UBC Botanical Garden Redevelopment Detailed Design Report

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University of British Columbia

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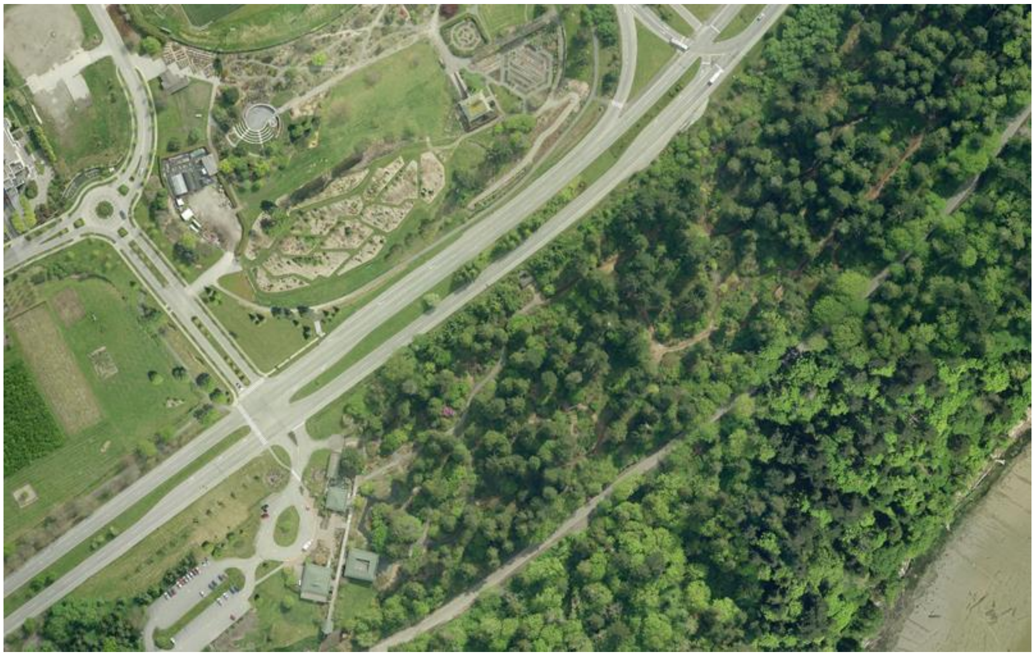
Prepared for

UBC CIVIL 446 and UBC Botanical Garden



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Executive Summary

This document "UBC Botanical Garden Redevelopment Detailed Design Report" is submitted by Group 1 in response to request by UBC Botanical Garden and also as a course deliverable for CIVIL 446. The design report presents Group 1's conceptual designs, detailed designs, construction schedule, and estimated costs for the Relaxation and Learning Design Project.

One detailed design and two conceptual design components are selected from the guideline for Project No.4, namely the Green Café, Conservatory Expansion and Signage Upgrade. Detailed design is performed for the Green Café, which focuses on three major engineering disciplines, namely: Structural Engineering, Geotechnical Engineering, and Hydrotechnical Engineering, with Structural Engineering being the primary focus. A Detailed Cost Estimate and a Construction Schedule are also completed for the Green Café Design. For the other two components of the project, only conceptual designs were completed. To perform this work, Group 1 reviewed technical guidelines and codes, as well as previous designs and analyses. Group 1 also performed site investigations to confirm the feasibility of the designs. The design considerations, analyses and calculations are presented individually in this report for each component.

The total estimated cost for the Green Café is approximately $1.24 million CAD. The estimated construction duration for the Green Café was estimated to be approximately 10 months. Some details may be adjusted depending on actual site conditions during construction, but the schedule and estimated cost make reasonable assumptions and develop a logical sequence of tasks for the Botanical Garden's planning and consideration.

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1.0 Introduction

This design report aims to provide UBC Botanical Garden and CIVIL 446 instructors with a summary of the work that Group 1 performed for the project, and also sufficient details for the design components to be implemented.

This design report is structured to first provide the design background of the UBC Botanical Garden and followed with our analysis and design details. The project background can be found in *Section 2.0*. A total of three designs are included in this report, namely the Green Café, Conservatory Expansion and Walkway Renovation. The design consideration, technical details, cost estimate, and schedule of the Green Café are presented in *Section 4.0*. The conceptual designs and layouts for the Conservatory Expansion and Signage Upgrade are presented in *Section 5.0* and *Section 6.0* respectively. The location of each design component is shown in Figure 1.

Figure 1: Components Summary

2.0 Project Background

The UBC Botanical Garden is located at the South West portion of the UBC Vancouver campus, with Southwest Marine Drive running through its center. They were established in 1916 and are Canada's oldest operating Botanical Garden based on a University Campus. Their main goal is to protect and maintain a vast array of unique plant species for research and conservation purposes. The Garden is currently home to a collection of 12 000 plants, representing 8000 taxa from around the world. The Garden also serves as a key part of UBC's biodiversity collections for researchers, students and the public. They rely on funding from the University, private donors, and the small proceeds from admission and event fees. Lately, the Botanical Garden has been struggling to obtain funding to maintain the garden, and relies on a network of garden volunteers to care for the plants. For this reason, the UBC Botanical Garden has requested Civil 446 Capstone Class to assist with detailed designs for their redevelopment plan.

The management committee of UBC and UBC Botanical Garden has selected and grouped the conceptual designs ideas submitted by CIVIL 445 into 5 design projects. Group 1 is assigned to complete the detailed designs for *Project #4 Relaxing and Learning: Conservatory, Café, Walkways*. The general description of the project is listed below:

1) Conservatory Renovation/Expansion
2) Greenhouse Café
3) Adventure/Educational Type Loops and Overhead Walkway
4) Consider ecological sensitivity of the area & Staged development

3.0 Codes and Standards

The proposed upgrades to the UBC Botanical Garden are being designed in accordance with the UBC Technical Guidelines for Architects and Engineers which govern all University owned buildings on campus. UBC specific live loads and climatic data will be as per Building, Structural & Snow Load Design requirements included in UBC Technical Guidelines – 2013 Edition, Division 3 Part 1. Additional requirements in the UBC Technical Guidelines will be considered. The structural components are designed to meet the guidelines provided by Part 4 of the British Columbia Building Code (BCBC 2012), as well as the National Building Code of Canada (NBCC 2010). All steel construction is designed in compliance with the Handbook of Steel Construction, 10th Edition, timber is designed using the Wood Design Manual 2010, by the Canadian Wood Council, and Concrete is designed using the Concrete Design Handbook, 3rd Edition.

4.0 Green Café Design

4.1 Design Considerations

The following sections describe the background, key assumptions and design approach for the for the Green Café design.

4.1.1 Structural Considerations

The main discipline of focus for the Green Café is the structural component. The following sections will focus on structural design including materials, requirements, and analyses.

4.1.1.1 Structural Materials Strength

Material strengths used in the design of the Green Café were taken from the materials' respective design codes. All glulam beams are of type D.Fir.L 24f-EX variety. The table below specifies the material strength for the glulam beams, timber columns, and steel columns.

Table 1: Material Strength Properties for Beams & Columns

Material	Douglas Fir Larch 24f-Ex		D.Fir-L No.2 Grade Timber Columns		Steel Columns	
Bending Moment (Fb)	30.6	MPa	10.0	MPa		MPa
Longitudinal Shear (Fv)	2.0	MPa	1.9	MPa		MPa
Compression Bearing (Fcp)	7	MPa	7.0	MPa		MPa
Modulus of Elasticity (E)	12 800	MPa	11000	MPa	200 000	MPa

4.1.2.2 Loading Requirements

The Green Café has been designed for the loads listed in the Table 2. The roof is designed to carry snow, green roof, self-weight, and live loading. The back half of the roof that is accessible by the public has been designed for assembly loading, whereas the front half of the roof has been designed for the loads of a maintenance crew only. The snow load has been calculated using data in the BC Building Code. Detailed calculations of the snow load can be found in the Appendix. The slab on Level 2 has been designed for six inches of growing media. The slab on Level 2 is designed as an assembly area, and has a superimposed load to account for partitions and permanent furniture, as well as its self-weight. Only vertical loads are given, as lateral design of the building was not part of the design scope.

Table 2: Green Café Design Loads

Roof Loads (kPa)		Level 2 Loads (kPa)	
Snow	2.00	**Superimposed Load**	1.00
Soil (ADL)	2.00	**Self-Weight**	2.40
Self-Weight	2.60	**Live Load (Assembly)**	4.80
Live Load (Assembly)	4.80		
Live Load (No Access)	1.00		

4.1.2.3 Serviceability Requirements

The Green Café has been checked against the deflection requirements specified in the British Columbia Building Code. The glulam roof beams have been designed with less than L/360 deflection. The deflection diagram from the RISA-2D modelling of the beams is provided below. Two diagrams are provided, as the beam analysis was split at the center node. The maximum deflection in the roof beam with the highest load is 25.62 mm over a 10 m span, under the allowable 27.8 mm for such span. The Serviceability Loads are summarized in Table 3.

Table 3: Serviceability Loads

Serviceability Loads		
Accessible Roof	8.31	kPa
Non-Access Roof	4.92	kPa

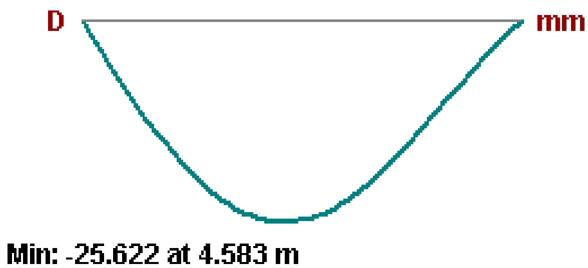

Figure 2: Roof Deflection for Green Café

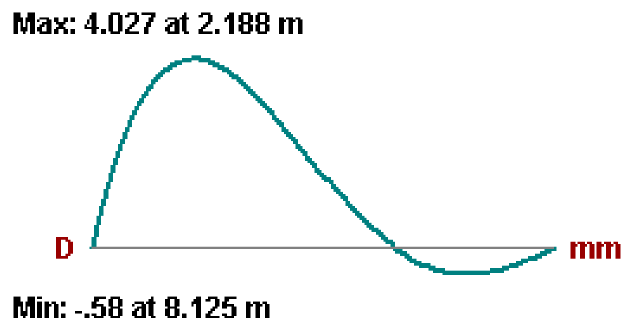

Figure 3: Roof Deflection for Green Café

4.1.3 Environmental Considerations

As a University of British Columbia requirement, all new buildings on campus need to achieve LEED Gold certification. LEED certification is a way of ensuring that buildings are designed with a holistic approach to achieving sustainability. The LEED certification is a point based system, where points are earned for each aspect of the design that promotes a building with a small environmental footprint. A LEED Gold building must achieve between 60 to 79 points. Our design portion for the Green Café will achieve points in construction waste management, recycled content materials, regional materials, rapidly renewable materials, and by using certified wood glulam beams. The building will also achieve many of its points from the Sustainable Site category.

4.1.4 Geotechnical Consideration

In order to understand the Geotechnical conditions of the proposed site for the Green Café, a Geotechnical Investigation was undertaken using technical studies completed on UBC. The *Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver completed by Piteau Associates Engineering Ltd* (Piteau, 2002) has provided a conclusive study on the Hydro-Geological conditions of the Northwest area of UBC Vancouver Campus, which contains borehole information from ground surface down to 10 m below sea level. These boreholes reveal that the UBC area has a relatively uniform soil profile with surficial till and an underlying sand layer, which is consistent with information provided by *GeoMap Vancouver* (Geological Survey of Canada, 1998) and *Surficial Geology Vancouver* (Geological Survey of Canada, 1979). The two maps describe UBC area as "Vcb", where soil is formed by glacial drift and is categorized as excellent foundation material with high bearing capacity and low earthquake liquefaction hazard. As Piteau's study was focused on the North side of UBC Area and UBC Botanical Garden is located at the South portion of UBC, additional sources are required. GeoPacific Consultants Ltd completed a Geotechnical Report for the proposed Pharmaceutical Science Building in 2009 (GeoPacific, 2009) which contains additional geology and borehole information of the South Campus. Similar to previous findings, the site has surficial till with underlying sand layer. Based on the above findings, it is concluded that UBC Area has a fairly consistent soil profile.

As no borehole or other geological studies have been completed at the UBC Botanical Garden, the soil properties and site stratigraphy have to be deduced. The proposed site for the Green Café is within 1 km diameter of the closest studied boreholes which suggests that the soil condition shall be fairly similar. The elevation of the proposed Green Café site is approximately 70 m above sea level, and the surficial till layers of the two studied area begins at 75 m above sea level, which suggests that there is no surficial till layer presents at the Green Café Site. Further, the studies also review that the water level of UBC is generally 40 m below ground surface. In order to complete the settlement and bearing capacity analysis of the site, the sand layer properties are extracted from Trow's Geotechnical Report on UBC Cliff Slope Stability Analysis (Trow, 2002). Based on current site condition, there exists a layer of top soil and vegetation which shall be over excavated and compacted prior to foundation construction. With all these information, the theoretical site stratigraphy is illustrated below in Figure 4.

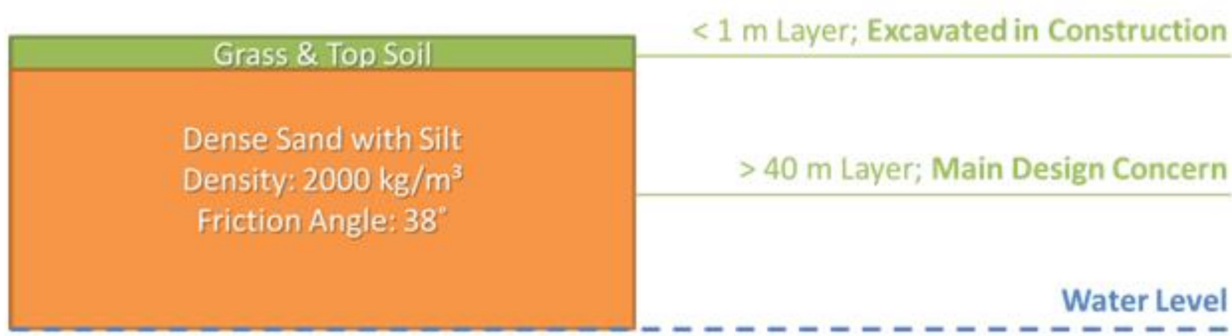

Figure 4: Site Soil Stratigraphy

4.1.5 Hydrotechnical Considerations

In order to reduce the reliance of water supply for the Green Roof, a storm water storage system is to be included in the Green Roof design. To perform the design, total annual precipitation and annual evapotranspiration data recorded at UBC from 1961 to 1990 were taken from the *Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver completed by Piteau Associates Engineering Ltd* (Piteau, 2002). As the design scope of the storm water storage system is only to reduce reliance on water supply, the average precipitation data was used instead of the maximum. The other design parameters used for the water retention system include catchment area of the green roof and net infiltration. The rest of the components such as the storage tank, pipes and pumps were sized based on the amount of infiltration produced by the data. The pump must be able to provide head greater than 8 m to pump the retained water back to the green roof. All the design parameters are summarized in Table 4.

Table 4: Hydrotechnical Parameters

Average Annual Precipitation (mm)	Average Evapotranspiration (mm)	Green Roof Catchment Area (m^2)
1288	646	290

4.2 Design Calculations

The following section will detail the structural and foundation load calculations.

4.2.1 Structural Loads Calculations

The load take-down for the Green Café was performed using the applied loads specified in Section 4.1.2.2, and factoring them according to the BC Building Code. Tributary areas for the roof beams and columns were measured off the Revit Model, so that loads could be carried down to the foundations. The load take-down is located in Appendix B. The snow load on the roof is calculated in accordance with Clause 4.1.6 of the BC Building code. Snow load calculations are shown below.

Table 5: Snow Load Calculations

I_S	**Importance Factor**	**1**	
S_S	1 in 50 year snow load	1.0	Kpa
C_W	Wind Exposure Factor	1	
C_S	Slope Factor	1	
C_A	Shape Factor	1	
S_R	1 in 50 year rain load	0.3	Kpa
C_B	Basic roof snow load factor	0.8	
Check: $S_R<S_SC_BC_WC_S$		OK	
S	Snow Load	1.82	Kpa

4.2.2 Foundation Loads Calculations

As noted, the top soil and vegetation will be over-excavated. The soil at founding level would consist of dense sand with silt, which would be suitable for a building foundation. The dense sand layer is categorized as coarse grained materials; therefore, *Effective Stress Analysis (ESA)* was selected to estimate the bearing capacity of the proposed shallow foundations and *Schmertmann's 1978 method* was used to estimate the settlement of the proposed shallow foundations. For the scope of the project and ease of construction, a typical square pad footing and a typical strip footing were designed for all the columns and walls respectively. The loads used in the calculation are the maximum loading of the columns and walls.

The design criteria for the foundation design are listed below:

1) Provide Sufficient Capacity for the Applied Load
2) Do not exceed 25 mm of total settlement and 10 mm/5m Differential Settlement

Key assumptions and equations used in the calculations of ESA and Settlement are described in *Section 4.2.2.1* and *Section 4.2.2.2* respectively. The final results and footing designs are presented in *Section 4.3.3*.

4.2.2.1 Effective Stress Analysis

The bearing capacity of the footing design is calculated using the parameters specified in *Section 4.1.4* and the ESA equation shown below.

Effective Stress Analysis (ESA)

$$q_u = \gamma D_f (N_q - 1)(s_q d_q i_q b_q g_q r_q w_q) + 0.5\gamma B' N_\gamma (s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma r_\gamma w_\gamma)$$

As shown in the stratigraphy, the water level is more than 40 m below surface, which is beyond the sum of embedded depth and footing width. This is categorized as *Case 1 for ground water* *correction*, which no correction is needed. The loads of the footing are assumed to be centric, thus the design footing dimensions are equal to the effective dimensions used in the equation. Due to the simplicity of the loading case and design geometry, none of the inclination and soil compressibility factors (*i*, *b*, *g*, *r*) were assumed to be relevant in the calculation. The shape factors (s) were calculated using the equation shown below.

$$s_{y} = 1 - 0.4\left(\frac{B}{L}\right);\;\; s_q = 1 + (\frac{B}{L} * \left(tan(Frictional\ Angle\right))$$

The N values used in the equation were calculated using *Meyerhof (1976) Equation* shown below.

$$\text{Meyerhof (1976): } N_\gamma = (N_q - 1)\tan(1.4\phi'_p);\ \phi'_p \text{ in degrees}$$

4.2.2.2 Settlement Calculation (Schmertmann's 1978 method)

The settlement of the footing design is calculated using the parameters specified in *Section 4.1.4* and the Schmertmann's Equation and Influence Factor Diagram shown below.

$$\rho = C_1 C_2 C_3 (q - \sigma'_{zD}) \Sigma \frac{I_\varepsilon H}{E_s}$$

$$C_1 = 1 - 0.5\left(\frac{\sigma'_{zD}}{q - \sigma'_{zD}}\right)$$

$$C_2 = 1 + 0.2 \log\left(\frac{t}{0.1}\right)$$

$$C_3 = 1.03 - 0.03\, L/B \geq 0.73$$

Where:
- δ = settlement of footing
- C_1 = depth factor
- C_2 = secondary creep factor (see discussion in Section 7.8)
- C_3 = shape factor = 1 for square and circular foundations
- q = bearing pressure
- σ_{zD}' = effective vertical stress at a depth D below the ground surface
- I_ε = influence factor at midpoint of soil layer
- H = thickness of soil layer
- E_s = equivalent modulus of elasticity in soil layer
- t = time since application of load (yr) ($t \geq 0.1$ yr)
- B = foundation width
- L = foundation length

Figure 5: Schmertmann's Equation

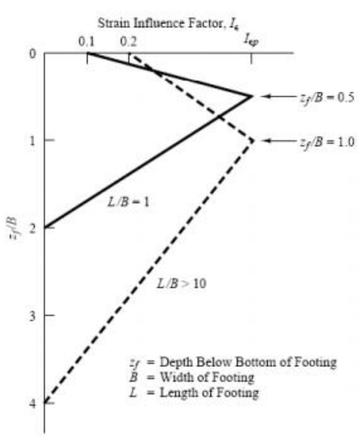

Figure 6: Influence Factor Diagram

The creep factor was calculated based on a service life of 100 years as prescribed by UBC and the peak influence factor is calculated by the equation shown below.

$$I_{\varepsilon p}=0.5+0.1\sqrt{[(q-\sigma'_{zd})/\sigma'_{zp}]}$$

4.3 Final Design

4.3.1 General Design

The Green Café was inspired by the Cactus Club at Coal Harbor and Group 1 chose to implement the accessible green roof into the design. A portion of the green roof is accessible to the public through a staircase at the back of the building while the front half of it remains blocked off. This is to minimize the live load on the roof beams and to prevent excessive loading on the tall steel columns hidden within the curtain wall system. The Green Café also features interior green walls to promote sustainability and create a friendly, relaxing atmosphere for all visitors. Figures 7 and 8 display the Green Café at a couple different angles.

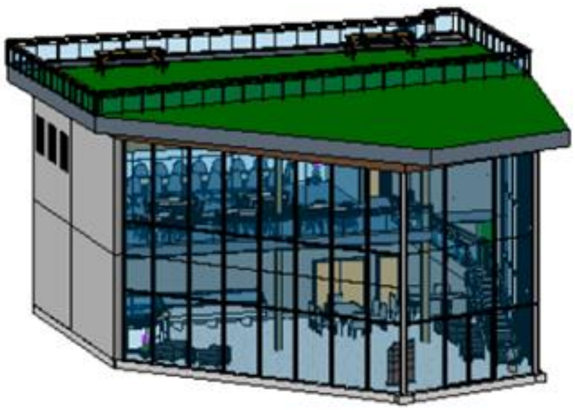

Figure 7: Overview of the Green Café

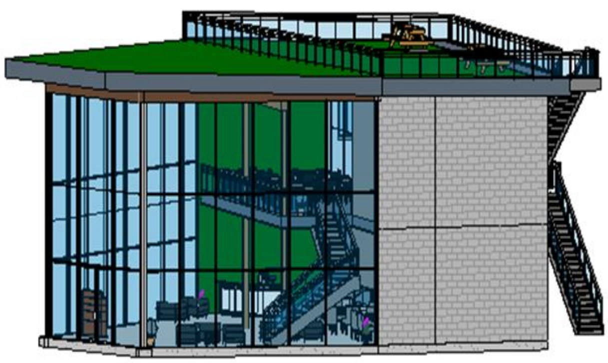

Figure 8: Overview of the Green Café

A curtain wall assembly design was implemented for the exterior front side of the café. This is to promote open space and to provide guests with an opportunity to look at peaceful surroundings while they enjoy their food and drinks. The Green Café is just less than 3800 ft^2 in size and serves multiple purposes.

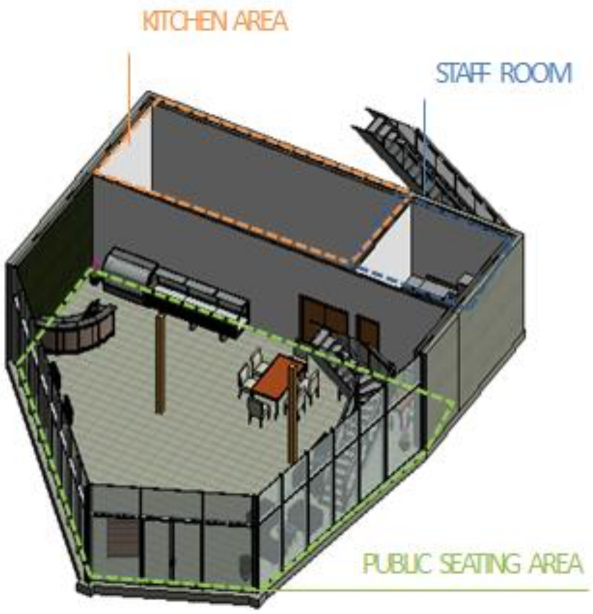

Figure 9: Green Café Level 1 Overview

Figure 10: Green Café Level 2 Overview

As shown in Figure 9, the 1st level of the Green Café holds 475 ft^2 of kitchen area, wherein food preparation and storage facilities are available. A staff room, sized 175 ft^2, provides space for staff meetings and breaks. The 1725 ft^2 of open space is available for events and public seating. This includes the food sales area and seating area for guests.

The second level of the Green Café can be seen in Figure 10, it features a 675 ft^2 interactive learning space which may be utilized in multiple classroom type settings. This also allows the students to examine the green wall of the Green Café and understand how it functions. The conference room, featuring 475 ft^2 of space, functions as both a meeting room and a more casual party room. The remaining space is allocated to washrooms which are separate for each gender.

4.3.2 Structural System Design

The Green Café is made up of steel and timber columns, concrete walls, and glulam beams with timber joists. Structural drawings are located in Appendix A. The scope of our work included the design of the glulam beams supporting the roof, timber columns on the interior of the building, and steel columns at the front of the café, hidden within the curtain wall system.

The glulam roof beams were modelled in RISA-2D to analyze moment and shear demand, as well as serviceability requirements. The results of the RISA-2D analysis are shown below. Similar analysis was performed for the beam perpendicular to the main roof beams, supporting them at mid-span, although this is not shown in the report.

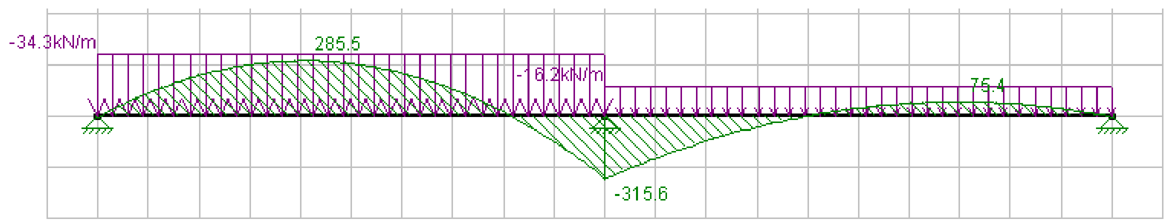

Figure 11: Roof Beam Moment Diagram

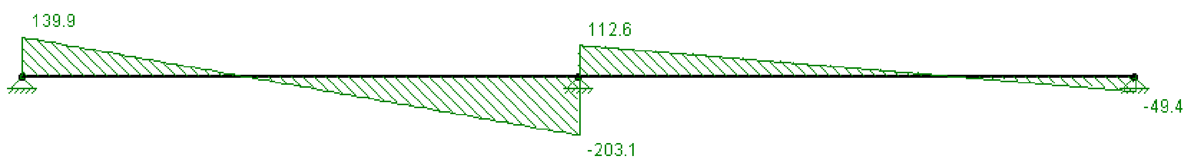

Figure 12: Roof Beam Shear Diagram

Glulam was chosen for the roof beams, with high utilization in all aspects of design, governed by shear at 94% utilization. The roof beams are all the same size, 315 mm wide and 532 mm deep. They are to be constructed out of Douglas-Fir.-Larch variety timber, grade 24f-Ex. This grade of timber is necessary due to the high load on the beams, as well as the requirement to resist both positive and negative bending moments. The beam that spans perpendicular to the main glulam beams, supporting them from below is to be manufactured in the same grade of timber, but will be 315 mm wide and 456 mm deep. The full design calculations are in Appendix B, and a design summary is shown below.

Table 6: Green Café Beam Design Summary

315x532 Douglas-Fir-Larch 24f-EX Beam			315x456 Douglas-Fir-Larch 24f-EX Beam		
Moment Check			Moment Check		
Factored Moment	315.60	kNm	Factored Moment	205.70	kNm
Moment Resistance	342.84	kNm	Moment Resistance	274.51	kNm
Utilization	92%	OK	Utilization	75%	OK
Deflection Check			Deflection Check		
Deflection Limit	27.78	mm	Deflection Limit	17.22	mm
Deflection	25.60	mm	Deflection	7.57	mm
Utilization	92%	OK	Utilization	44%	OK
Shear Check			Shear Check		
Factored Shear	203	kN	Factored Shear	165	kN
Shear Resistance	215.0	kN	Shear Resistance	172.0	kN
Utilization	94%	OK	Utilization	96%	OK

The structural system has been designed so that columns are pin-pin configuration for all members to prevent excessive moments from being transferred to the columns. This helped simplify load and force analysis on the members. Also, it is assumed that the reinforced concrete walls will fully resist any lateral loads exerted upon the structure. Therefore, lateral forces are not considered in the analysis of the columns.

From Section 4.2.1, axial load on the interior first floor columns is approximately 270kN. Table 7 shows the analysis for No. 2 Grade 191x191mm D.Fir-L lumber column. There will be two of these columns on the first floor; both working to support the roof loads and any loads from the mezzanine level. Utilization is about 50%, however smaller standard columns cannot sustain the axial loading. Otherwise, the column meets slenderness and resistance requirements.

Table 7: Green Café Column Design Summary – First Floor

Interior Columns		
Length	8	m
First Floor		
Material	No. 2 Grade D.Fir-L Lumber	
Width	191	mm
Depth	191	mm
Slenderness Check		
Deflection Limit	50	
Slenderness Ratio	20.94	
Check	GOOD	
Axial Check		
Axial Resistance, factored	282.09	kN
Axial Load, factored (per column)	135.29	kN
Check	GOOD	
Utilization	48%	

Interior columns on the second floor (mezzanine layer) are also designed to be timber columns. Using the same material – No. 2 Grade 191x191mm D.Fir-L – can help minimize wastes and ease installation. There will be three columns running from the mezzanine layer up to the roof-beam system, with the columns supporting the cross-beam.

Table 8: Green Café Column Design Summary – Second Floor

Second Floor		
Material	No. 2 Grade D.Fir-L Lumber	
Width	140	mm
Depth	140	mm
Slenderness Check		
Deflection Limit	50	
Slenderness Ratio	28.57	
Check	GOOD	
Axial Check		
Axial Resistance, factored	98.89	kN
Axial Load, factored (per column)	97.31	kN
Check	GOOD	
Utilization	98%	

Table 8 shows the analysis results for the two second floor interior columns. 1st and 2nd floor columns are the same type, but smaller dimension were used for 2nd floor for the smaller load. The utilization for these columns are 98%, which are more efficient than the first floor columns. The slenderness and resistance checks are adequate.

Table 9: Green Café Exterior Columns Design Summary

Exterior Column		
Length	8	m
First Floor		
Material	W200x36	
Flange Width	165	mm
Flange Thickness	10.2	mm
Web Depth	201	mm
Web Thickness	6.2	mm
Slenderness Check		
Deflection Limit	200	
Slenderness Ratio	195.60	
Check	GOOD	**Limiting**
Axial Check		
Axial Resistance, factored	200.79	kN
Axial Load, factored (per column)	80.00	kN
Check	GOOD	
Utilization	40%	

The exterior columns run from the ground level up to the roof system. Steel was the chosen material because it was determined that the long length could cause slenderness issues for timber. Table 9 above shows the design values for the two exterior columns fronting the Café. The axial resistance is larger than the design load and although the utilization is only 40%, a smaller size column could not be chosen because slenderness was found to be the limiting factor.

4.3.3 Foundation Design

Based on loading requirements, considerations described in *Section 4.1.4* and calculations described in *Section 4.2.2*, one pad footing and one strip footing are designed for all the structural columns and walls respectively. Using the same designs for all the columns and walls simplified the design process to meet the scope of the project. However, it is noted that the design can be tailored and optimized for each column and wall, for which would exceed the scope of work. Nonetheless, the proposed foundation designs meet all the design criteria and codes. The design drawing is attached in Appendix A. The summary of the design and calculations are presented in Table 10.

Table 10: Foundation Design Summary

	Footing Type	Embedded Depth	Dimensions	Bearing Capacity	Max. Load	Utilization	Settlement
		(m)	W x L x D (mm)	(kPa)	(kPa)	(%)	(mm)
Columns	Square Pad	0.5	900 x 900 x 300	1106	320	28.9%	24
Walls	Strip	0.5	800 x L x 300	1177	341	28.9%	22

4.3.4 Drainage and Water Storage Design

The Green Roof will feature mainly grass and wildflowers that are native to Vancouver, and can handle wet winters and hot dry summers. These plants require minimal top soil depth of 3” and will be underlain by a filter layer, a drainage layer, a protection mat, a waterproof membrane, and an insulation layer from the concrete slab as shown in Figure 13. This design will provide sufficient filtering and minimal maintenance. However, the waterproof membrane must be inspected annually to prevent leakage to the concrete.

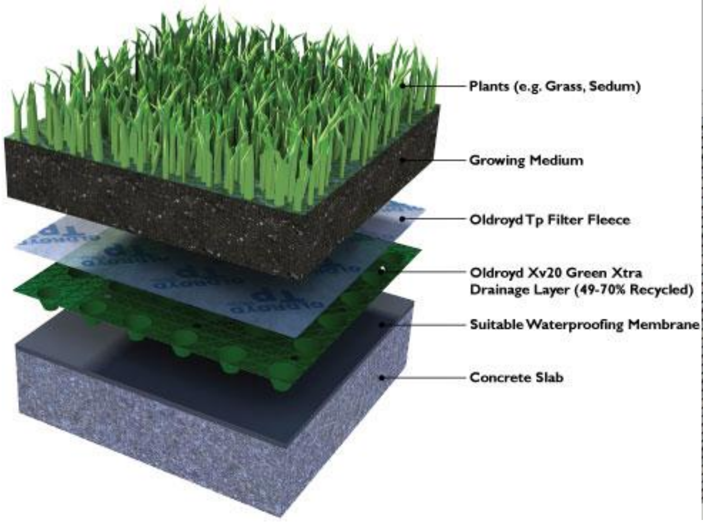

Figure 13: Green Roof Layers

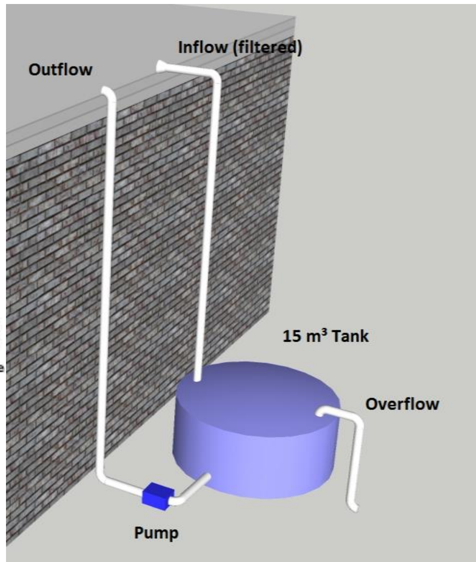

Figure 14: Green Roof Storage Design

The proposed water retention system reduces the storm run-off by capturing rainwater from the green roof for storage in an exterior tank for irrigation during dry months. An example of the storage system is shown in Figure 14. The green roof has a 1.75° slope to funnel the storm water into a 100 mm diameter pipe that carries the water to a 15 m^3 tank. This size is equivalent to one month worth of net precipitation, calculated based on the precipitation data shown in *Section 4.1.5*. A Summary of the calculation is shown in Table 12. A 75 mm pipe with an 8 m head pump will distribute the water back to the roof during dry seasons. The tank is fitted with an overflow outlet to allow excess run-off to drain to the pond near the café during any intense rainfall events.

Table 11: Tank Size Calculations

Area of roof	290	m^2
Precipitation	1288	mm/year
Evapotranspiration	646	mm/year
Assumed tank height	1.5	m
Volume of catchment water	15.52	m^3
Required tank diameter	3.63	m

4.4 Construction Schedule

The construction of the Greenhouse Café is planned to be complete in a ten month time frame. Excavation and foundation work is planned for 40 working days, with Level 1 and 2 structural work taking 53 days. The roof structure, green roof and curtain wall glazing will take approximately 55 days to install, with mechanical and electrical along with all finishing and fit out work will take the remaining 62 day to complete. The Green Cafe is planned to start in the spring months, allowing for the foundation and structure work to take place during better weather, reducing potential delays. Figure 15 below shows a general schedule break down. A detailed schedule breakdown can be found in Appendix C. In the detailed schedule, tasks in blue are main summary task, while tasks in red are sub tasks of these summary tasks. The subtasks from two main summary tasks are shown in the detailed schedule to demonstrate how the specifics of the schedules were formed, all other sub tasks are kept hidden for simplicity.

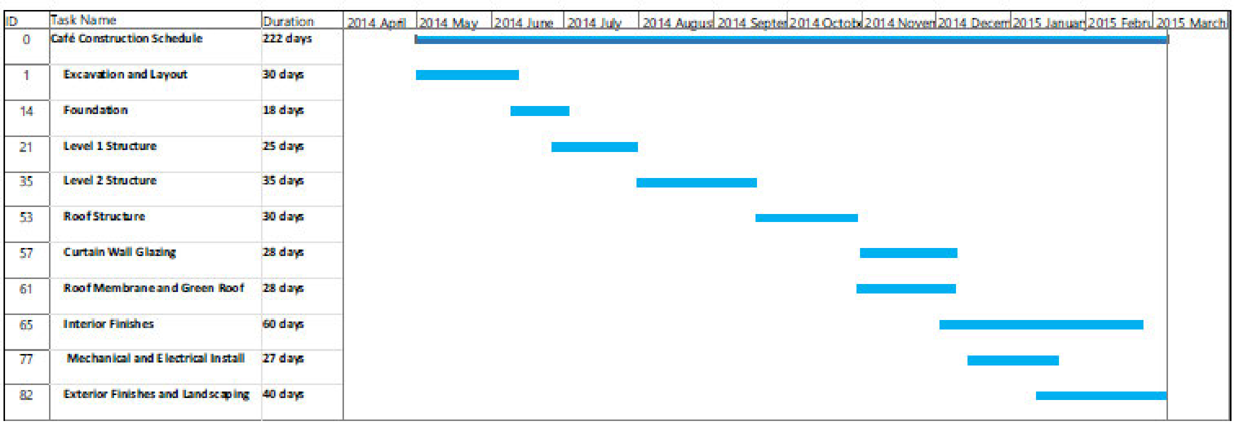

Figure 15: Schedule Breakdown

4.5 Detailed Cost Estimate

The total cost of the Green Café is expected to be $1.24 million dollars. This cost estimate was prepared on RS Means using data from the first quarter of 2014, by using typical costs for the City of Vancouver. By entering the dimensions and construction type, as well as extra fixtures and innovations for the Green Café, RS Means created the cost estimate using data from other environmentally friendly restaurants. The total calculated cost is based on assumption that the project runs smoothly. The detailed cost breakdown is shown in Appendix C.

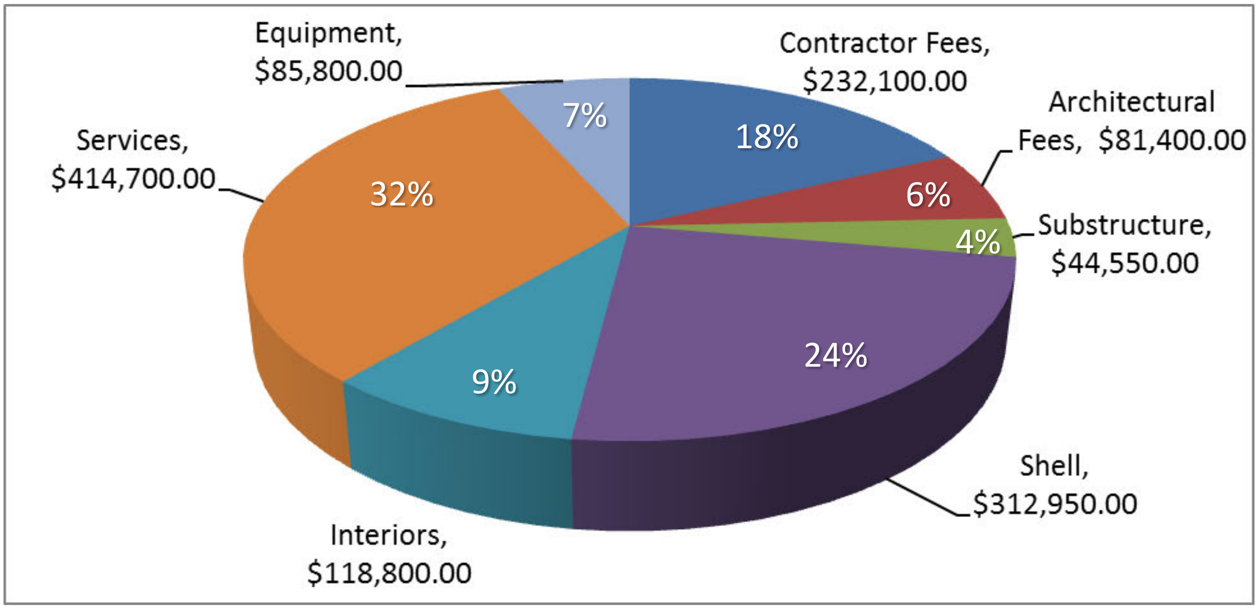

Figure 16: Detailed Cost Breakdown

5.0 Conservatory Expansion/Renovation Design

5.1 Design Considerations

Design considerations for the renovation and expansion of the Conservatory at UBC Botanical Gardens include the impact on the garden, the utilization of space along with the benefits to the garden and its guests. Details on general considerations are given below.

5.1.1 General Considerations

The Botanical Garden Conservatory is located in the North Garden next to the Food Garden. The current structure has a prominent footprint in the garden with two levels totaling approximately 250 square meters. With such a central location in the Botanical Garden the conservatory is currently being underutilized, adding little public value. The goal of renovating and expanding the Conservatory is to make it a main anchor point for the garden, adding features that will attract guests and add positive value to the Botanical Gardens. The current space does not flow with the tranquil setting of the garden, considerations will be given to updating the exterior façade giving it a more natural, inviting feeling. An expansion will be designed to have a limited impact on the garden, keeping with the gardens values and minimize its consumption of valuable garden space. The renovations and an addition will help to develop the space to its full potential, inviting guests in for an interactive learning experience and allowing the garden to host events that it once could not. Details into the conceptual design of the Conservatory's renovation expansion are given in the sections below.

5.2 Conceptual Design

The following sections detail the high-level design for the Conservatory including a new floor plan of the existing building, and a model of the expansion.

5.2.1 Renovation Floor Plan

The renovation of the existing Conservatory is designed to transform the space into an inviting learning area for guests of the Botanical Garden. The main level shown in Figure 17 will be converted into an open learning area, filled with interactive educational exhibits about the botanical garden and the species it holds. The exterior of the existing structure outlined in orange will benefit from updated glazing walls, bring natural light into the space and making it flow with the proposed expansion. The updated glazing walls will help to give to space a more natural feel, blending it in with the surrounding garden. The basement level of the existing Conservatory, shown in Figure 18, will benefit from cosmetic upgrades, modifying the space into two classrooms with an operable partition divider. This will allow the garden to adapt the space to its needs, giving them the opportunity to run educational seminars and workshops, attracting visitors to the garden. The renovation of the conservatory will transform the space into a key attraction in the Botanical Garden. It will give the garden a space to feature unique exhibits, attracting guest who would otherwise not visit such a place.

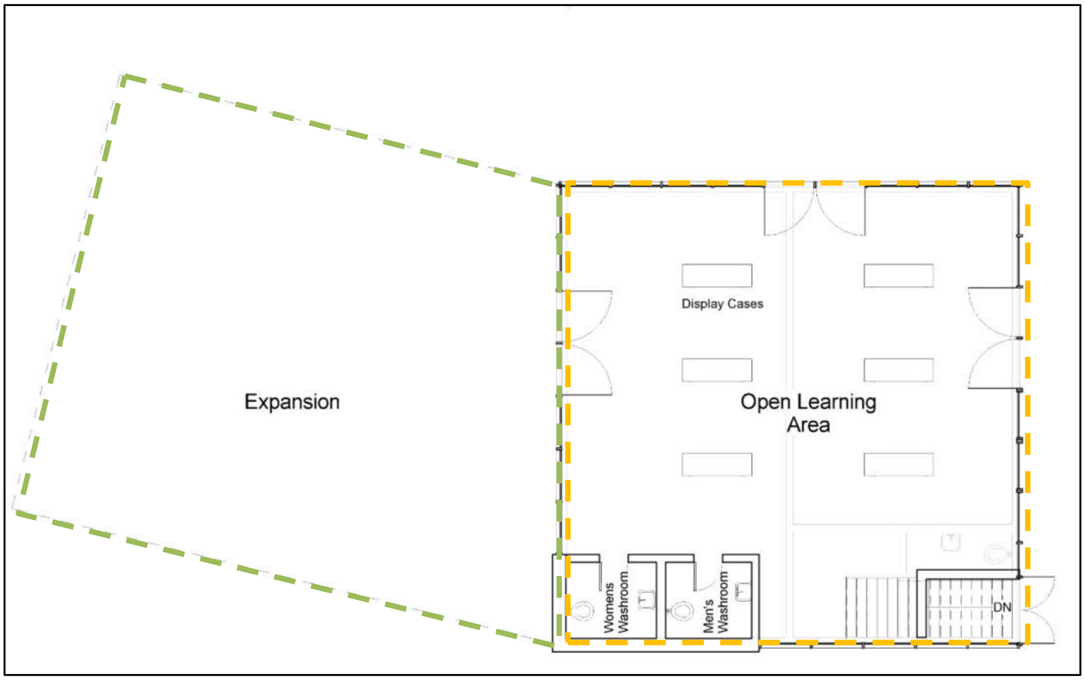

Figure 17: Conservatory Renovation Main Level

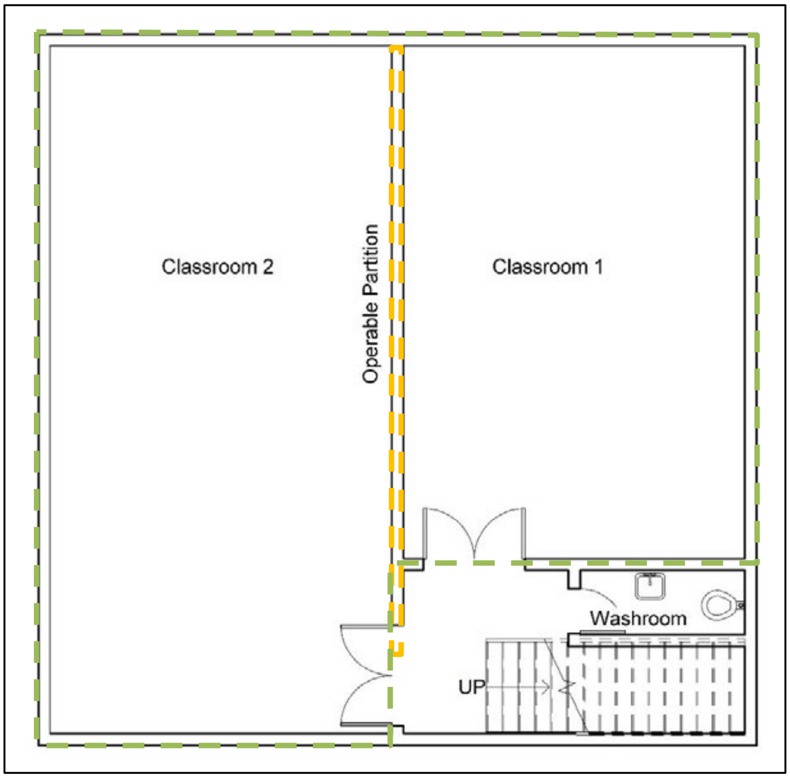

Figure 18: Conservatory Renovation Basement Level

5.2.2 Expansion

The expansion of the conservatory will include an additional wing connecting to the North side of the existing building.

Figure 19 below shows a model of the expansion; the wall in the rear is part of the existing building. The structural component of the expansion will rely mainly on timber beams and columns creating a frame structure. Supporting the roof will be several wooden trusses on top of the beam and column frame. Wooden joists will be installed in between the trusses to support the roof, but the joists are not shown in the model to avoid clutter. The exterior of the expansion will mainly be glazing fastened to the frame.

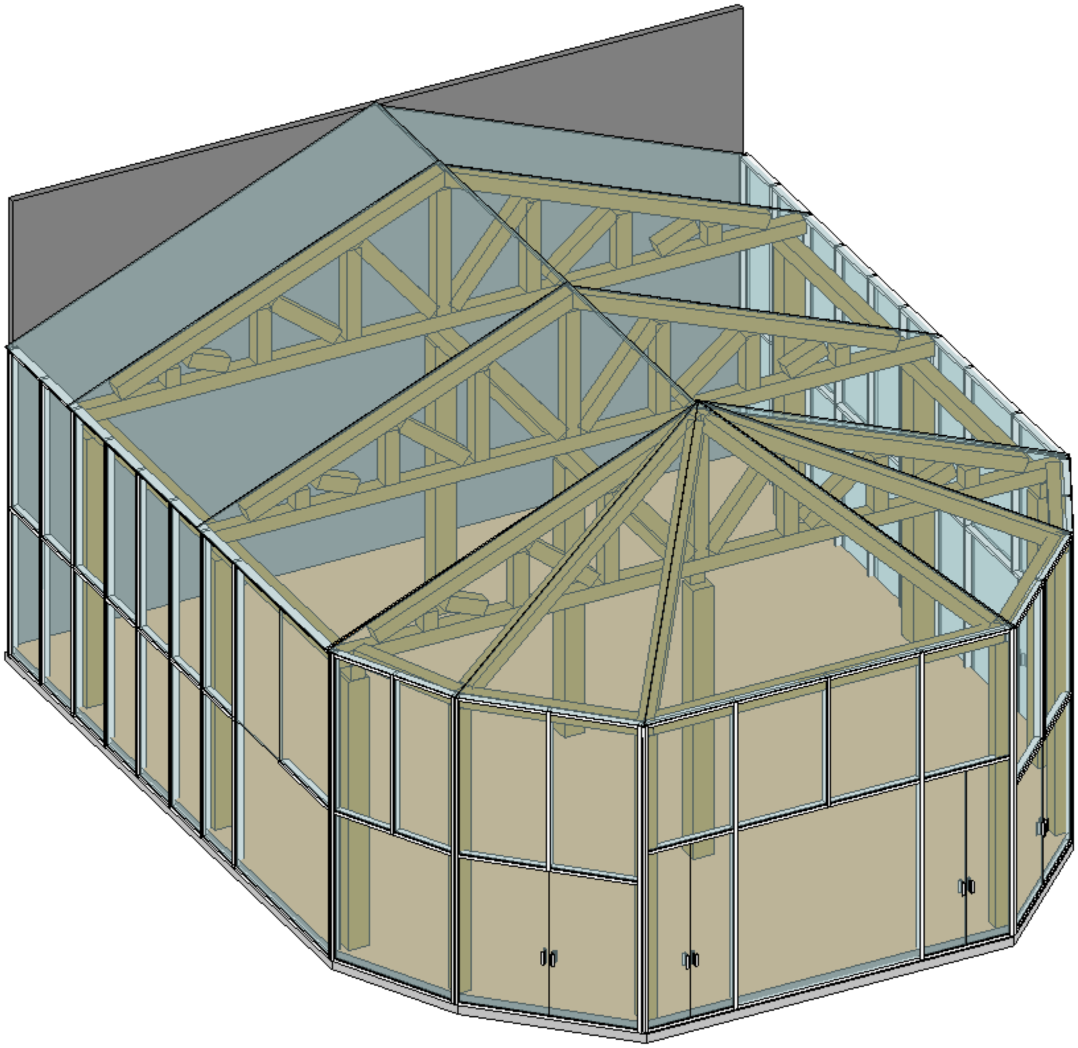

Figure 19: Conservatory Expansion

The expansion will be used as a modular space; normally it will house displays and plants for garden guests, but when outfitted with tables and chairs can be used as a banquet hall for festivities and other occasions. The glazing allows ample amounts of sunlight into the building and allows guests to enjoy the garden while inside. Large doors also allow for easy accessibility of guests and equipment.

The renovation and expansion of the UBC Botanical Garden's Conservatory will create a more interesting place where guests can participate in activities, learn about the garden, and enjoy various events in the future.

6.0 Signage Upgrade

6.1 Design Considerations

The following section details the reasons that necessitate signage upgrade at the Botanical Garden.

6.1.1 General Considerations

The lack of innovative signage at the UBC Botanical Garden prevents the garden from effectively educating and providing information to the visitors. Therefore, the proposed upgrade aims to increase the quantity and quality of both informative signs and Way-finding signs in the garden. The upgrades for the signage will be non-intrusive to the garden and sustainable. The construction of the upgrade shall also avoid damage to the plants. Therefore, the new designs will be simple, and require no heavy machinery and low number of laborers. The garden contains 2.5 kilometers of pathways; therefore, the design must be efficient in upgrading in a timely manner to avoid prolonged closure of key parts of the garden.

6.2 Conceptual Design

The following section details the signage upgrades and a signage plan for the Botanical Garden.

6.2.1 Signage Locations

Based on the existing path designs and the anchor points of the Garden, new signage locations are proposed. These signs aim to assist visitors in finding the garden's key locations and provide interesting information to the visitors. Site visits were made to confirm the practicality of these locations. The locations of these signs are show in Figure 20 below.

Figure 20: Map of New Sign Locations

6.2.2 Signage and Automated Audio System

There are two types of visitor interfaces proposed for the UBC Botanical Garden. The first type is a signage system primarily designed to help visitors navigate within the garden and be directed to key areas of interest easily and effectively. The second system being proposed is an automated system that features a touch screen interface. This audio system will be designed such that information will be played through an optional headphone that visitor can acquire at the entrance. Two examples of the designs are shown below in Figure 21.

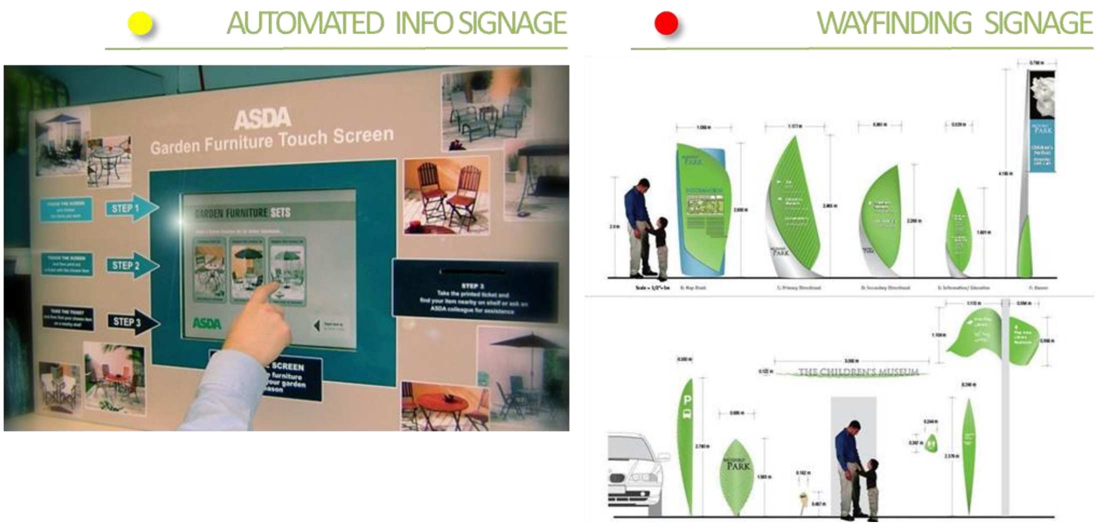

Figure 21: Examples of Signage Designs

7.0 Closure

This Detailed Design Report has been prepared by Group 1 in response to request from UBC CIVIL 446 and UBC Botanical Garden.

Please contact Mike Lam at *(604) 808 076*6 or *mike.kh.lam@gmail.com* if you have any questions or concerns.

8.0 References

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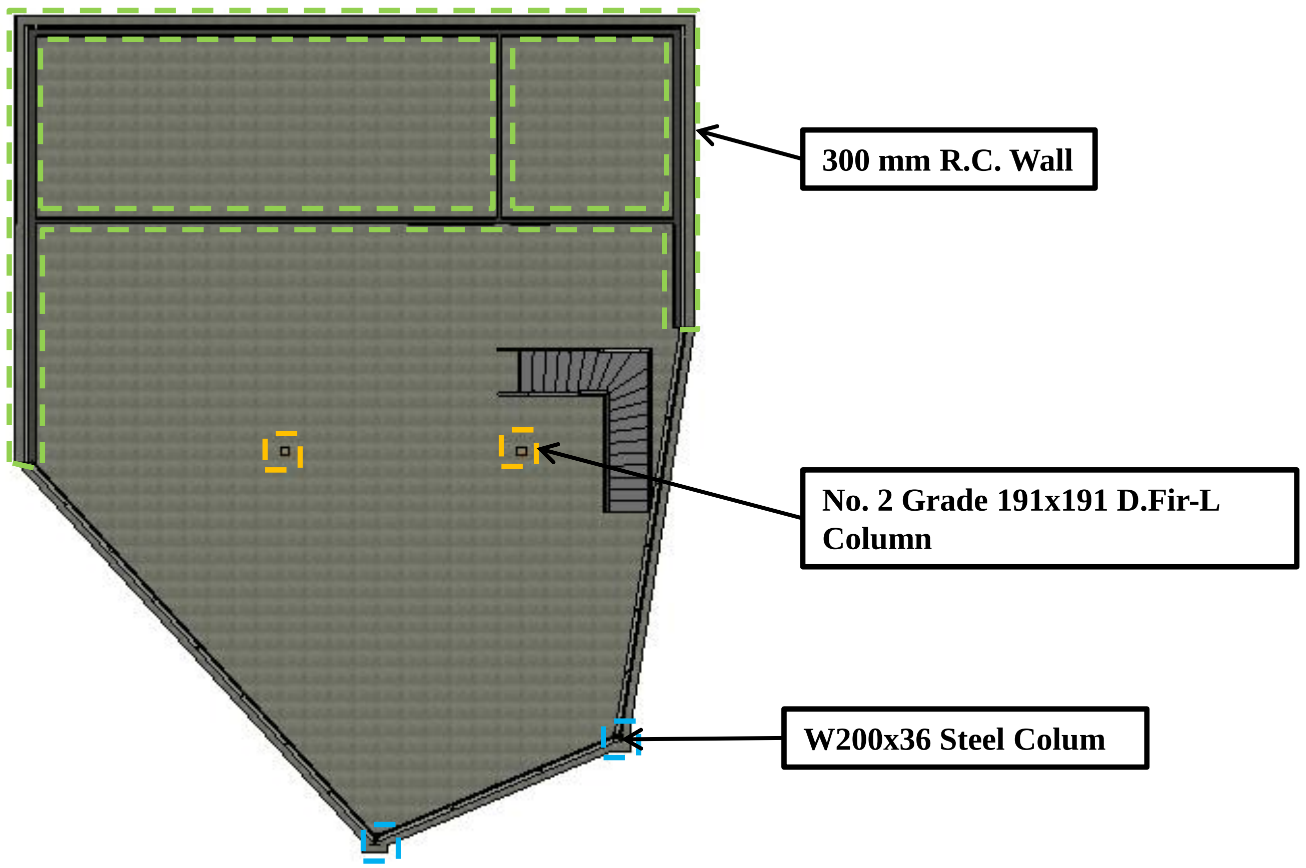
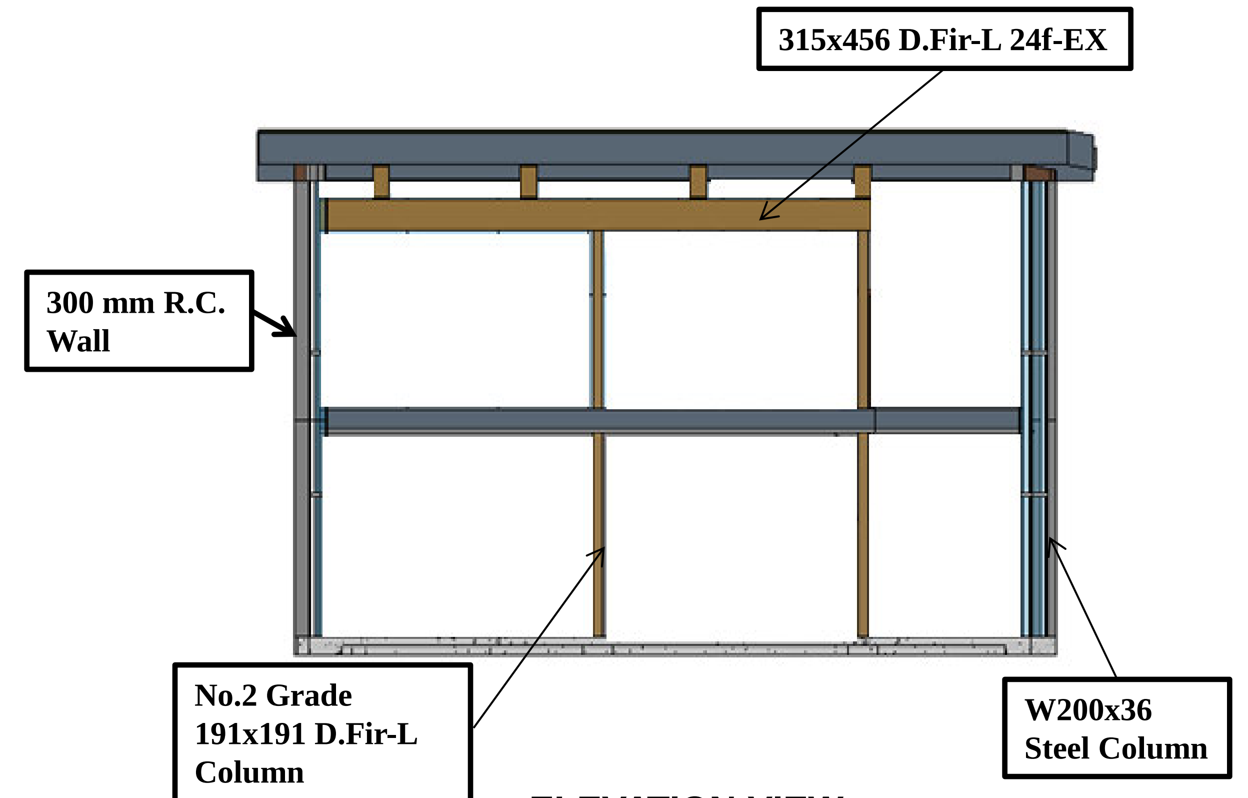
(Consultants, GeoPacific, 2009)

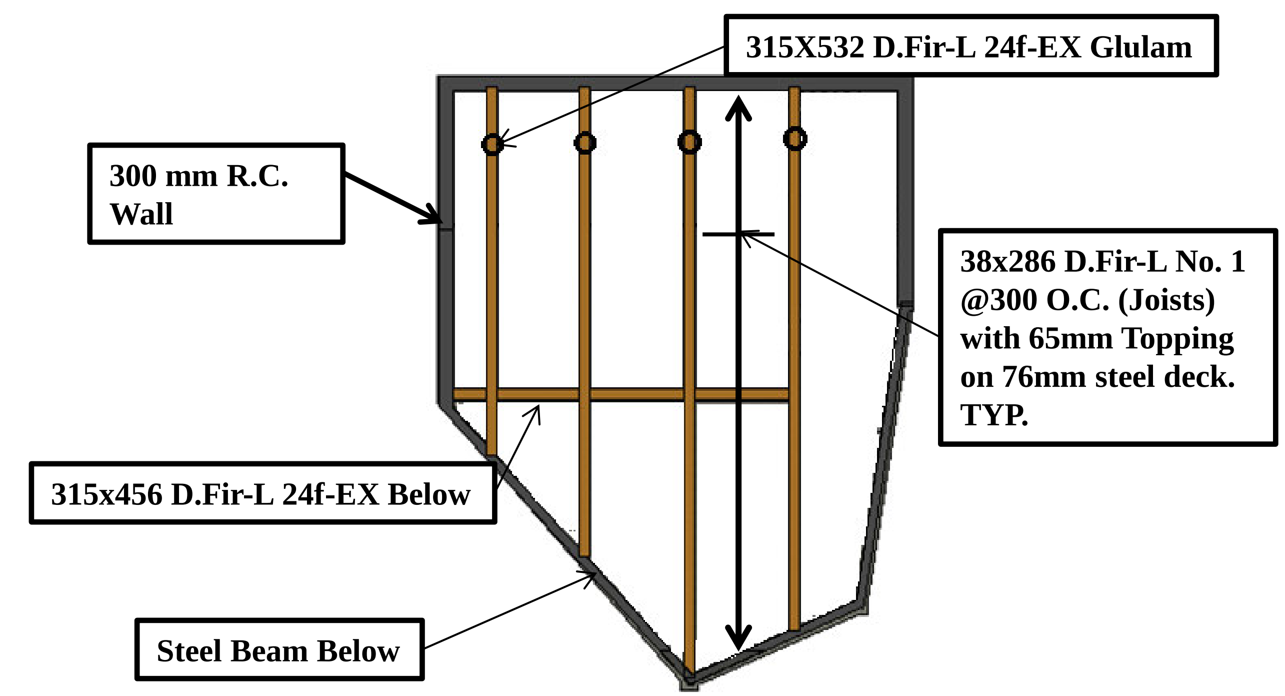
Appendix A: Design Drawings



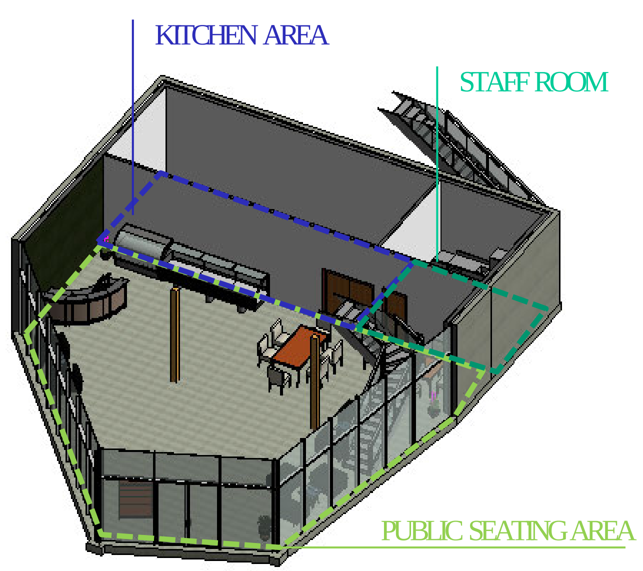
PLAN VIEW OF LEVEL 1



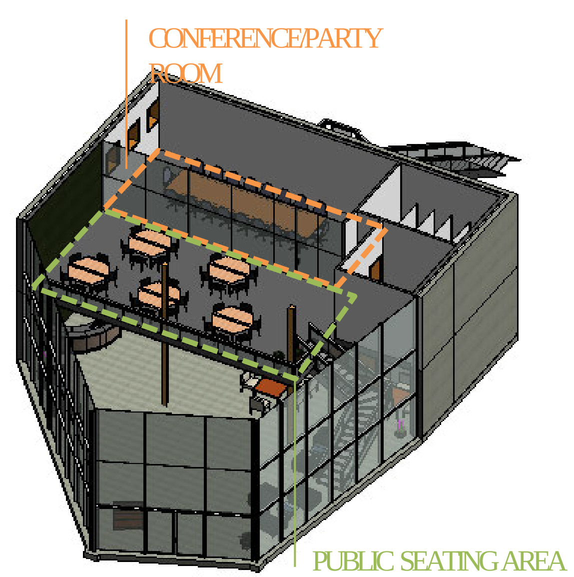
ELEVATION VIEW



PLAN VIEW OF ROOF



OVERVIEW OF LEVEL 1



OVERVIEW OF LEVEL 2

UBC engineering

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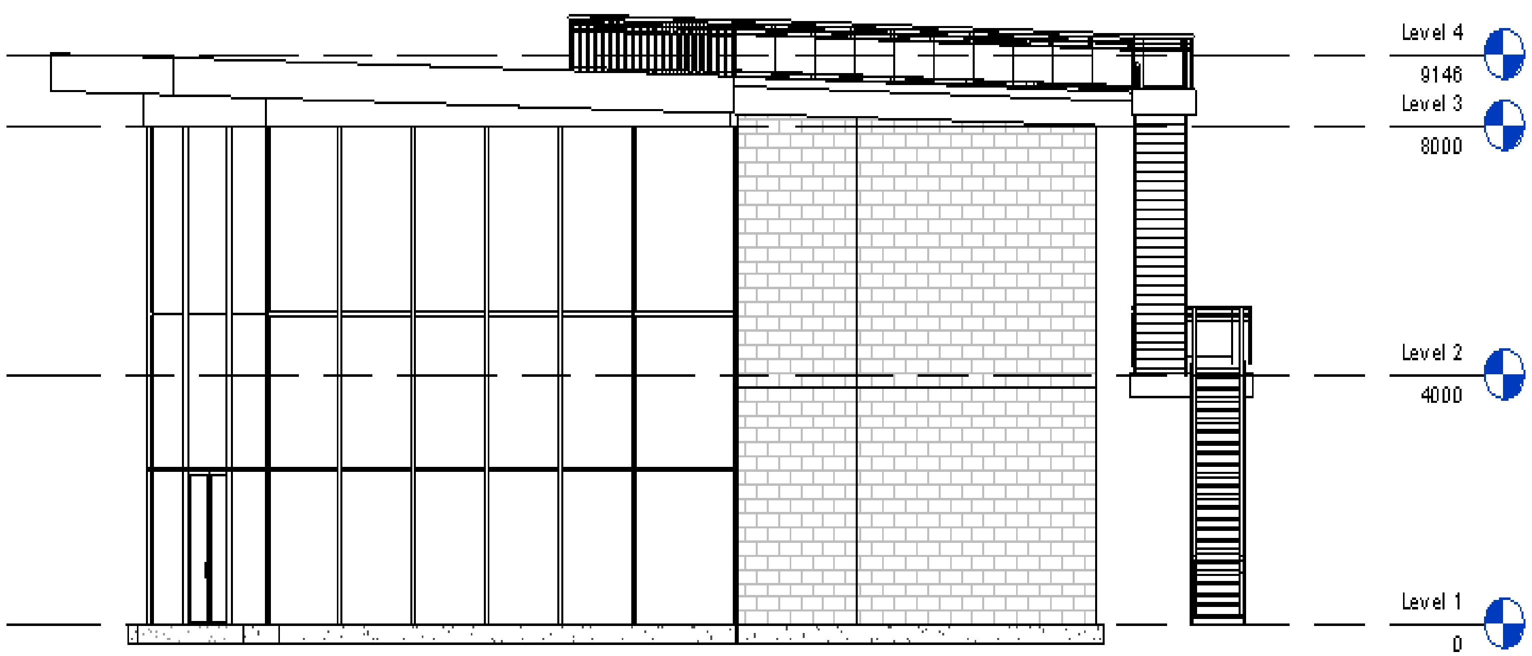
Structural Components & Floor Plans

Plan and Elevation Views

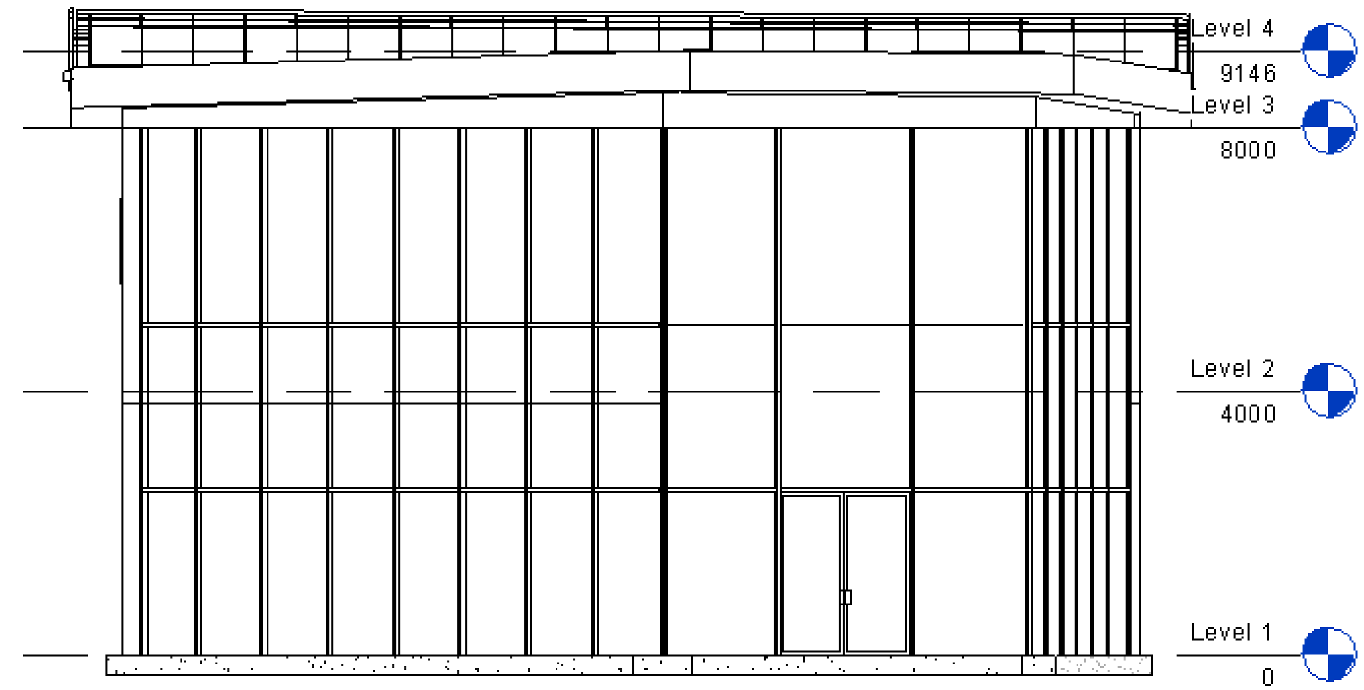
Job No: CIVIL446.2014
Filename: StructuralFloorPlans_11by17_MT.pptx

UBC Botanical Garden Redevelopment

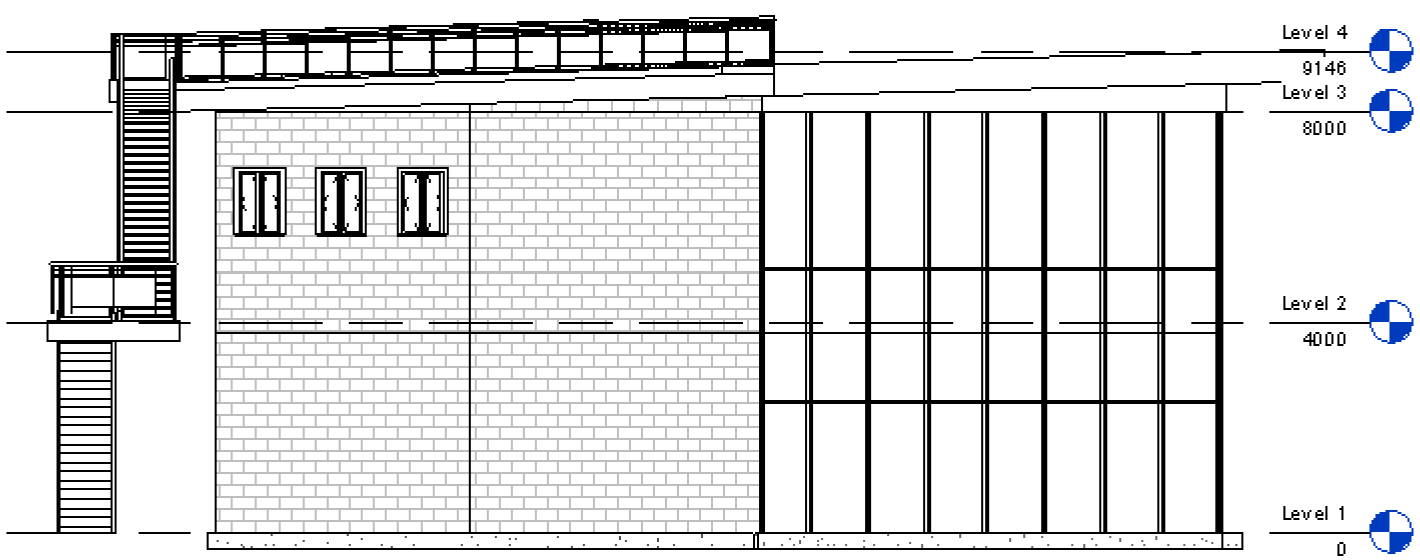
Date:	Approved:	Figure:
March 2014	MT	1.0



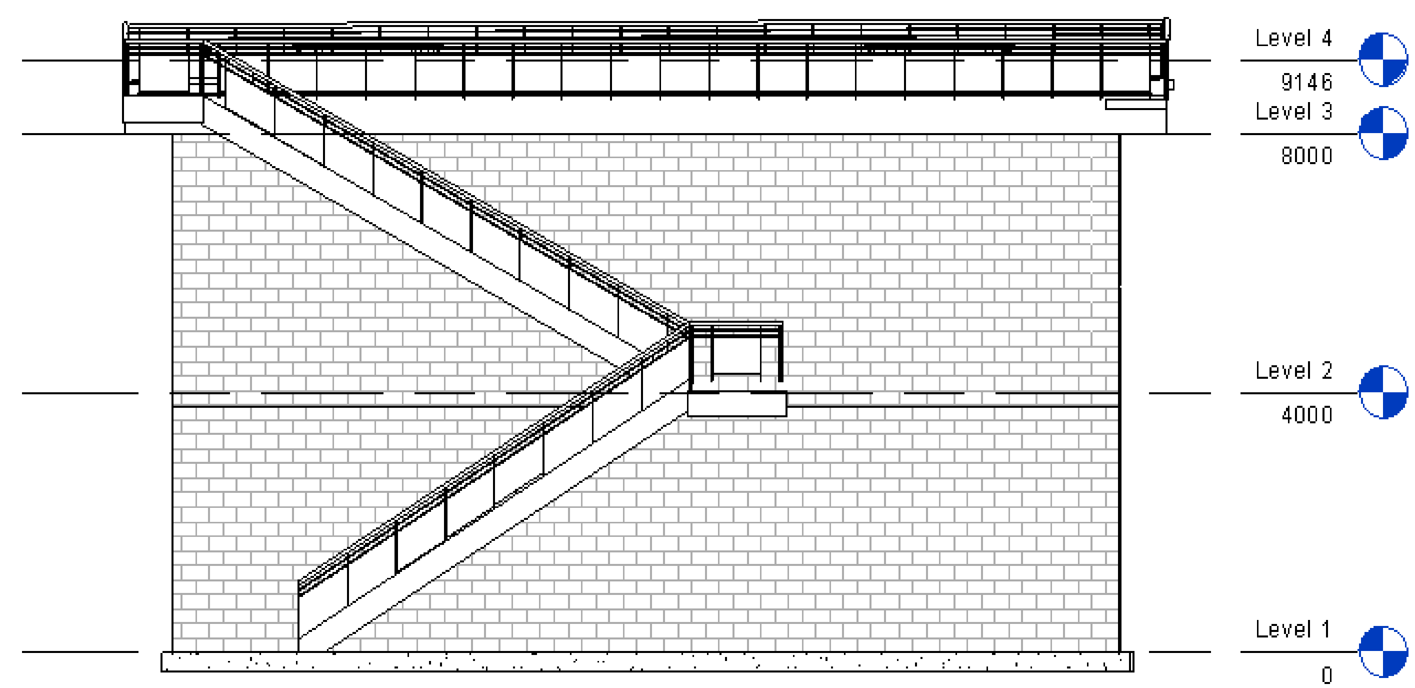
EAST ELEVATION



FRONT OF BUILDING



WEST ELEVATION



BACK OF BUILDING

UBC engineering

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BUILDING ELEVATIONS

Elevation Views

Job No: CIVIL446.2014

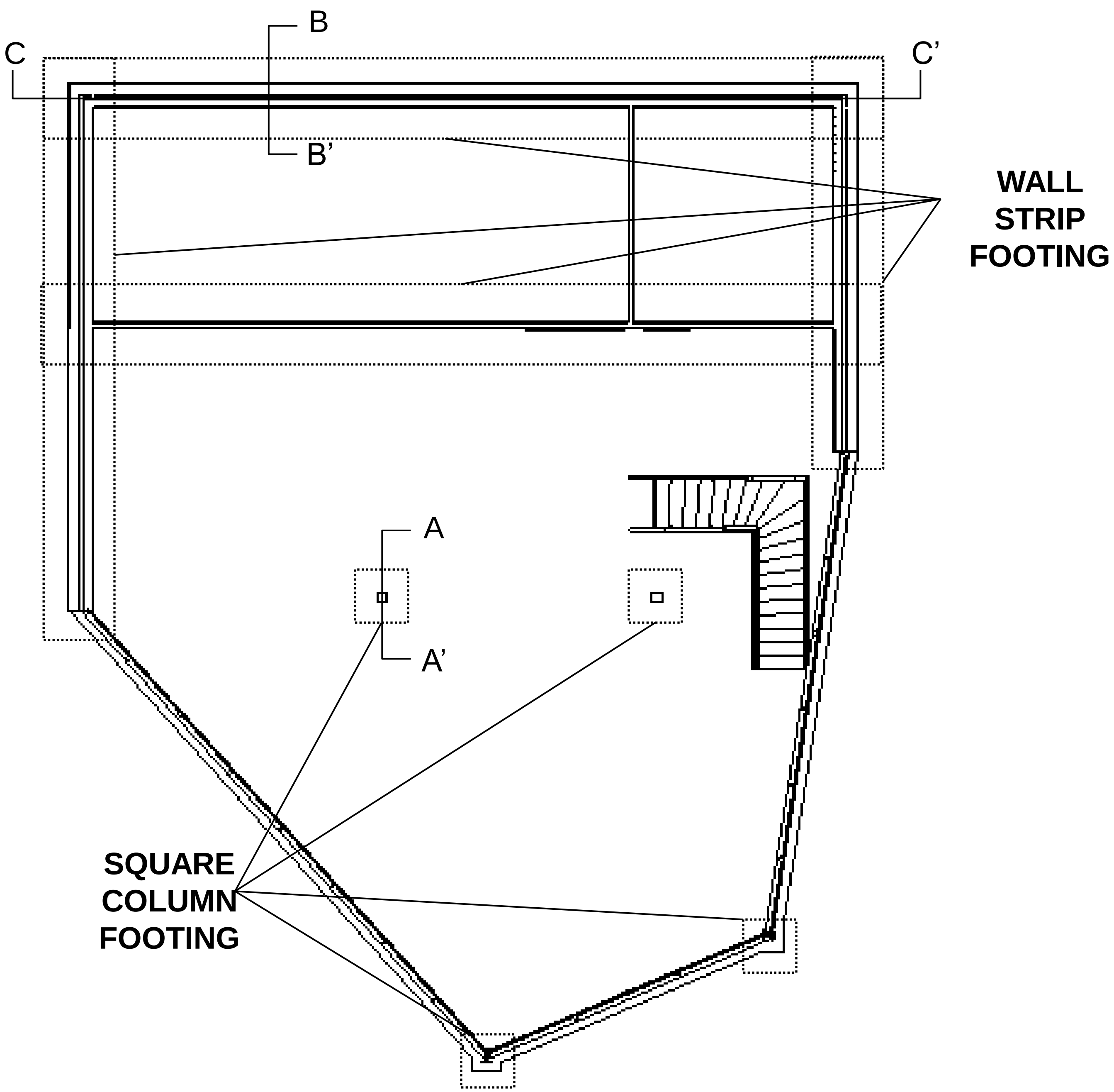
Filename: Elevations_11by17_MT.pptx

UBC Botanical Garden Redevelopment

Date: March 2014

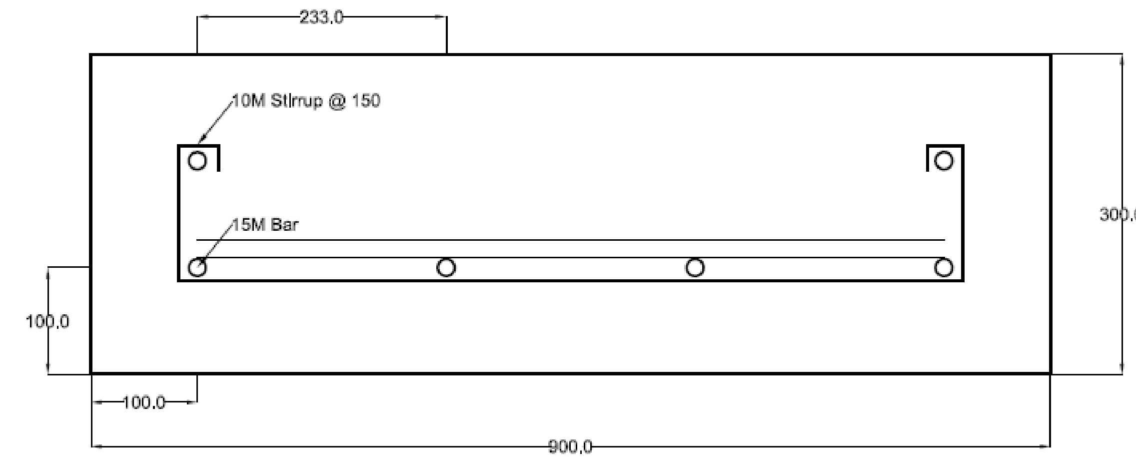
Approved: MT

Figure: 1.1

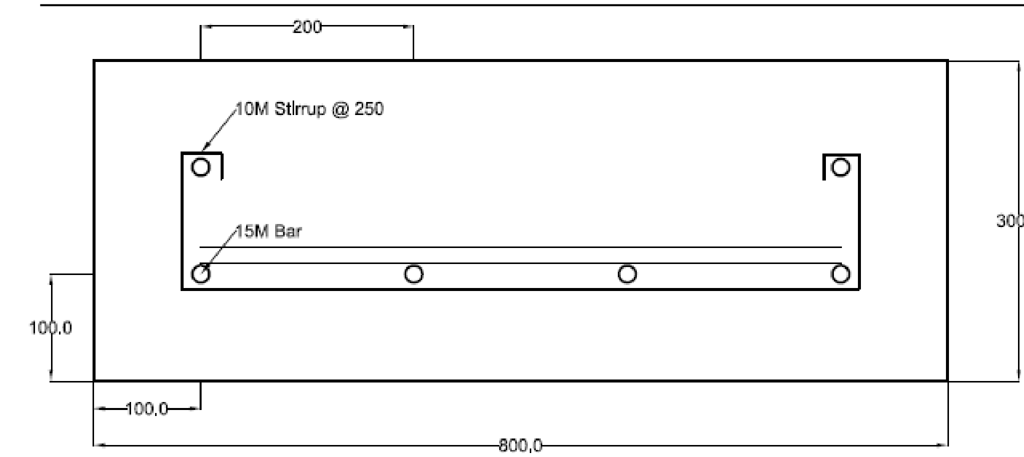


PLAN VIEW

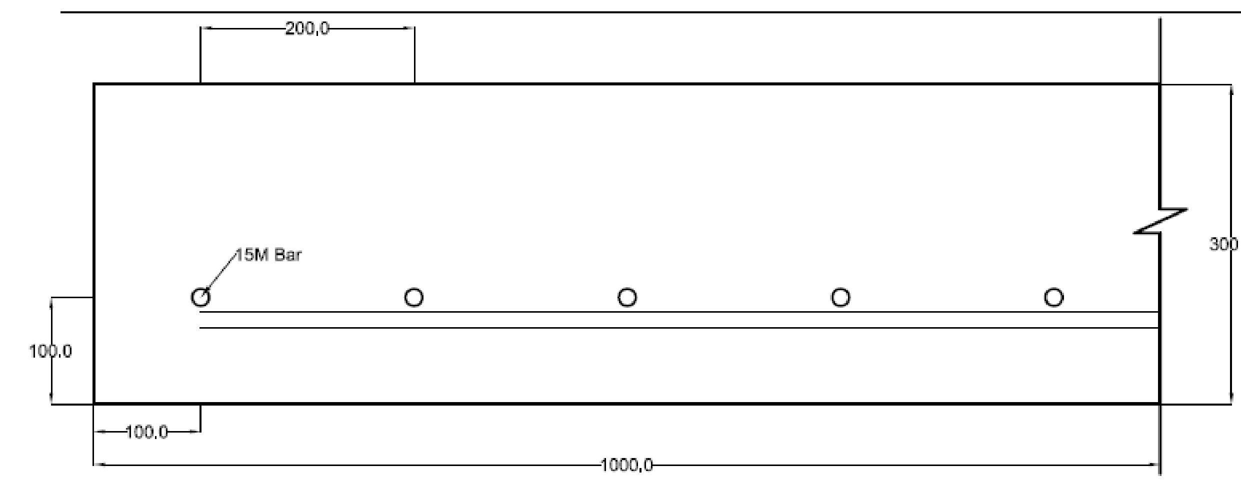
SQUARE COLUMN FOOTING DETAIL A-A'



WALL STRIP FOOTING DETAIL B-B'



WALL STRIP FOOTING DETAIL C-C'



NOTES

1. Concrete strength should be 30 MPa.
2. All vegetation and top soil must be excavated to competent sand layer.
3. Floor Slab to be underlain by Polyethylene barrier and 100 mm of 19 mm clear crush gravels to inhibit upward migration of moisture beneath the slab.
4. To provide support for any concrete slabs-on-grade, fills be compacted in 300 mm loose lifts to a minimum of 98% ASTM D698 (Standard Proctor) maximum density at a moisture content within 2% of optimum for compaction.

UBC engineering	ubcbotanicalgarden & centre for plant research	Foundation Drawings **Plan and Elevation Views**
Job No: CIVIL446.2014 Filename: Foundation_11by17_ML.pptx	UBC Botanical Garden Redevelopment	Date: March 2014 / Approved: ML / Figure: **2.0**

Appendix B: Design and Cost Calculations

Green Café Load Take-Down

		Roof								Level 2								Level 1	Total	
Element	Length (m)	Trib Area m2	Live Load kPa	Dead Load kPa	Green Roof kPa	Snow Load kPa	Factored Load kPa	Load	Units	Trib Area m2	Live Load kPa	Dead Load kPa	Self Weight kN/m	Snow Load kPa	Factored Load kPa	Load	Units	Self Weight kN/m	**Foundation Load**	Units
Wall 1	10.0	25	4.8	2.6	2.0	1.82	9.8	24.5	kN/m	10	4.8	3.54	27.6	0	11.6	46.1	kN/m	27.6	**125.8**	kN/m
Wall 2	15.0	50	4.8	2.6	2.0	1.82	9.8	32.7	kN/m	29	4.8	3.54	27.6	0	11.6	89.2	kN/m	27.6	**177.0**	kN/m
Wall 3	7.0	25.7	4.8	2.6	2.0	1.82	9.8	36.0	kN/m	8.8	4.8	3.54	27.6	0	11.6	58.0	kN/m	27.6	**149.2**	kN/m
Wall 4	15.0	0	4.8	2.6	2.0	1.82	9.8	0.0	kN/m	61.4	4.8	3.54	27.6	0	11.6	188.8	kN/m	27.6	**244.0**	kN/m
Ext. Col	0	16.8	1.0	2.6	2.0	1.82	4.6	77.5	kN	0	0		0	0	0.0	0.0	kN	0	**77.5**	kN
Int. Col	4	27	2.9	2.6	2.0	1.82	7.2	194.6	kN	10.3	0	5.79	0	0	7.2	74.5	kN	0	**269.2**	kN

Glulam Roof Beam Design Calculations

Factors:			**Description**
phi_b	0.9		Resistance Factor in Bending
Fb	30.6	MPa	Douglas-Fir-Larch 24f-EX Variety
E	12800	MPa	Modulus of Elasticity
L	10	m	Length
Kt	1		Untreated
Ks	1		For dry service conditions
Kh	1		System Factor
Kl	1		Continuous lateral supported on compression side
Kx	1		for uncurved members
Kd	1		Standard Duration Load

Trial Size	Back Half		Front Half	
Width	315	mm	315	mm
Depth	532	mm	532	mm
Tributary Width	3.5	m	3.5	m
Distributed Load	34.3	kN/m	16.2	kPa
Moment Check				
Factored Moment	315.60	kNm	From RISA	
Size Factor	0.838			
Section modulus	14858760	mm3		
Moment of Inertia	3.95E+09	mm4		
Cross Section A	167580	mm2		
Moment Resistance	342.84	kN/m		
Utilization	92%	OK		
Deflection Check				
Factored Live Load	16.8	kN/m		
Deflection Limit	27.78	mm		
Deflection	25.60	mm	From RISA	
Utilization	92%	OK		
Shear Check				
Factored Shear	203	kN	From Risa	
Shear Resistance	215.0	kN	From Wood Code	
Utilization	94%	OK		

Timber Column Factors and Properties

Specified Strengths				
Bending Moment	fb	=	10	MPa
Longitudinal Shear	fV	=	1.9	MPa
Compression Parallel	fc	=	14	MPa
Compression Perpendicular	fcp	=	7.0	MPa
Tension	ft	=	5.8	MPa
Modulus of Elasticity	E	=	11000	MPa
Modulus of Elasticity, 95th	E05	=	7000	MPa

Steel Column Factors and Properties

Yield Strength of Section	Fys	=	350	MPa
Ultimate Strength of Section	Fus	=	450	MPa
Gross Area	As	=	4570.0	mm^2
Flange Thickness	tf	=	10.2	mm
Flange Width	bf	=	165.0	mm
Web Thickness	tw	=	6.2	mm
Web Depth	bw	=	201.0	mm
Elastic Modulus of Steel	Es	=	200000	MPa
Connection Factor	k	=	1	
Length	l	=	8000	mm
Radius of Gyration, axis XX	rx	=	87	mm
Radius of Gyration, axis YY	ry	=	41	mm
Compression Parameter	ns	=	1.34	

Steel Column Calculations

GEOMETRY CHECKING						
Column						
Flange Width-to-Thickness Ratio	bf_tf	=	bf / 2 / tf	=	8.1	
Check Flange	chkf	=	IF(bf_tf <= 200 / SQRT(Fys), "OK", "FAIL")	=	OK	
Web Height-Thickness Ratio	bw_tw	=	(bw - 2 * tf) / tw	=	29.1	
Check Web	chkw	=	IF(bw_tw <= 670 / SQRT(Fys), "OK", "FAIL")	=	OK	
Slenderness Ratio about Unbraced	klr	=	k * l / min(rx, ry)	=	195.6	
Check Slenderness	chksl	=	IF(klr <= klrmax, "OK", "FAIL")	=	OK	
FAILURE IN COLUMN						
Axial Compression						
lambda	lmda	=	klr * SQRT(Fys / (PI() ^ 2 * Es))	=	2.6	
Compressive Resistance	Cr	=	phi * As * Fys * (1 + lmda ^ (2 * ns)) ^ (-1 / ns) / 1000	=	201	kN

Timber Column Calculations

Timber Column – Interior Second Floor

Factored Loads						
Mass of Individual Column	mc	=	L * b * d * G' / 1000^2	=	38.42	kg
Self Weight of Columns	wc	=	mc * g' / (b * d) * 1000	=	19.23	kPa
Total Self Weight of Columns, Load	Pc	=	wc * b * d / 1000^2 * nc	=	0.75	kN
From Loads.xlsx						
Factored Load from Roof	wf_r	=			194.63	kN
Factored Axial Load, per column	Pf	=	wf_r / nc	=	97.31	kN
Axial Resistance						
Factored Compressive Strength, Parallel to Grain	Fc	=	fc * KD * KH * KSc * KT	=	14.00	MPa
Area	A	=	b * d	=	19600.00	mm2
Buckling Factore	KZc	=	min(6.3 * (min(d,b) * L) ^ -0.13, 1.3)	=	1.13	
Slenderness Factor	KC	=	(1.0 + Fc * KZc * Cc^3 / (35 * E05 * Kse * KT)) ^ -1	=	0.40	
Slenderness Ratio	Cc	=	L / min(b, d)	=	28.57	
			if(Cc <= 50, "Acceptable", "Not Acceptable")	=	Acceptable	
Compressive Resistance, Parallel to Grain	Pr	=	φ_0.8 * Fc * A * KZc * KC / 1000	=	98.89	kN
			if(Pr >= Pf, "Acceptable", "Not Acceptable")	=	Acceptable	

Timber Column – Interior First Floor

Factored Loads						
From Loads.xlsx						
Factored Load from Roof	wf_r	=			194.63	kN
Factored Load from 2nd Floor	wf_2	=			74.55	kN
Total Self Weight of 2nd Floor Columns	Pc_2	=		=	0.75	kN
Factored Axial Load	Pf	=	((wf_r + wf_2) + Pc_2) / nc	=	134.96	kN
Axial Resistance						
Factored Compressive Strength, Parallel to Grain	Fc	=	fc * KD * KH * KSc * KT	=	14.00	MPa
Area	A	=	b * d	=	36481.00	mm2
Buckling Factore	KZc	=	min(6.3 * (min(d,b) * L) ^ -0.13, 1.3)	=	1.08	
Slenderness Factor	KC	=	(1.0 + Fc * KZc * Cc^3 / (35 * E05 * Kse * KT)) ^ -1	=	0.64	
Slenderness Ratio	Cc	=	L / min(b, d)	=	20.94	
			if(Cc <= 50, "Acceptable", "Not Acceptable")	=	Acceptable	
Compressive Resistance, Parallel to Grain	Pr	=	φ_0.8 * Fc * A * KZc * KC / 1000	=	282.09	kN
			if(Pr >= Pf, "Acceptable", "Not Acceptable")	=	Acceptable	

Appendix C: Construction Schedule

ID	Task Name	Duration
0	**Construction Schedule**	**220 days**
1	**Mobilize on Site**	**9 days**
7	**Site Grading and Utilities**	**21 days**
13	**Foundations**	**18 days**
20	**Prepare and pour slab on grade**	**11 days**
26	**Prepare and pour Level 1 Walls**	**10 days**
27	Form Walls Level 1	4 days
28	Set Rebar	4 days
29	Pour concrete	1 day
30	Strip wall forms	1 day
31	**Install Level 1 Columns**	**2 days**
33	**Prepare and Pour Level 2 Slab**	**10 days**
34	Install Level 2 Slab Formwork	4 days
35	Install In slab Mechanical and Electrical	3 days
36	Set Rebar	1 day
37	Pour Slab	1 day
38	Remove Formwork	1 day
39	**Prepare and Pour Level 2 Walls**	**9 days**
44	**Install Level 2 Columns**	**3 days**
46	**Install Interior Stairs**	**5 days**
48	**Erection of Steel Beams and Columns At Entrance**	**8 days**
50	**Glulam Beam Roof Structure**	**25 days**
53	**Install Curtain Wall Glazing**	**30 days**
57	**Roof Membrane and Green Roof**	**31 days**
61	**Interior Framing**	**7 days**
63	**Mechanical and Plumbing Install**	**25 days**
65	**Electrical Install**	**25 days**
67	**Interior Finishes**	**40 days**
76	**Exterior Finishes and Landscaping**	**20 days**
78	**Site Demobilization and Turnover**	**8 days**