne/1000 kg = 21.75 tonnes |
| | 5.6 Envelope | | |
| | | 5.6.1 - XBM_Envelope Materials_Roof_R1/R2 | PVC membrane mechanically fastened therefore no ballast needed. Based on sample bill of materials for PVC roofing in the IE, 5.047 kg of PVC membrane used per m^2 of roofing.<br>Assume Extruded Polystyrene (4 inches as indicated) - isocyanurate insulation N/A in the IE<br>Use 1/2 inch Type"X" Fire-rated gypsum board on decking instead of 1/4" dens deck (N/A in the IE). Based on research online, similar properties, but divide area by 2 to compensate for double thickness input. <http://www.gp.com/build/product.aspx?pid=4664><br>As some rounded profile of roof creates minimal error in plan area measurement. Also, only difference between R1 and R2 type is color of membrane.<br><br>Area of R1/R2 = 18635 m^2.<br>Therefore, Total PVC membrane (kg) is: 18635*5.047 = 94050.845 kg<br>Total Extruded Polystyrene (m^2, 25mm basis) is 18635*4inches*25.4mm/inch/25mm = 75732.64 m^2<br>Total 1/2" Fire-rated Type X Gypsum Board (m^2) is 18635/2 = 9317.5 m^2 |
| | | 5.6.2 - XBM_Envelope Materials_Roof_R3 | PVC membrane mechanically fastened therefore no ballast needed. Based on sample bill of materials for PVC roofing in the IE, 5.047 kg of PVC membrane used per m^2 of roofing.<br>Assume Extruded Polystyrene (2 inches as indicated) - isocyanurate insulation N/A in the IE<br>Use 1/2 inch Type"X" Fire-rated gypsum board on decking instead of 1/4" dens deck (N/A in the IE). Based on research online, similar properties, but divide area by 2 to compensate for double thickness input. <http://www.gp.com/build/product.aspx?pid=4664><br>As some rounded profile of roof creates minimal error in plan area measurement. Also, only difference between R1 and R2 type is color of membrane.<br><br>Area of R3 = 2696 m^2.<br>Therefore, Total PVC membrane (kg) is: 2696*5.047 = 13606.7 kg<br>Total Extruded Polystyrene (m^2, 25mm basis) is 2696*2inches*25.4mm/inch/25mm = 5478.27 m^2<br>Total 1/2" Fire-rated Type X Gypsum Board (m^2) is 2696/2 = 1348 m^2 |
| | | 5.6.3 - XBM_Envelope Materials_Roof_R4 | PVC membrane mechanically fastened therefore no ballast needed. Based on sample bill of materials for PVC roofing in the IE, 5.047 kg of PVC membrane used per m^2 of roofing.<br>Assume Extruded Polystyrene (4 inches as indicated) - isocyanurate insulation N/A in the IE<br>Use 5/8 inch Type"X" gypsum board on decking as indicated.<br><br>Area of R4 = 663.8 m^2.<br>Therefore, Total PVC membrane (kg) is: 663.8*5.047 = 3350.2 kg<br>Total Extruded Polystyrene (m^2, 25mm basis) is 663.8*4inches*25.4mm/inch/25mm = 2697.7 m^2<br>Total 5/8" Fire-rated Type X Gypsum Board (m^2) is = 663.8 m^2 |
| 6 Earthworks | | | |
| | 6.1 Pre-Loading | | |
| | | 6.1.1 Pre-load material | Volumes were taken from the drawing "Preload Plan" provided by Delcan. Preload material was assumed to be gravel (aggregate stone) and the density was assumed to be 1330kg/m^3 from "Life Cycle Assessment of Road" issued by the Swedish Environmental Research Institute. Dry density was used to avoid the IE Impact Estimator considering volume of water as stone for the purposes of resource extraction and disposal. |

**Table 22 - Stair Dimension Calculations**

| Stair # | Floor | throat | width | length | height | slope |
|---|---|---|---|---|---|---|
| 1 | 1-2 | 300 | 3000 | - | 4900 | 10900 |
|  | 2-3 | 300 | 1900 | - | 4500 | 9000 |
| 2 | 1-2 | 300 | 1900 | - | 4900 | 9000 |
|  | 2-3 | 300 | 1900 | - | 4500 | 9000 |
| 3 | 1-2 | 175 | 1800 | 8100 | 4900 | 9500 |
|  | 2-3 | 175 | 1800 | 8100 | 4500 | 9300 |
| 4 | 1-2 | 175 | 1400 | 8900 | 4900 | 10200 |
|  | 2-3 | - | - | - | 4500 | - |
| 5 | 1-2 | 175 | 7100 | 11300 | 4900 | 12300 |
|  | 2-3 | - | - | - | 4500 | - |
| 6 | 1-2 | 175 | 1600 | 8000 | 4900 | 9400 |
|  | 2-3 | - | - | - | 4500 | - |
| 7 | 1-2 | 175 | 1800 | 8100 | 4900 | 9500 |
|  | 2-3 | 175 | 1800 | 8100 | 4500 | 9300 |
| 8 | 1-2 | 175 | 1800 | 8100 | 4900 | 9500 |
|  | 2-3 | 175 | 1800 | 8100 | 4500 | 9300 |
| 9 | 1-2 | 175 | 3200 | - | 4900 | 11100 |
|  | 2-3 | - | - | - | 4500 | - |

## Table 23 - Typical Beam Reinforcement Calculations

| | | | | | |
|---|---|---|---|---|---|
| Total Beam Length | 113900 | mm | Density of Steel | 7.85 | g/cm^3 |
| Beam Width | 3600 | mm | | | |
| Beam Area | 410040000 | mm^2 | | | |

| **Top Reinforcement** | | **Bottom Reinforcement** | | **Stirrups** | |
|---|---|---|---|---|---|
| Type | Length (mm) | Type | Length (mm) | Type | Length (mm) |
| T1B | **2850** | B19 | **8700** | C | **6900** |
| T19 | **15400** | | 9900 | J12 | **1100** |
| T14 | 7800 | B14 | 8000 | CC | 8100 |
| | 7800 | | 9000 | | 8900 |
| | 7800 | | 8000 | Sub Total | **17000** |
| | 7800 | | 9000 | R | 1150 |
| | 16200 | Sub Total | **43900** | | 21500 |
| Sub Total | **47400** | B10 | **9000** | | 20500 |
| T8 | 7800 | B9 | 9000 | | 9300 |
| | 7800 | | 9000 | Sub Total | **52450** |
| | 7800 | | 8000 | T | 3050 |
| Sub Total | **23400** | | 9300 | | 13350 |
| T6 | **7800** | Sub Total | **35300** | Sub Total | **16400** |
| 4-20M bars | 113900 | B18 | **13650** | | |
| LENGTH CHECK | 96850 | LENGTH CHECK | 110550 | | |

**Reinforcement**

| Type | Bar Size | # of Bars | | Area (mm^2) | Volume (mm^3) |
|---|---|---|---|---|---|
| Type | | | | | |
| T1 | 20M | 4 | | 300 | 140100000 |
| T19 | 35M | 13 | | 1000 | 200200000 |
| T14 | 30M | 12 | | 700 | 398160000 |
| T8 | 25M | 9 | | 500 | 105300000 |
| T6 | 25M | 6 | | 500 | 23400000 |
| B19 | 35M | 12 | | 1000 | 104400000 |
| B14 | 30M | 11 | | 700 | 338030000 |
| B10 | 25M | 11 | | 500 | 49500000 |
| B9 | 25M | 10 | | 500 | 176500000 |
| B18 | 30M | 15 | | 700 | 143325000 |
| | | | | **TOTAL** | **1678915000** |

**Ties**

| Type | Bar Size | Area (mm^2) | Spacing (mm) | Length (mm) | # of ties | Volume (mm^3) |
|---|---|---|---|---|---|---|
| C | 10M | 100 | 250 | 7800 | 27.6 | 21528000 |
| J | 15M | 200 | 225 | 7800 | 12 | 18720000 |
| CC | 10M | 100 | 200 | 10800 | 85 | 91800000 |
| R | 15M | 200 | 300 | 10800 | 174.8333333 | 377640000 |
| T | 15M | 200 | 250 | 10800 | 65.6 | 141696000 |
| | | | | | **TOTAL** | **651384000** |

| | | |
|---|---|---|
| GRAND TOTAL (mm^3) | 2330299000 | |
| GRAND TOTAL (cm^3) | 2330299 | |
| Total Mass | 18292847.15 | g |
| Total Mass | 18.29284715 | tonnes |
| **TONNES PER SQUARE METER** | **0.044612348** | **tonnes/m^2 concrete slab band** |

**Table 24 - Typical Slab Reinforcement Calculations**

**Typical Slab**

| Type | Bar Size | Bar Area (mm^2) | Spacing (mm) |
|---|---|---|---|
| TYP | 15M | 200 | 100 |

m^3 steel/m^2 slab

0.002

**TONNES PER SQUARE METER:**

**0.0157**

**HCP cover slab**

| Type | Bar Size | Bar Area (mm^2) | Spacing (mm) | |
|---|---|---|---|---|
| Top | 10M | 100 | 300 | each way |

m^3 steel/m^2 slab

0.000666667

**TONNES PER SQUARE METER:**

**0.005233333**

**Table 25 - Pre-loading Volume Calculations**

| **Lobby Slope** | | | | | |
|---|---|---|---|---|---|
| Height 1 | Height 2 | delta height | width | length | volume |
| 8.4 | 4 | 4.4 | 5.77 | 53.45 | **678.4943** |

| **Northern Loading** | | |
|---|---|---|
| Area (m2) | Height (m) | Volume (m^3) |
| 4557.25 | 8 | 36458 |
| 3316.84 | 7 | 23217.88 |
| 1174.72 | 6 | 7048.32 |
| | **TOTAL** | **66724.2** |

| **Northern Slopes** | | | | |
|---|---|---|---|---|
| Height 1 | Height 2 | delta height | area | volume |
| 8 | 7 | 1 | 579.02 | 289.51 |
| 7 | 6 | 1 | 170.61 | 85.305 |
| 6 | 0 | 6 | 692.63 | 2077.89 |
| 7 | 0 | 7 | 711.32 | 2489.62 |
| 8 | 6 | 2 | 29.49 | 29.49 |
| 8 | 0 | 8 | 411.1 | 1644.4 |
| 8 | 4 | 4 | 486.88 | 973.76 |
| 4 | 0 | 4 | 310.52 | 621.04 |
| | | | **TOTAL** | **8211.015** |

| **GRAND TOTAL VOLUME (m^3):** | **288335** | | |
|---|---|---|---|
| From Swedish Road LCA: | | | |
| Loose Gravel Density (dry): | 1330 | kg/m^3 | (assumed dry) |
| Loose Gravel Density (wet): | 2130 | kg/m^3 | |

| **TOTAL WEIGHT (kg)** | **383485508.6** |
|---|---|

# APPENDIX C – DELCAN PRE-LOADING DIAGRAMS