UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

PROJECT II - Chancellor Boulevard and Wesbrook Mall Intersection at UBC

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CIVL 446

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EXECUTIVE SUMMARY

Northco Engineering Ltd. was asked to redesign the Chancellor Boulevard and Westbrook Mall intersection that is currently outdated and unsafe. After inputting all the data that we have gathered, the analysis shows that a roundabout is the best design that meets our three main project objectives: longevity, safety, and cost.

The updated design features a roundabout that improves all three of the main objectives over the original intersection, while also improving access for pedestrians and cyclists via crosswalks and designated bike lanes. The center of the roundabout features a structural monument that creates an appealing entry point for students and other guests coming to the university. While above ground this center piece improves the aesthetic quality of the intersection, below ground, there is a detention tank for water storage that aims to reduce water waste and help UBC achieve its' sustainability goals.

The project is estimated to cost a total of $539,486.70 for construction and a yearly operational and maintenance cost of $1,666.67 is expected to maintain the roadway and landscaping. These costs are based on a start date of May 2017 with a full completion of the project in August 2017.

The roundabout design is a design that can solve the ongoing issues at the Chancellor Boulevard and Westbrook Mall while welcoming guests.

Northco

Engineering Ltd

Table of Contents

List of Tables

List of Figures

1.0 PROJECT OVERVIEW

Our Northco Engineering consultant team has developed a new design of the intersection at Chancellor Boulevard and Wesbrook Mall to meet the safety standards, current traffic demands, and future traffic growth. The objective of the project is to create a safe, long lasting intersection at a minimal cost for all users of the intersection. The existing intersection is inefficient and creates driver confusion due to the unorthodox layout. Additionally, the lack of crosswalks and bike lanes is also a safety concern for the community in the area. The new design of the intersection has addressed and satisfied the following requirements:

- Cyclists can travel safely through the intersection
- Pedestrians can safely cross the intersection in all directions
- Buses and larger vehicles can navigate through the intersection with ease
- Current and projected traffic demands are met
- The cost of the intersection is appropriate
- UBC sustainability goals reached where possible

The majority of these requirements can be grouped together to form the main goal of the project. We grouped these requirements into three main objectives: design for longevity, design for safety, and reduce cost. Thus, the roundabout design was chosen since it addresses and solves the ongoing issues as mentioned previously. The description of the design components, design criteria, design codes, as well as the detailed cost estimate can be found in the body of the report below.

Name	Contributions
Justin Chan	2.8 Storm Water Management
	4.1 Overview
	8.1 Construction Plan
	9.1 Detailed Schedule
	MS Project Scheduling
Colin Eriks	2.0 Intersection Components
	2.1 Overview
	2.2 Sidewalks and Crosswalks
	2.3 Bike Lanes
	2.4 Truck Apron
	2.5 Street Lighting
	2.6 Splitter Islands
	2.7 Structural Monument
	2.8 Storm Water Management
Sebastian Huang	5.1 Design Criteria
	6.1 Transportation Software and Design Standards
	7.0 Site Layout and Configuration
	AutoCAD Drawings
	Synchro Modeling
Title Jirakul	1.0 Project Overview
	5.2 Technical Considerations
	8.2 Field Tests, Surveying, and Inspections
Lyndon Martell	3.1 Overview
	3.2 Technical Drawings and Specifications
	4.2 Detention Tank
	6.2 Structural Software and Design Standards
	AutoCAD Drawings
	Structural Calculations
Paul Trinh	Title Page
	Executive Summary
	1.0 Project Overview
	9.2 Detailed Cost Estimate
	Formatting

Table 1: Contribution table

2.0 INTERSECTION COMPONENTS

The intersection is a roundabout design with many features including side walk, cross walks, bike lanes, a truck apron and street lighting. Also, included in the design is a gateway monument and a storm water management system, which are described in sections 3 and 4.

2.1 Overview

An overhead view of the intersection can be found in Figure 1, shown below. It is a roundabout with 3 main entrances: east bound and west bound on Chancellor Boulevard and northbound on Westbrook Mall. Additionally, users entering from Westbrook Cres first proceed onto Chancellor Boulevard heading west and then enter the intersection. These users will be controlled by a stop sign, while all entrances into the roundabout intersection are controlled by yield signs. The total diameter of the roundabout is approximately 38 m, which consists of a 14 m inner diameter, a 4 m truck apron, a 6 m wide lane and a 1.5 m wide bike lane.

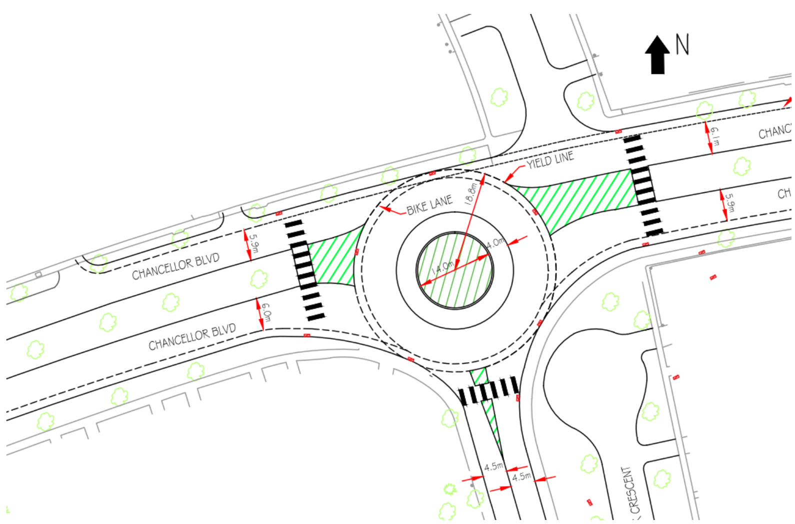

Figure 1: Overview of updated intersection

2.2 Sidewalks and Crosswalks

In the current intersection, there are sidewalks on all corners of the intersection, but no crosswalks exist. Our design includes crosswalks on all 3 entrances into the intersection. Although, for pedestrians crossing Westbrook Cres, a cross walk was not implemented. This is due to the fact that the road crossing is controlled by a stop sign and has minimal daily traffic volume. The three major pedestrian crossings are crossing Chancellor Boulevard on either side of the intersection and crossing Westbrook Mall just south of the intersection. These crosswalks are 3 m in width and are located a minimum of 1 m away from the yield signs. For the east side of the intersection, the crosswalk is located further back due to Westbrook Cres.

All three crosswalks will also feature pedestrian controlled lighting. A picture of the lighting model can be found below in Figure 2. As you can see in the figure, these are solar powered, so to further implement UBC's sustainability goals by using renewable energy whenever possible. Additionally, these are much simpler to install as they do not require any underground electrical ducts.

Figure 2:Image of solar powered pedestrian crosswalk

2.3 Bike Lanes

One of our initial goals was to make this intersection accessible for all modes of transportation. This includes pedestrians and buses, but also includes making the intersection bike friendly.

Bike lanes already exist along Chancellor Boulevard, so we've continued these through the intersection. The intersection overhead shot in Figure 1, shows the 1.5 m wide bike lane circling the perimeter of the intersection. This is a unique method of accommodating cyclists' travel through roundabouts, which is usually done by guiding cyclists through pedestrian crosswalks. We feel this will improve cyclists' experience because it will shorten the travel time through the intersection (cyclists will not have to dismount) and it treats these users as they should be treated: as a vehicle.

2.4 Truck Apron

In order to accommodate large vehicles such as buses and heavy haul trucks, we have included a truck apron in the intersection design. This is a 4 m wide shallow curb on the inside of the roundabout, which allows bigger trucks to drive over top of and navigate in all directions of the roundabout. The shallow curb encourages regular drivers to stay within the proper lane and reduces the confusion that could arise if the driving lane was widened (ex: drivers thinking there are 2 lanes). Figure 3 below shows the 4 m wide truck apron in more detail.

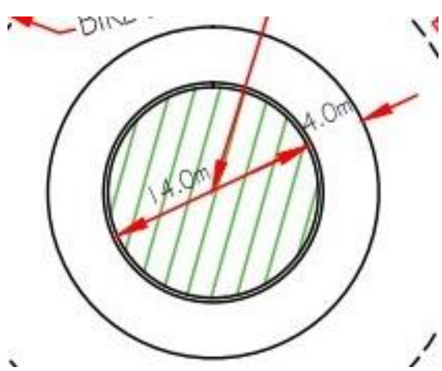

Figure 3: Close up of roundabout truck apron

2.5 Street Lighting

The intersection design also includes updated street lighting. These are also solar powered and will be in 6 spots around the intersection, as shown in Figure 4 below. This enhances the safety of the intersection at night, making it easier for both pedestrians and vehicles to see each other. Once again, solar power was chosen for both sustainability purposes and ease of installation.

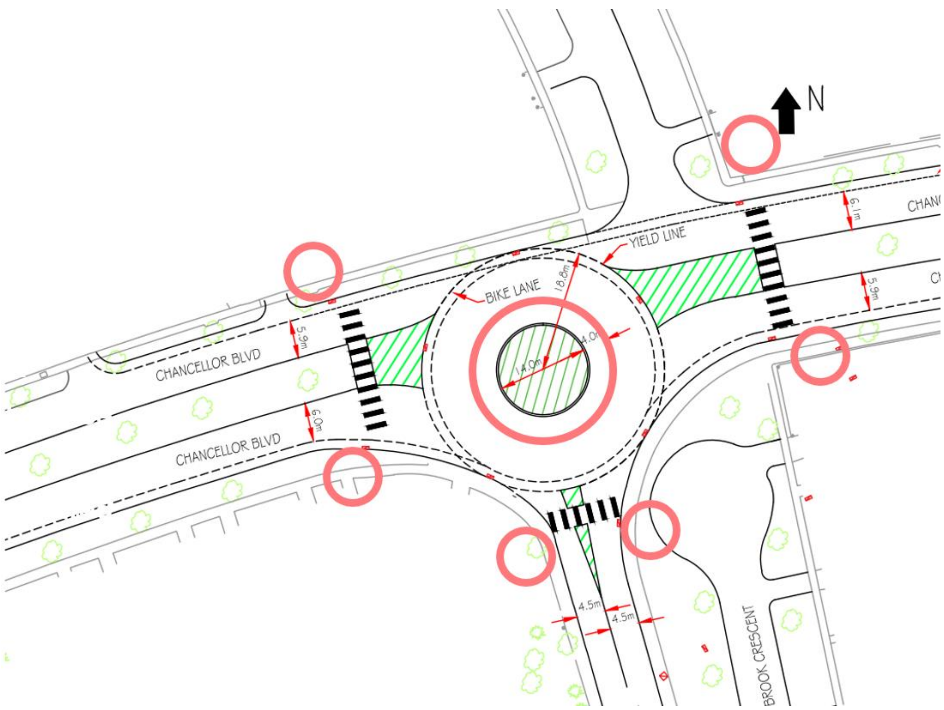

Figure 4: Location of solar powered street lights

2.6 Splitter Island

Splitter islands are included as a safety precaution to guide vehicles while entering and exiting the intersection. Figure 5, shown below, zooms in on the green hatching that represents the splitter island. These are designed as continuations of the boulevard in the middle of the road. These are designed to ensure adequate deflection into the roundabout.

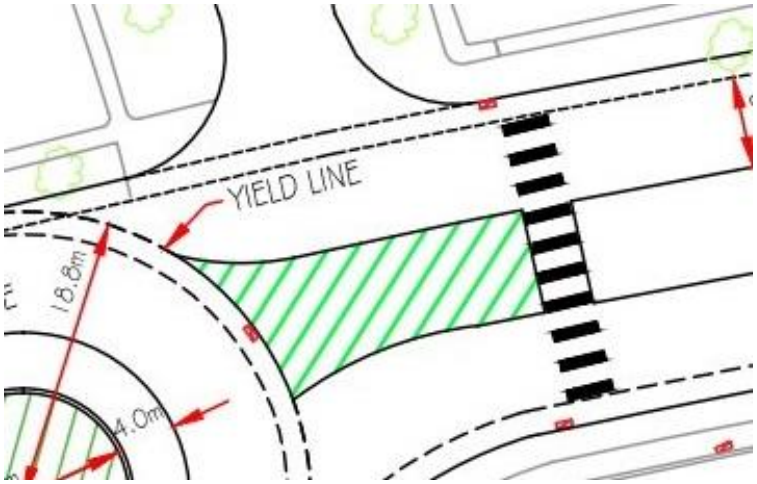

Figure 5: Close up of splitter island around roundabout

2.7 Structural Monument

Another feature of the roundabout is a structural gateway monument that is located in the middle of the roundabout. This is discussed in detail in section 3.0.

2.8 Storm Water Management

To meet UBC sustainability goals, the intersection has its own storm water management system which includes a detention tank to irrigate the nearby neighborhood. This is further discussed in section 4.0.

The storm water management component of the intersection has been designed to capture rainwater and divert it into a detention tank, which will then be used for irrigation purposes. The slopes of the intersection will direct rainfall into catch basins. 10 Catch basins have been strategically placed around the round-about intersection to maximize the catchment areas from pervious and impervious materials. The top of the detention tank is located 0.5 m below grade and slightly offset from the center of the round-about and the structural monument. Catch basin leads transport the runoff water to the tank from each of the catch basins. The detailed design for the storm water management system can be found in Section 4.

3.0 STRUCUTRAL MONUMENT

3.1 Overview

The intersection at Chancellor Blvd. and Wesbrook Mall is not only intended to transport pedestrians, vehicles, and cyclists safely and efficiently but it is also intended to welcome visitors and residents to the UBC campus with an attractive entry point. To create an attractive entry point we have decided to design a structural monument which will be placed in the middle of the roundabout. We have designed a monument that is structurally sound and appropriate for its' application. The monument displays the UBC letters on a cantilever slab supported by a square concrete column and is a total of 4.45 m (14'-6") tall. The UBC letters are connected to a concrete wall that is doweled into the concrete slab. The perimeter of each letter illuminates at night with a blue and yellow gradient. The lights have been designed with UBC's sustainability goals in mind and will be powered by solar energy. A solar panel will be mounted on an inclination on the rear of the concrete wall. White Portland cement will be used in the concrete to maximize the architectural appeal of the concrete portion of the monument. The foundation however, does not need to be appealing and thus will be poured with normal concrete. A front and rear schematic of the monument is included below which shows a visual representation of the above criteria.

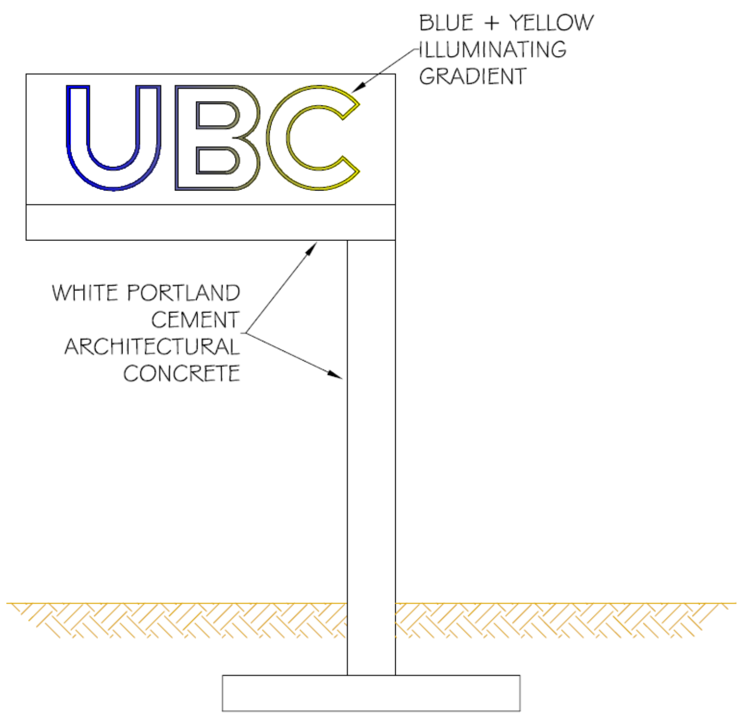

Figure 6: UBC Gateway monument front elevation

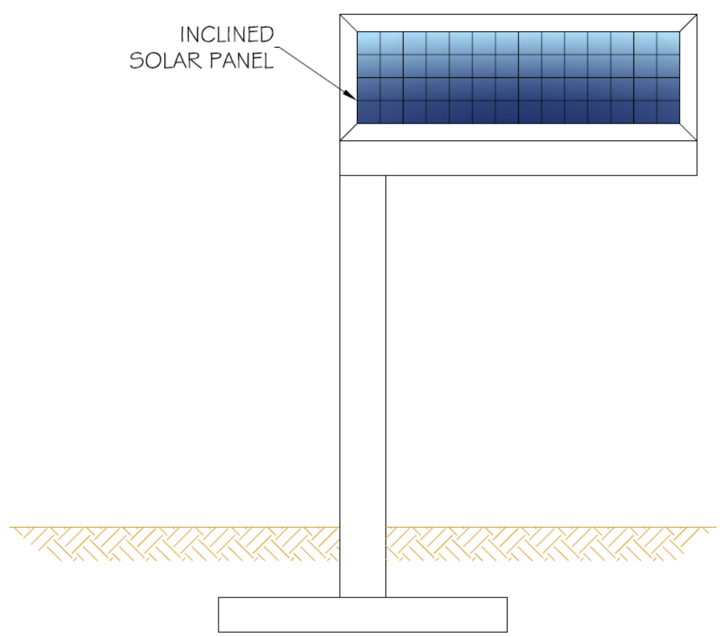

Figure 7: UBC Gateway monument rear elevation

3.2 Technical Drawings and Specifications

As mentioned above the concrete monument is 4.45 m (14'-6") tall with the letters UBC mounted on a wall supported by a cantilever slab. The clear span of the 300 mm thick cantilever slab is 2.7 m. The height of the wall that the UBC letters are mounted is 1.1 m. The figures below provide a detailed outline of the dimensions and size of key monument components.

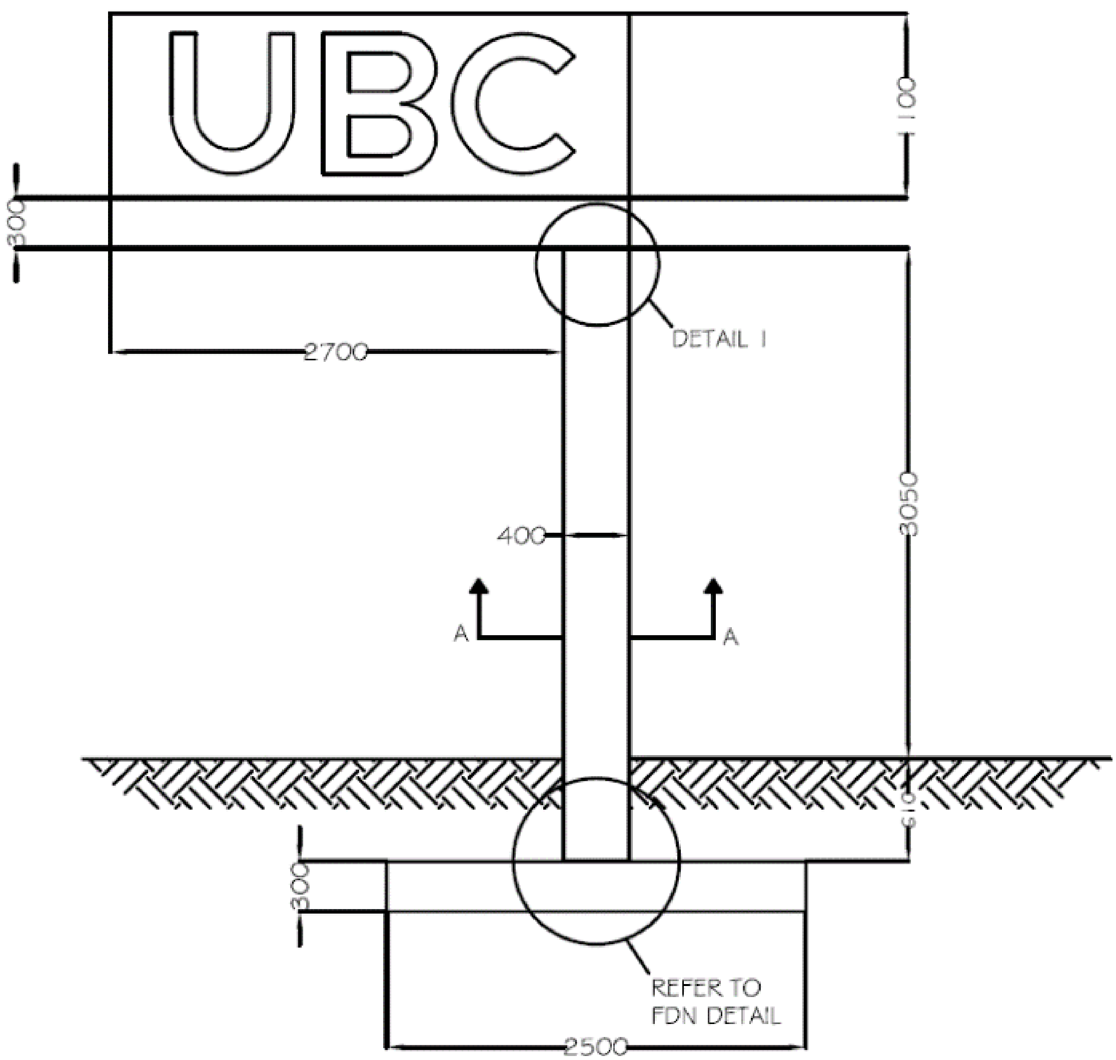

Figure 8: UBC gateway monument front elevation with dimensions

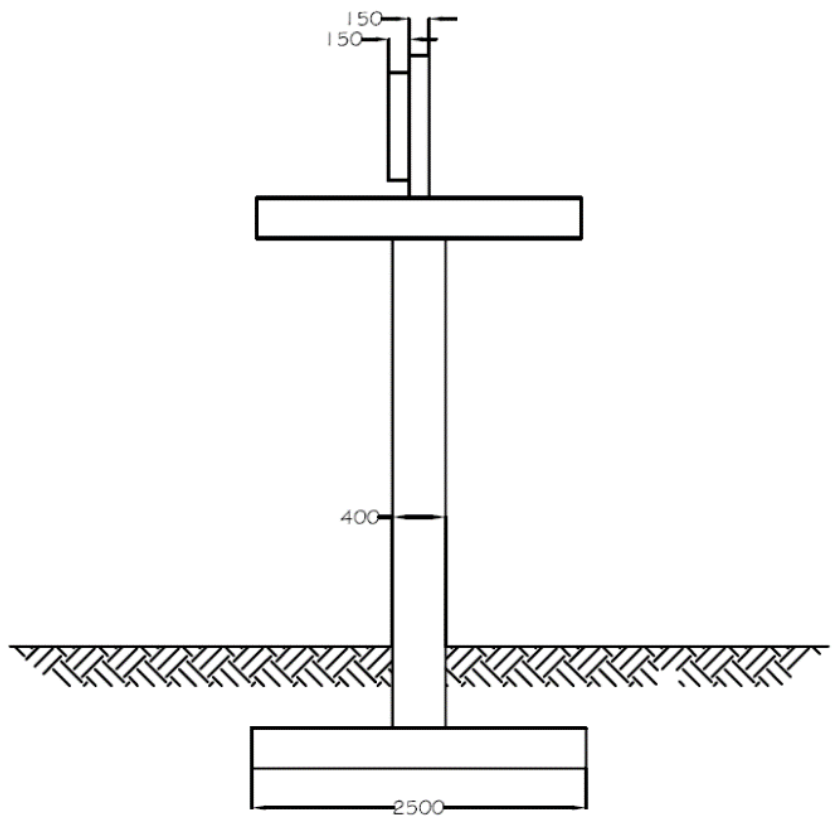

Figure 9: UBC gateway monument right elevation with dimensions

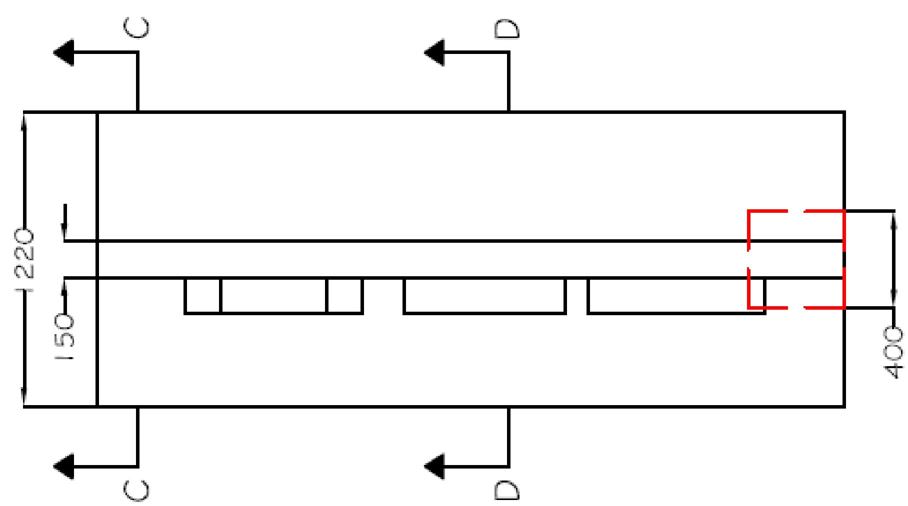

Figure 10: UBC gateway monument top slab plan view

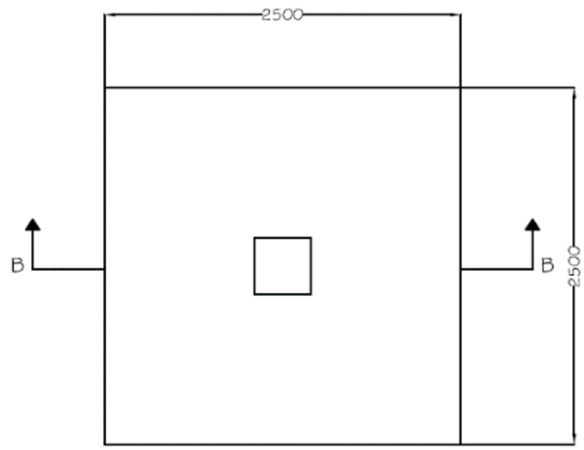

Figure 11: Foundation plan view

The concrete strength used in the design is 25 MPa and the steel reinforcement yield strength is 400 MPa. Normal density concrete has been used which corresponds to $\lambda = 1$. Cover to reinforcement is a minimum of 40 mm at all locations of exterior exposure and a minimum of 75 mm at all locations where cast against earth permanently. The monument and footing is reinforced with the appropriate bars ranging from 10M-20M to ensure the structure acts in a ductile manner when induced to severe climatic conditions. Climatic conditions respective to the location of Vancouver (Granville and 41st Ave) were used when analyzing the structure. The bearing capacity of the soil was taken from a nearby site which was classified as silty sand. A conservative bearing capacity of 100 kPa for silty sand is consistent with present day practice and is recommended by the current Concrete Design Manual, A23.3-14. The monument was designed using the worst load combination for each structural element as per the BC Building Code 2012. A normal importance factor was applied to the specified snow, wind, and seismic loads as well. A summary of the loading is listed below along with rebar specifications. Refer to the appendix for detailed drawings and calculations.

	Importance Factor:	Specified Load:
Snow:	1.0	1.82 kPa
Wind:	1.0	0.96 kPa
Seismic:	1.0	13.77 kN

Table 2: Specified loads

	Dimensions	Flexural/Temp and Shrinkage Reinforcement	Shear Reinforcement
Pad Footing	2.5m x 2.5m x 0.3 m	9-15M bars E/W	N/A
Column	0.4 m x 0.4 m x 3.66 m	8-20M Long. Bars	10M Ties @300mm c/c
Slab	1.22 m x 3.1 m x 0.3 m	20M Tension Bars @250mm c/c, 20M Trans. Bars @400mm c/c	N/A
Wall on Top of Slab	0.15 m x 3.1 m x 1.1 m	10M Bars @300mm c/c E/W	N/A

Table 3: Monument reinforcement details

4.0 STORM WATER MANGEMENT

4.1 Overview

The storm water management system was designed using the Surrey Design Guidelines and the Metro Vancouver storm water source control design guidelines. The detention tank has been designed to hold a capacity of 90 cubic meters (2.5x6x6 meters). This value was obtained by anticipating for a 2-year return period at 24 – hour rainfall. Based on design guidelines, the target aims to capture 72% of the 2 year, 24-hour rainfall depth from the West Vancouver IDF curve. Multiplying the rainfall target by the total impervious catchment area will produce the total catchment volume needed for the detention tank. Infiltration through pervious materials such as soil or a rain garden was also taken into account when developing the total volume. In the case of any over flow, an outfall pipe has been implemented to allow water to leave the tank in the case of a full tank. The following formula was used in calculating the total detention tank volume.

$$V_T = 0.72 * IDF * A$$

$V_T = Total\ Volume\ of\ the\ detention\ tank$

$A = Total\ Impervious\ Area$

$IDF = Data\ from\ the\ 22\ year\ return\ period\ at\ 24\ hour\ rainfall$

The intersection was also designed to consider overland flow times to avoid flooding and to design for the correct rainfall intensity. The slopes on the intersection were designed at 2% grade to allow water to flow off the streets and into the catch basins. The surrey design codes restricts the time concentration developed in basins to a maximum of 20 minutes. The following equations were used to analyze the time concentration at a specific rainfall intensity.

$$T_o = \frac{6.92\ L^{0.6} n^{0.6}}{i^{0.4} S^{0.3}}$$

$$T_c = T_o + T_t$$

$T_o = Overland\ flow\ travel\ time\ in\ minites$

$L = Length\ of\ Overland\ Flow\ Path\ in\ Meters$

$S = Slope\ of\ Overland\ Flow$

$n = Manning\ Coefficient$

$T_t = Travel\ time\ in\ pipe$

$T = Time\ concentration$

4.2 Detention Tank

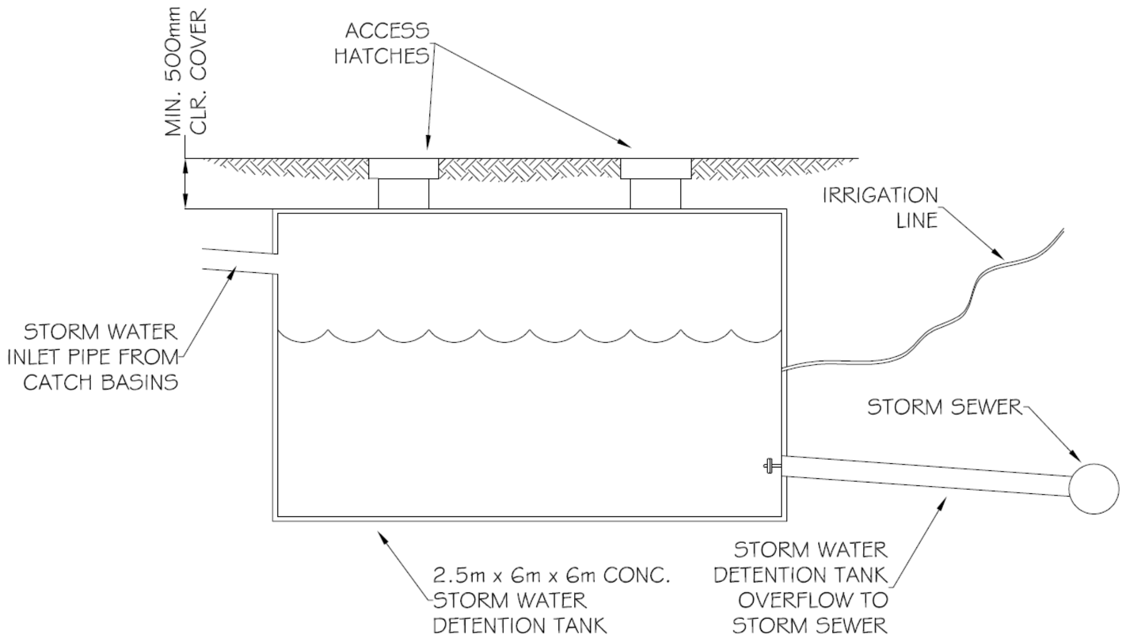

Figure 12: Storm water detention tank

As mentioned above the storm water detention tank is 6 m x 6 m x 2.5 m deep. The walls were analyzed by considering lateral earth pressures from the adjacent soil and snow surcharge. A snow surcharge of 1.9 kPa was used respective to Vancouver (Granville and 41 Ave). A conservative suggested unit weight of 19 kN/m^3 for silty sand was used from a correlation between the soil friction angle. The friction angle of the soil was taken from a nearby site which was 38°. The walls were analyzed using Rankine's Earth Pressure theory with active conditions considered. For a detailed pressure distribution refer to the calculations in the appendix.

The top, bottom and side walls of the detention tank are all 250 mm thick. The appropriate amount and size of reinforcement is placed on the inside face of each wall to ensure ductility is provided in the design. The table below provides details of the reinforcement spacing and size.

	Dimensions	Flexural/Temp and Shrinkage Reinforcement	Shear Reinforcement
Side Walls	2.5 m x 6 m	15M bars @ 400 mm c/c E/W	N/A
Top/Bot Walls	6 m x 6 m	15M bars @ 300 mm c/c E/W	N/A

Table 4: Detention tank reinforcement details

The required 75 mm of cover is attained in all locations for structures permanently cast against soil. 30 MPa concrete and 400 MPa steel has also been used in the design. Two access and maintenance hatches are located at the top of the tank to provide an entryway into the confined space. Each irrigation line and catch basin lead is to be sealed properly with grout or a similar water proof substance.

5.0 TECHNICAL DESIGN COMPONENTS

5.1 Design Criteria

The roundabout has been designed by integrating UBC's sustainability goals to accommodate the traffic demand and provide safe access for all users of the intersection. It provides an active transportation to accommodate pedestrians, cyclists and disabled persons more appropriately within the road environment. With the consideration of future traffic pattern changes, the new roundabout is estimated to have a lifespan of 50 years. Currently, most of the vehicles entering the intersection are eastbound traffic, reaching 800 vehicles per hour during peak hours. The new roundabout is designed to operate efficiently under the current traffic volume. Based on the analysis from the Synchro transportation software, the delay per vehicle before entering the intersection during peak hours is estimated to be 6 seconds. With the average speed of 33km/h, the peak-hour queue line on eastbound is 12m long. The improved traffic situation, compared to the three-way-stop intersection, facilitates the drivers entering the UBC campus and significantly decreases the carbon dioxide emission. Since most of the intersection users are UBC campus students, the traffic volume is expected to increase no more than 10% within the design life. Also, the Broadway Extension of the Millennium Line will relieve the traffic demand in the proposed intersection in the upcoming decade. The new SkyTrain line will connect Broadway Avenue to Downtown Vancouver, Richmond, Burnaby and Surrey, providing a convenient public transportation for UBC commuters in Metro Vancouver. The 10% future traffic increase will not have a significant impact on the roundabout design, while the change of major traffic parameters is negligible. The comparison of the current and future demand can be seen below.

Intersection Demand	Current	Future
Delay / Veh (s)	7.1	7.1
St Del/Veh (s)	1.1	1.2
Stop/Veh	0.15	0.1
Avg Speed (kph)	37	35
Fuel Eff. (kpl)	3.2	2.8
Hourly Exit Rate	1290	1356

Table 5: Traffic demand summary 1

Intersection Demand	Current			Future		
Movement	EB	WB	NB	EB	WB	NB
Maximum Queue (m)	16.2	16.5	8.6	21.2	9.2	8.3
Average Queue (m)	11.8	12	1.7	14	7.2	1.7

Table 6: Traffic demand summary 2

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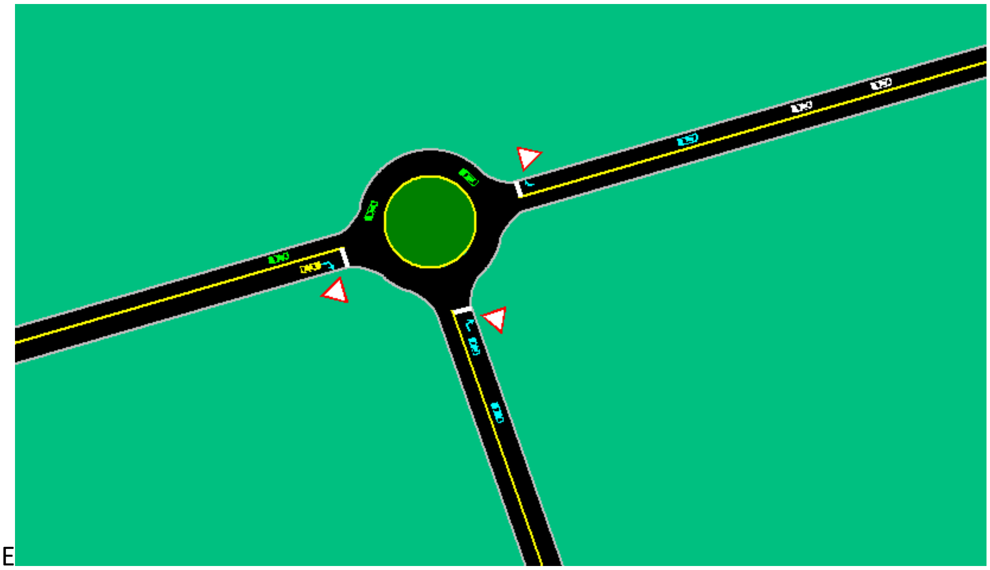


Figure 13: Synchro modeling of the roundabout

5.2 Technical Considerations

In the design process of the project, there are several key important technical considerations to take into account such as the design rules and consistencies, workmanship and concrete work in the construction process, and compaction of the soil on the site. These technical design considerations help ensure that the project meets its requirements while making it feasible to construct in practice. By keeping the design rules consistent throughout the project, the engineers in the design can work effectively together without confusion and coordinate and collaborate with contractors easier. Additionally, the completion of the project with the least amount of complications can be ensured by minimizing the difficulty of the workmanship and concrete work during the construction process. Thus, the project time frame can be greatly impacted by the construction process when incorporating these technical considerations.

When designing the structural monument, one of the key design considerations is the compaction of the soil in the site. To design the foundation to support the structural monument, the allowable capacity of soil is calculated to ensure that the maximum pressure applied to the soil by the structure does not cause shear failure and settlement that will cause unacceptable damage to the structure. At the same time, the seismic conditions are also need to be considered in the design process. Since the maximum pressure applied by the structure is roughly 45 kPa (shown as qf in Figure 14) and the bearing capacity of the soil is roughly 100 kPa, the foundation is sufficient enough to support the structure at this site.

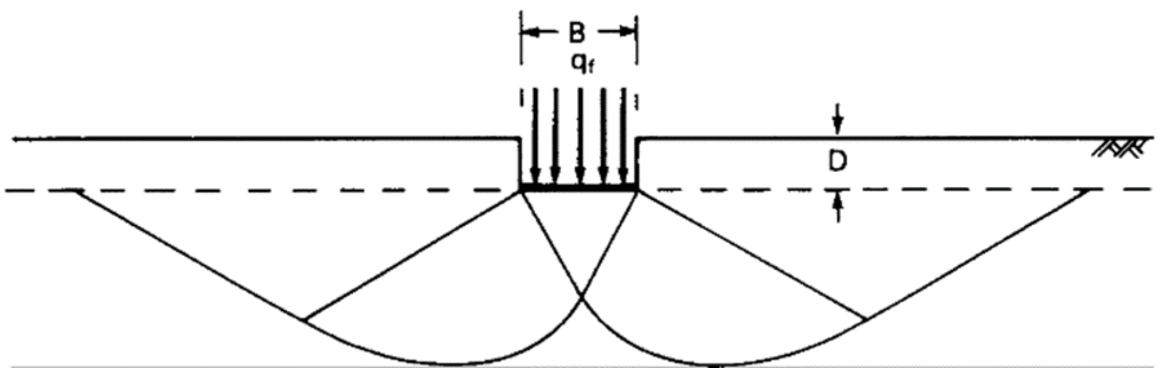


Figure 14: Bearing capacity of soil

6.0 SOFTWARE AND DESIGN STANDARDS

6.1 Transportation Software and Design Standards

The design of the intersection follows the Geometric Design Guidelines for B.C Roads-Intersection by Ministry of Transportation and Infrastructure in British Columbia and was modeled using Synchro Software. The roundabout has a turning radius of 18.8 m, and it can facilitate inter-city bus, fire trucks, and long logging trucks with a design speed of 25 km/h. The design speed is lower than the expected average speed from the Synchro software which is 37 kph, still the heavy vehicles will not have a significant impact on the intersection efficiency because of the limited heavy traffic demand. The roundabout has a truck apron around the central garden island to prevent the heavy vehicle from stopping inside the intersection and to ensure the traffic flows smoothly in extreme cases. Also, the new design is complied with the policy on Geometric Design of Highway and Street in British Columbia. To maintain free flow and high capacity, yield signs are used as the entry control. Entering traffic is deflected to the right by the central island of the roundabout and by channelization at the entrance into an appropriate curved path along the circulating roadway. Research has shown that roundabouts can reduce collisions with fixed objects by approximately 30% of all fatal collisions in North America and an additional 10% of road fatalities attributable to non-collision rollovers. The geometry of the roundabout together with the speed limit sign force traffic to enter and circulate at a slower speed of 30 kph while avoid sacrificing the capacity and efficiency of the intersection.

6.2 Structural Software and Design Standards

Structural and geotechnical design standards were used in the design of both the storm water detention tank and structural monument. For the rebar detailing of both structures CSA-A23.3-14 was used. This is the newest Concrete Design Handbook published by the CSA group. For the analysis and dimensioning of the pad footing the 4th Edition Canadian Foundation Engineering Manual was used. The 4th Edition Canadian Foundation Engineering Manual was also used to analyze earth pressures on the storm water detention tank. All climatic loads were taken from the 2012 BC Building Code. Mathcad computational software and Microsoft excel were used to perform design calculations. The detailed structural drawings were prepared using the Autodesk products, AutoCAD and Revit.

7.0 SITE LAYOUT AND CONFIGURATION

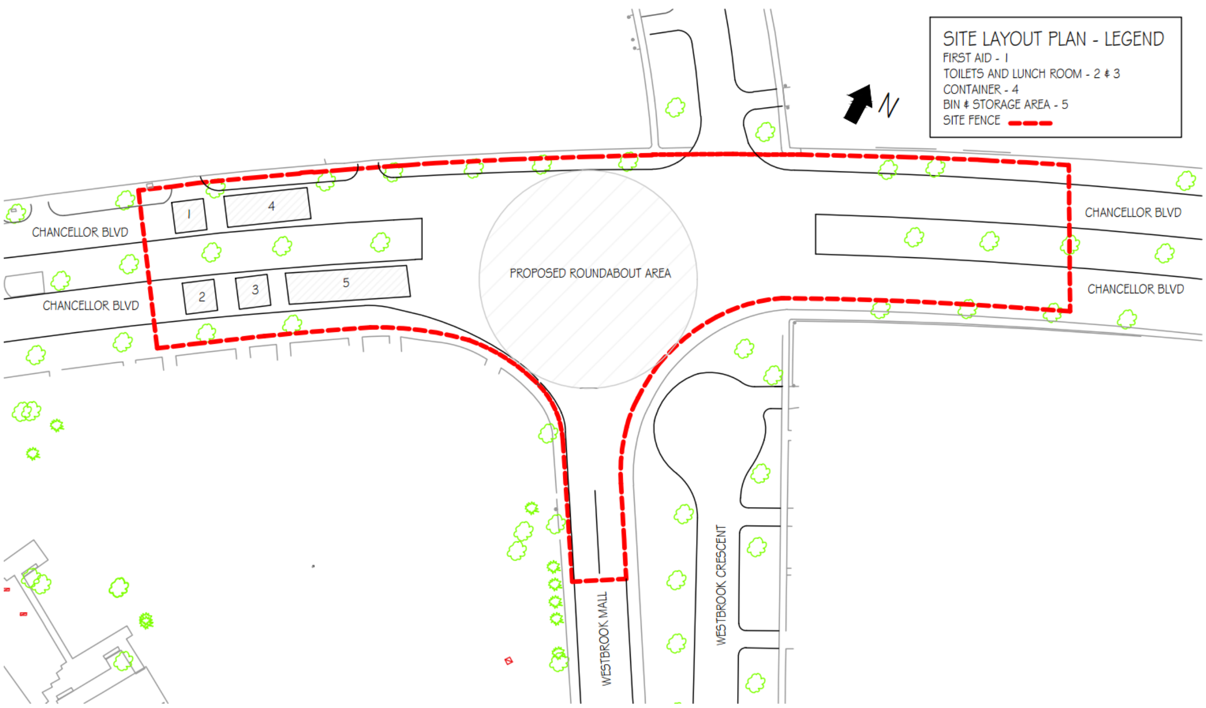


Figure 15: Site layout and configuration

The construction site of the new roundabout is extended along the Chancellor Blvd in the East and West directions and Westbrook Mall in the South direction to ensure enough space to place construction materials, equipment and temporary facilities. The East side of the proposed roundabout is used for construction materials storage and construction vehicles parking, while the West side is for temporary facilities, such as first aid, toilets, lunch rooms, containers, bins and storage areas. The construction side is separated by placing site fencing around the perimeter to protect the safety of the people in the neighbourhood.

During the construction, pedestrians and cyclists still have access to the intersection since the pedestrian lanes are not included in the construction site. Vehicles need to detour when they go across the intersection. Vehicles traveling along Chancellor Blvd will drive through NW Marine Dr. and Acadia Road as shown by the blue dotted line on the detour map while the red circle represents the proposed location of the roundabout. Vehicles on Westbrook Mall will detour through Water Gage Road and Iona Road, and reach the intersection between NW Marine Dr. and Chancellor Road.

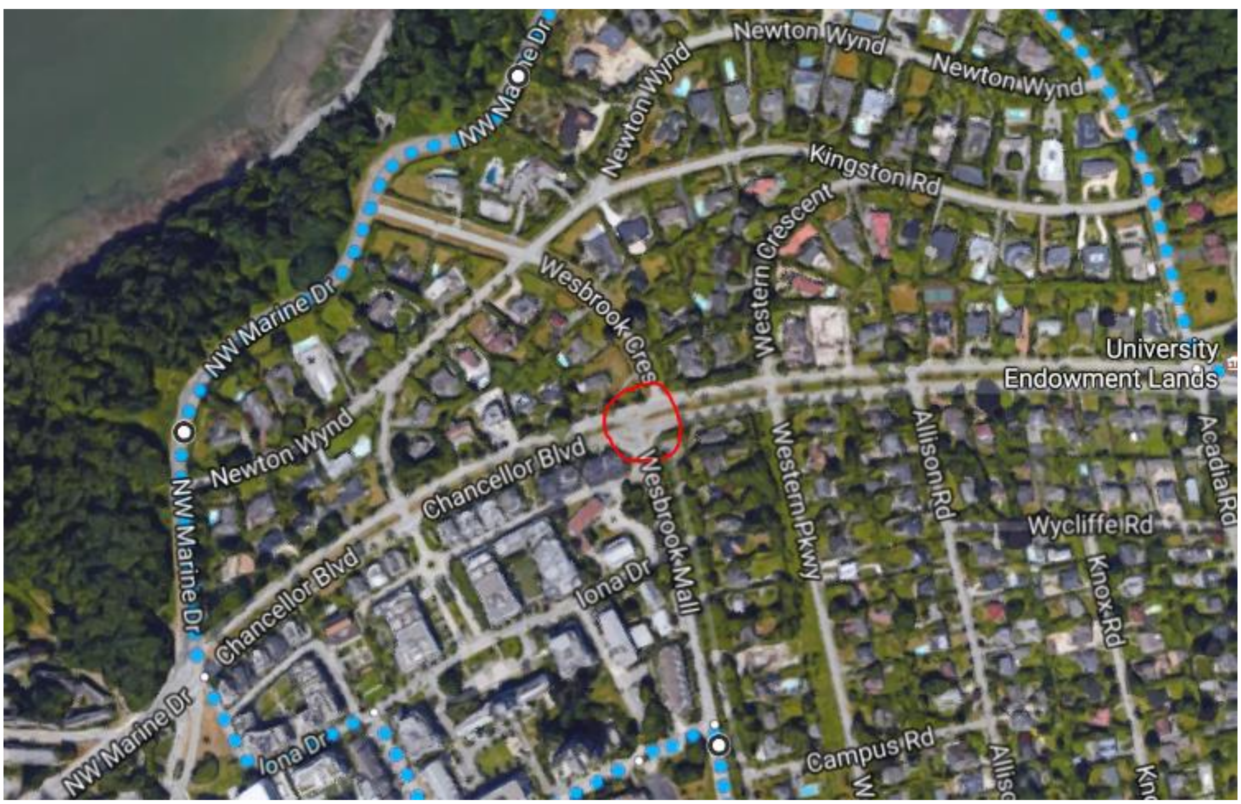


Figure 16: Overhead photo of site

8.0 CONSTRUCTION WORK

8.1 Construction Plan

The construction aspect of the project will dictate the total expenses and usually controls how well a project is conducted and completed. As the construction is the largest contributor to the total expense, an important consideration for the construction planning is that the crew is not scheduled to work weekends. This causes major milestones and task to be planned out with precision. Major task such as pouring and curing concrete must be done all at once and not in sections (due to a weekend). The concrete composition will differ if done improper, therefore, this can cause more delays to the planned schedule.

The project will be built during the summer months (May –August). This way the disruption caused will not affect a significant number of people. Substantially less students will be registered in summer courses than the fall and winter semesters. A limited number of people will thus be affected. There will also be less disruption to the construction work being done. The weather is also more cooperative during the summer months which is very important when considering the backfilling, compacting and the paving stages of the project. A timely completion of the project with minimal disruption will help the project meet its' total budget.

A key engineering component of the construction process will be to ensure inspections, as-built surveys, and site layouts are performed at appropriate times. The contractor should contact Northco well in advance of these checkpoints during construction. A minimum 24 - 48 hrs notice is recommended to ensure the project continues on time with minimal construction delays.

A reliable contractor in which we are familiar with would be ideal for completing the construction process with little to no set backs. We will provide a list of contractors which we would recommend for the job. From past experience, easy co-ordination and co-operation will help ensure the construction is performed at a high quality, on time and on budget.

The materials and services needed for the project should be ordered and planned well in advance. Construction delays occur regularly from absence of materials and services at times of need during construction.

In summary, the main construction planning issues that are most important for the intersection project at Chancellor Blvd. and Wesbrook Mall are:

- Precise task planning
- Time of year of construction
- Weather during construction
- Communication of required engineering
- Services during the construction process
- Absence and availability of material and additional services
- Reliability of contractor

All of which directly affect the duration and the cost of the intersection project

8.2 Field Tests, Surveying, and Inspections

At the site where the intersection and structural monument will be constructed, the soil type in the area is a pervious well draining glacial till which is very close to a silty sand. Glacial till is unsorted glacial sediment deposited directly from glacial ice with angular rock fragments as shown in Figure 17. Glacial till can vary in size, from clay-size material all the way to boulder size material. It has an acceptable bearing capacity and coarse textured with decent drainage, making it an adequate foundation material. The typical value of the allowable bearing capacity for the site is approximate 100 kPa. To obtain accurate properties of the site, the exact soil conditions at the footing location could be confirmed by taking a test pit or a bore log. A geotechnical field review is recommended to verify the allowable bearing capacity.

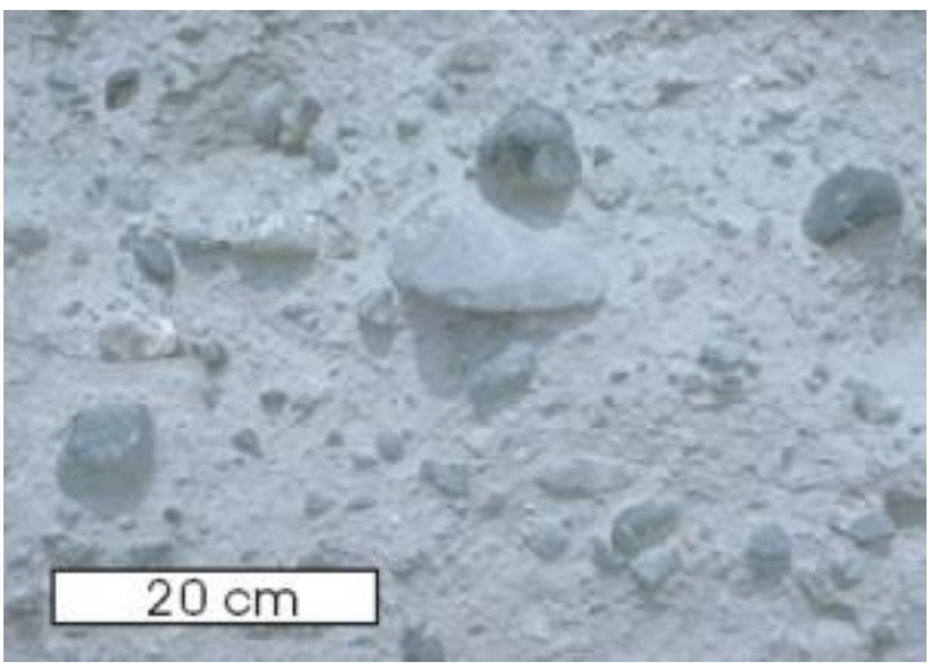


Figure 17: Glacial till material

9.0 DETAILED SCHEDULE AND COST ESTIMATE

9.1 Detailed Schedule

The detailed construction schedule for the construction plan was developed on MS Project. The project start date is May 1st, 2017 and the project end date is arranged to be August 25th, 2017. The total number of working days is 85 days, which does not include weekends. The schedule includes a critical path (red) and a non-critical path (blue). Although the construction schedule changes as the project proceeds, this schedule highlights the main milestones for the intersection project. Some major milestones include: Demolition and excavation, backfill and compaction, pouring and curing of concrete, and finial inspections. Below are 2 figures that show the construction schedule and the cost associated with each major task.

Figure 18: Construction Schedule

Task Name	Duration	Start	Finish	Cost
Round About	**85 days**	**Mon 17-05-0**	**Fri 17-08-25**	**$436,915.76**
Site Set up & Mobilization	2 days	Mon 17-05-01	Tue 17-05-02	$0.00
Demolition of the existing intersection/Excavatior	5 days	Wed 17-05-03	Tue 17-05-09	$153,325.00
Removal & Disposal of Contaminants/Soil Removal	5 days	Wed 17-05-10	Tue 17-05-16	$64,330.00
Replace & Install Manholes	4 days	Wed 17-05-10	Mon 17-05-15	$4,500.00
Removal & Reroute of affected Civil Services	6 days	Tue 17-05-16	Tue 17-05-23	$15,000.00
Instal Catch Basin and Sprinklers	6 days	Wed 17-05-24	Wed 17-05-31	$20,000.00
Backfill to Appropriate Elevation	3 days	Thu 17-06-01	Mon 17-06-05	$3,200.00
Instal Street Light Ducts	7 days	Tue 17-06-06	Wed 17-06-14	$18,000.00
Install Electrical Junction Box	7 days	Tue 17-06-06	Wed 17-06-14	$5,000.00
Backfil and Compact Site to Final Grade	10 days	Thu 17-06-15	Wed 17-06-28	$2,000.00
Pour Curbs & Sidewalk	10 days	Thu 17-06-29	Wed 17-07-12	$20,000.00
Pave Whole Intersection	3 days	Thu 17-07-13	Mon 17-07-17	$50,000.00
Pour Foundation (Middle of the round about)	3 days	Tue 17-07-18	Thu 17-07-20	$5,676.86
Pour and Brace (Rebar) Monument into Foundation, Erect Structure	12 days	Fri 17-07-21	Mon 17-08-07	$5,000.00
Paint Lane Indicators	1 day	Tue 17-07-18	Tue 17-07-18	$849.90
Instal Signage and Erect Street Lights	4 days	Wed 17-07-19	Mon 17-07-24	$65,034.00
Landscape, Rain Gardens, Inspections and Finishing Work	14 days	Tue 17-08-08	Fri 17-08-25	$5,000.00

Figure 19: Major task in the construction schedule

9.2 Detailed Cost Estimate

The total cost for this intersection from conception to completion has been estimated at $539,486.70 with a yearly operational and maintenance cost of $1,666.67. The total cost of this project includes design, permitting, and construction.

As part of this work, engineering design and specifications are provided for this project based on the standard set by the BC Ministry of Transportation and Infrastructure.

Deliverables include:

- Preliminary design that meets all of the objectives of improving the intersection in terms of the design goals
- A Report which includes methodology, assumptions, preliminary, class C cost estimate, analysis results, and final recommendations

Below is the table displaying the cost estimate of the team of consultants consisting of:

- 1 Project Engineer
- 1 Assistant Project Engineer
- 2 Engineer-in-Training
- 1 Technician
- 1 Technologist

Item #	Description	Total Cost
1	Engineering Design and Analysis Report	$35,940.00
2	Disbursement Costs	$12,849.84
3	Misc. Fees	$5,871.26
	Total	$54,661.10

Table 7 Design Cost Summary

The main permitting fees associated with the construction of the new intersection will be a $8,400 road closure fee under the Miscellaneous Fees By-law - #5664 of the 2016 Planning & Development and Community Services document from the City of Vancouver. Other fees associated with this project will be the construction permit, reserved parking permit for equipment, and a permit for the deliveries of materials to the job site. These fees do not have a set cost and are determined on a case by case basis, because of this we are allocating $5,000 of the budget to these fees. Other costs associated with this project are insurance and contingency. Based on current estimates a project of this size would have an insurance cost of $8,820.00 and assuming a contingency of 5%, the contingency fee would equal $25,689.84. The table below provides a summary regarding the costs of construction for the design.

Item #	**Description**	**Total Cost**
1	Asphalt	$44,925.00
2	Concrete	$29,328.39
3	Formwork	$21,423.47
4	Solar Pedestrian Signs	$14,034.00
5	Sign Install	$3,000.00
6	Road Paint	$299.90
7	Road Reflectors	$50.00
8	Road Reflectors Install	$500.00
9	Street Lights	$48,000.00
10	Street Light Install	$18,000.00
11	Steel Rebar	$5,000.00
12	Excavation	$148,325.00
13	Soil Removal	$59,330.00
14	Manholes/Catch Basins	$4,500.00
15	Fill Material	$5,200.00
16	Waste Removal	$10,000.00
17	Sprinkler System	$20,000.00
18	Landscaping	$5,000.00
	Total	$436,915.76

Table 8 Construction Cost Summary

The estimated construction cost for this intersection is $436,915.76; this cost includes labour, materials, and equipment. A full breakdown of this cost estimation can be found in Appendix E of this report; the estimation focuses on the cost of the asphalt, concrete, and formwork. As seen in Table 8, the majority of this construction cost comes from the excavation and removal of the current intersection; these costs are estimated to be $148,325.00 and $59,330.00 respectively. The construction material cost for the new intersection is relatively small with the concrete, formwork, and asphalt estimated at $29,328.39, $21,423.47, and $44,925.00 respectively. Other items associated with the construction of this roundabout can be found in Table 8 above and account for $133,583.90 (26.5%) of the total.

The operating and maintenance cost of the roundabout will be limited to maintaining landscaping features and the maintenance of the asphalt surface. Based on the current market price of routine landscaping, we estimate that $1,000 will be required annually in order to maintain appropriate levels of care. The maintenance of the asphalt surface will be done on an as needed basis with the expectation of a minimum of 3 years of use after each pavement. A cost of $\$50/m^2$ is expected for the pavement with an additional $2,000 cost for the use of related equipment and labour.

APPENDIX A – SITE OVERVIEW

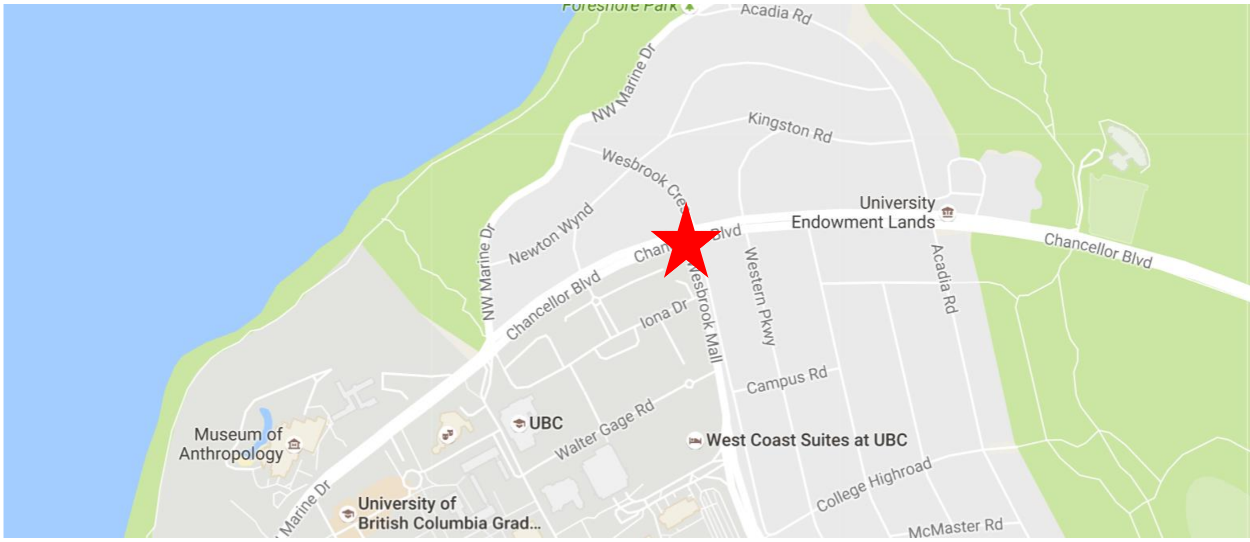


Figure 20 Map Overview of Site 1

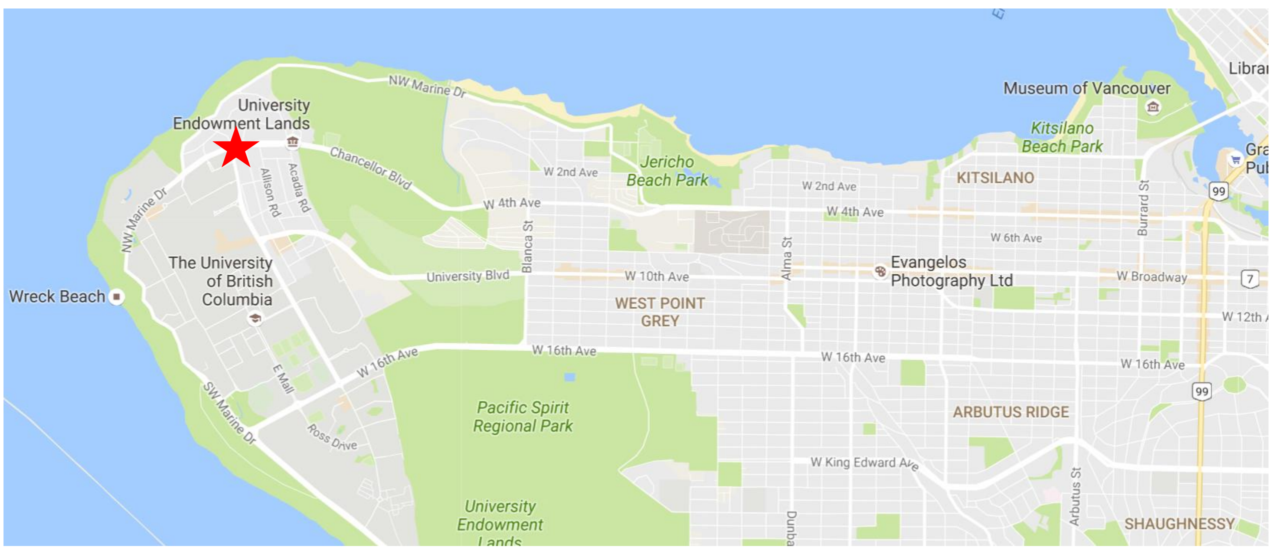


Figure 21 Map Overview of Site 2

Figure 22 Overhead view of Site

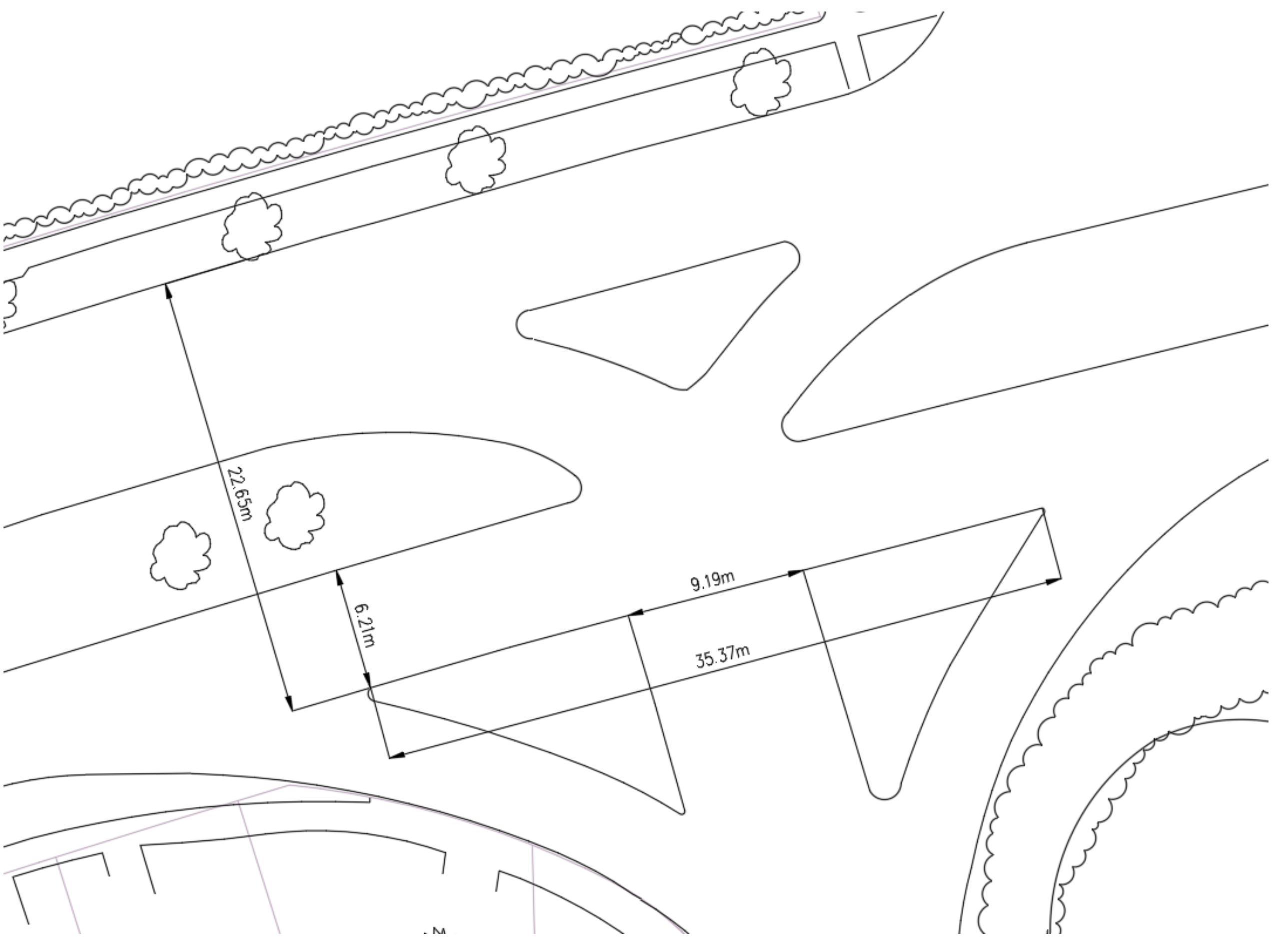


Figure 23 Simplified Drawing of Current Site

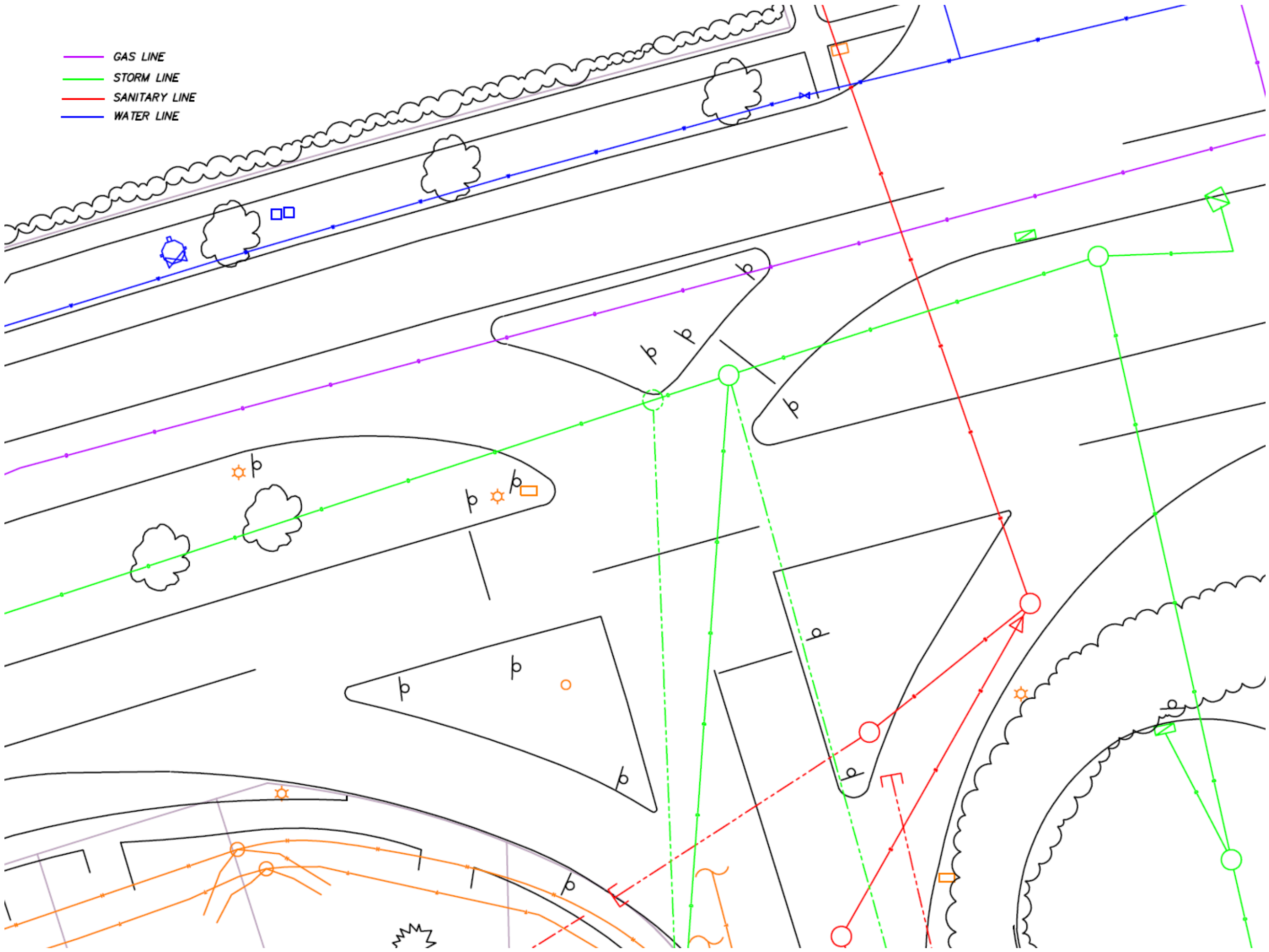


Figure 24 Detailed Drawing of Current Site

APPENDIX B – SITE PHOTOS

Figure 25 Photo of Site Facing South 1

Figure 26 Photo of Site Facing South 2

Figure 27 Photo of Site Facing South 3

Figure 28 Photo of Site Facing South 4

Figure 29 Photo of Site Facing East 1

Figure 30 Photo of Site Facing North 1

Figure 31 Photo of Site Facing North 2

APPENDIX C – POSPOSED DESIGN DRAWING

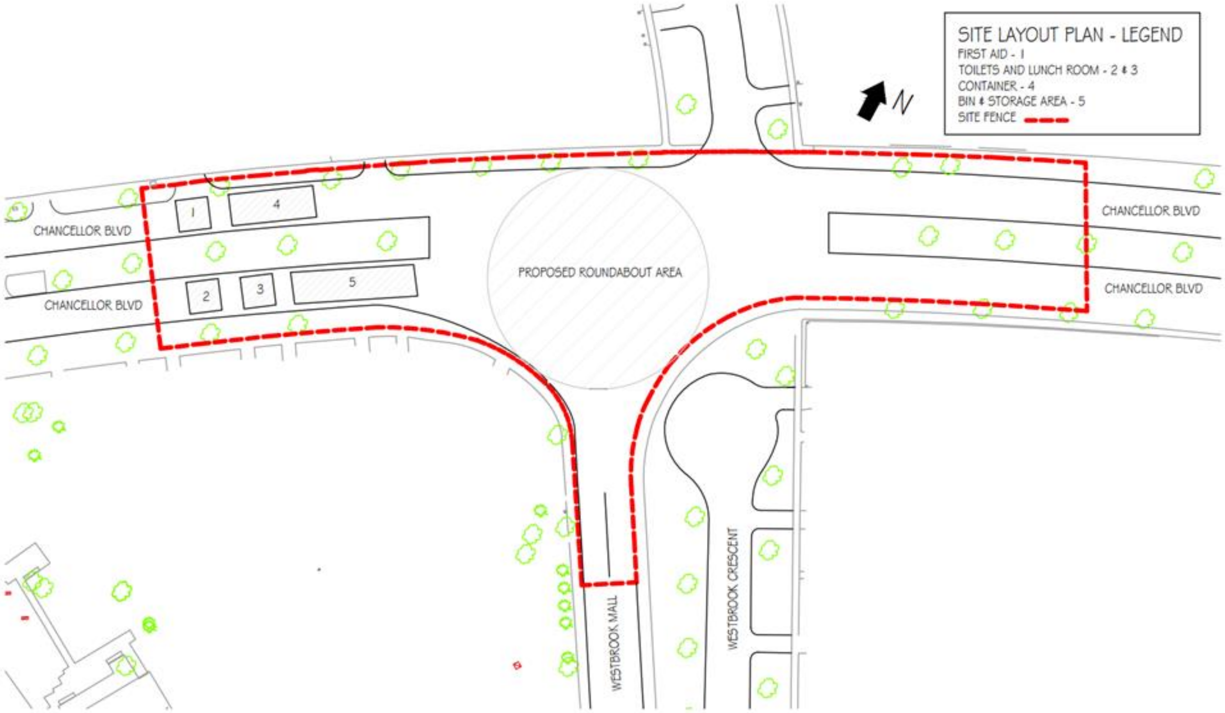


Figure 32 Detailed Drawing of Proposed Intersection

APPENDIX D – CALCULATIONS

SEISMIC LOAD CALCULATION

BUILDING PERIOD

$$T = C_t \times (h_n)^{0.75} = 0.05 \times (5.06)^{0.75} = 0.169s$$

SEISMIC DATA

For Building period < 0.2s in Site Class C,

$$S(T_a) = S(0.2) = F_a \times S_a(0.2) = 1.0 \times 0.95 = 0.95$$

BASE SHEAR

$$V = S(T_a) \times M_v \times I_e \times \frac{W}{R_d \times R_o} = 0.95 \times 1.00 \times 1.0 \times \frac{W}{1.5 \times 1.3} = 0.487W$$

BASE SHEAR SHOULD NOT EXCEED

$$V \leq (\frac{2}{3}) \times S(0.2) \times I_e \times \frac{W}{R_d \times R_o} = (\frac{2}{3}) \times 0.95 \times 1.0 \times \frac{W}{1.5 \times 1.3} = 0.325W$$

BASE SHEAR SHALL NOT BE LESS THAN

$$V \geq S(2.0) \times M_v \times I_e \times \frac{W}{R_d \times R_o} = 0.17 \times 1.00 \times 1.0 \times \frac{W}{1.5 \times 1.3} = 0.087W$$

BASE SHEAR AT THE FOUNDATION

$$V = 0.325W = 0.325 \times 54.83KN = 17.81KN$$

BENDING MOMENT AT THE FOUNDATION

$$M = \sum V_n \times h_n = 5.06m \times 4.89KN + 3.96m \times 8.88KN + 3.66m \times 4.05KN = 74.68KN.m$$

Snow Drift Figure G-8 (NBCC 2010)

Climatic Data

Location

Province: British Columbia

Location: Vancouver (Granville & 41 Ave)

Density

Snow density, γ: 3 kN/m³

Factors

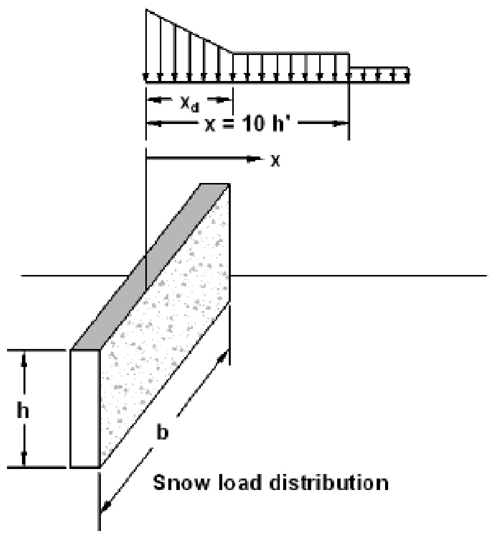
Importance factor

I_s: Normal

Factors

C_b: 0.8

C_w: 1.0



Roof Projection

Length, b: 3.14 m

Height, h: 1.07 m

Roof geometry

Pitch: 0 /12

Slippery: No

Specified Snow Load

$S = I_s[S_s(C_bC_wC_sC_a)+S_r]$ [4.1.6.2]

Factors

Location: Vancouver (Granville & 41 Ave), British Columbia

Ss = 1.9 kPa Sr = 0.3 kPa

Importance Factors

ULS: I_s = 1.0 SLS: I_s = 0.9

Roof slope = 0 degrees

Slope Factor

For non-slippery roof:

Slope <= 30 degrees.

C_s = 1

C_b = 0.8 Density = γ = 3 kN/m³

Drift Factors & Distribution [Structural Commentaries Fig G-8]

$C_a(0) = 0.67*\gamma\ h/(C_bS_s) = 1.415$

a) when $C_a(0) < (0.8/C_b=1)$: $C_a(0)=0.8/C_b$

b) when $C_a(0) > (2/C_b=2.5)$: $C_a(0)=2/C_b$

$C_a(0) = 1.41$

$x_d = 2h = 2.14$ m. But $3\ m \le x_d \le 9$ m:

$x_d = 3$ m

$h' = h - C_bC_wS_s/\gamma = 0.563$m

Min dist where (C_w = 1.0) = 10*h' = 5.633 m

Obstruction effect limit = 3 S_s / γ = 1.9 m

Snow Load Summary

(b = 3.14 m) > (3*S_s / γ = 1.9 m)

x = 0

C_w = 1 $C_a(0)$ = 1.4149

S_{ULS} = 1.0[1.9(0.8*1*1*1.415)+0.3] = 2.451 kPa

S_{SLS} = 0.9[1.9(0.8*1*1*1.415)+0.3] = 2.206 kPa

$0 < x \le (x_d = 3m)$

C_w = 1

$C_a(x)$ decreases linearly over $0 < x \le x_d$

Ca(x) = 1.4149 - 0.1383 * x (with x in meters)

$x = x_d = 3m$

C_w = 1 $C_a(x_d)$ = 1

S_{ULS} = 1.0[1.9(0.8*1*1*1)+0.3] = 1.82 kPa

S_{ULS} = 0.9[1.9(0.8*1*1*1)+0.3] = 1.638 kPa

$x > (x_d = 3m)$

C_w = 1.0 $C_a(x)$ = 1

S_{ULS} = 1.0[1.9(0.8*1.0*1*1)+0.3] = 1.82 kPa

S_{SLS} = 0.9[1.9(0.8*1.0*1*1)+0.3] = 1.638 kPa

Specified Wind Load Figure I-24 (NBC 2010)

Free Standing Plates, Walls, and Billboards

Climatic Data

Location

Province: British Columbia

Location: Vancouver (Granville & 41 Ave)

Return Period: 50 year

Factors

Importance factor

I_w: Normal

Exposure

Terrain: Open terrain

Gust Factor

C_g: 2

Geometry

Length, L: 3.14 m

Height, h: 1.07 m

Distance from Ground to Underside

y: 3.35 m

Factors

Location: Vancouver (Granville & 41 Ave), British Columbia

q_{50}: 0.45kPa

Importance Factor, ULS: $I_w = 1.0$ / SLS: $I_w = 0.75$

C_e = greater of: $((h+y)/10)^{0.2}$ and $0.9 = 0.9$

Wind Pressure

$C_f = 1.18$ for walls above the ground

$C_g = 2$

Normal Force

$F_n = C_f * C_n * q * C_g * C_e * h * L$

Transverse Force

$F_t = C_f * C_t * q * C_g * C_e * h * L$

<u>Case 1</u>

$C_n = 1.0$	$C_t = 0.2$
$F_n = 3.21$ kN	$F_t = 0.64$ kN

<u>Case 2</u>

$C_n = 0.6$	$C_t = 0.3$
$F_n = 1.93$ kN	$F_t = 0.96$ kN

Project: Chancellor Blvd. and West Mall Intersection
Client: UBC
Designer: Lyndon Martell
Date: Feb 27, 2017

DESIGN OF WALL ON TOP OF SLAB

<u>Wall Dimensions:</u>

$h_{wall} := 3.5ft$	Clear Span of Cantilever Wall
$l_{slab} := 9ft$	Length of Slab to Column Face
$b_{col} := 400mm$	Column Dimensions
$l_{wall} := l_{slab} + b_{col} = 3.143\,m$	Total Length of Wall
$t_{req} := \frac{h_{wall}}{10} = 106.68 \cdot mm$	Required Thickness of Cantilever Wall
$t_{wall} := 6in$	Design Thickness of Wall
$b := 1000mm$	Wall Unit Width

<u>Wind Loads (fig I-24 NBCC):</u>

$F_{n1} := 3.21kN$	Case 1 Normal Force
$F_{n2} := 1.93kN$	Case 2 Normal Force
$q_{n1} := \frac{F_{n1}}{h_{wall} \cdot l_{wall}} = 0.957 \cdot kPa$	Case 1 Normal Wind Pressure
$q_{n2} := \frac{F_{n2}}{h_{wall} \cdot l_{wall}} = 0.576 \cdot kPa$	Case 2 Normal Wind Pressure
$w_{n1} := q_{n1} \cdot 1m = 0.957 \cdot \frac{kN}{m}$	Uniform Distributed Wind Load Case 1
$w_{n2} := q_{n2} \cdot 1m = 0.576 \cdot \frac{kN}{m}$	Uniform Distributed Wind Load Case 2

$w_f := 1.4 \cdot \max(w_{n1}, w_{n2}) = 1.34 \cdot \frac{kN}{m}$ Factored Wind Distributed Load

$M_f := w_f \cdot \frac{h_{wall}^2}{2} = 0.763 \cdot kN \cdot m$ Max Factored Moment

$V_f := w_f \cdot h_{wall} = 1.43 \cdot kN$ Max Shear Force

Concrete and Steel Specs:

$f_c := 25MPa$

$f_y := 400MPa$

$\phi_c := 0.65$

$\phi_s := 0.85$

$\lambda := 1$ Normal Concrete

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$d_b := 10mm$ Bar Diameter

$A_b := 100mm^2$ Bar Area

$cover := 40mm$ Exterior Slab Cover Exposed to Freeze Thaw

$a_{max} := 30mm$ Max Aggregate Size

$d := \frac{t_{wall}}{2} = 76.2 \cdot mm$ Design Effective Depth

Design Slab for Moment:

$$A_s := \frac{(\alpha_1 \cdot \phi_c \cdot f_c \cdot b)}{\phi_s \cdot f_y} \cdot \left(d - \sqrt{d^2 - \frac{2 \cdot M_f}{\alpha_1 \cdot \phi_c \cdot f_c \cdot b}} \right) = 29.586 \cdot mm^2$$

$s_s := b \cdot \frac{A_b}{A_s} = 3.38 \times 10^3 \cdot mm$ Bar spacing for Wall

$A_{smin} := 0.002 \cdot b \cdot t_{wall} = 304.8 \cdot mm^2$ Minimum Wall Reinforcement

$s_{min} := \min\left[3 \cdot t_{wall}, \frac{(b \cdot A_b)}{A_{smin}}, 500mm, s_s\right] = 328.084 \cdot mm$ Minimum Spacing for Reinforcement in Wall

$s_{des} := 300mm$

$A_{sdes} := \frac{(b \cdot A_b)}{s_{des}} = 333.333 \cdot mm^2$

$\rho_b := 0.022$ Balanced Reinforcement Ratio for 25 MPa Conc.

$\rho := \frac{A_{sdes}}{b \cdot d} = 4.374 \times 10^{-3}$

$$BalancedRatio := \begin{vmatrix} \text{"Good"} & \text{if } \rho_b \geq \rho \\ \text{"Not Good"} & \text{otherwise} \end{vmatrix}$$

BalancedRatio = "Good"

10M Long. Bars @ 300 mm c/c

Design Wall for Shear:

$d_v := \max(0.9 \cdot d, 0.72 \cdot t_{wall}) = 109.728 \cdot mm$ Effective Shear Depth

$\beta := \frac{230mm}{1000mm + d_v} = 0.207$ Section Contains No Shear Reinforcement

$V_c := \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{f_c} \cdot b \cdot d_v \cdot (\sqrt{MPa}) = 73.912 \cdot kN$ Shear Resistance of Concrete

$$ShearReinforcement := \begin{vmatrix} \text{"Not Needed"} & \text{if } V_c \geq V_f \\ \text{"Needed"} & \text{otherwise} \end{vmatrix}$$

ShearReinforcement = "Not Needed"

Project: Chancellor Blvd. and West Mall Intersection
Client: UBC
Designer: Lyndon Martell
Date: Feb 27, 2017

DETERMINATION OF CANTILEVER SLAB SPECS

<u>Slab Dimension Design:</u>

$l_n := 9ft = 2.743 \cdot m$	Clear Span of Cantilever
$t_{req} := \frac{l_n}{10} = 274.32 \cdot mm$	Required Cantilever Thickness
$t_{slab} := 12in = 304.8 \cdot mm$	Design Thickness of Slab
$w_{slab} := 4ft = 1.219\,m$	Width of Slab

Dead Loads:

$\gamma_c := 24 \frac{kN}{m^3}$	Unit Weight of Concrete
$t_{wall} := 6in = 152.4 \cdot mm$	Thickness of Walls
$t_{let} := 6in = 152.4 \cdot mm$	Thickness of Letters
$h_{wall} := 3.5ft = 1.067 \cdot m$	Height of Wall
$h_{let} := 2.75ft = 0.838 \cdot m$	Height of Letters
$b_{col} := 400mm$	Column Dimension
$L_{wall} := l_n + b_{col} = 3.143 \cdot m$	Total Length of Wall
$L_{let} := 26in = 0.66\,m$	Length of Letter
$Slab_{DL} := 1m \cdot t_{slab} \cdot \gamma_c = 7.315 \cdot \frac{kN}{m}$	Unit Width Uniform Dead Load of Slab

$Wall_{DL} := \frac{(L_{wall} \cdot t_{wall} \cdot h_{wall})}{l_n} \cdot \gamma_c = 4.471 \cdot \frac{kN}{m}$ Uniform Dead Load of Total Wall Length

$Let_{DL} := \frac{(3L_{let} \cdot t_{let} \cdot h_{let})}{l_n} \cdot \gamma_c \cdot \left(\frac{1}{2}\right) = 1.107 \cdot \frac{kN}{m}$ Approx. Uniform Dead Load of UBC Letters

$q_{DL} := Slab_{DL} + Wall_{DL} + Let_{DL} = 12.893 \cdot \frac{kN}{m}$ Total Uniform Dead Load

Snow Loads:

Snow drift should be considered since wall obstructions at rear and side of slab

$SL_0 := 2.45kPa$ Snow Load at x = 0 m

$SL_3 := 1.82kPa$ Snow Load at x = 3 m

$SL_1 := SL_0 - (SL_0 - SL_3) \cdot \left(\frac{0.61}{3}\right) = 2.322 \cdot kPa$ Snow Load at x = 0.61 m

$SL := \frac{(SL_0 + SL_1)}{2} = 2.386 \cdot kPa$ Equivalent Design Snow Load

$q_{SL} := SL \cdot 1m = 2.386 \cdot \frac{kN}{m}$ Unit Width Uniform Snow Load

Factored Loads:

$q_f := 1.25 \cdot q_{DL} + 1.5 \cdot q_{SL} = 19.695 \cdot \frac{kN}{m}$ Factored Uniform Load on Cantilever

$V_f := l_n \cdot q_f = 54.028 \cdot kN$ Factored Shear Force at Column Face

$M_f := \frac{(q_f \cdot l_n^2)}{2} = 74.105 \cdot kN \cdot m$ Factored Moment at Column Face

$M_s := \frac{\left[(q_{DL} + q_{SL}) l_n^2\right]}{2} = 57.489 \cdot kN \cdot m$ Service Moment (for Design of Footing)

Concrete and Steel Specs:

$f_c := 25MPa$

$f_y := 400MPa$

$\phi_c := 0.65$

$\phi_s := 0.85$

$\lambda := 1$ — Normal Concrete

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$d_b := 20mm$ — Bar Diameter

$A_b := 300mm^2$ — Bar Area

$cover := 40mm$ — Exterior Slab Cover Exposed to Freeze Thaw

$a_{max} := 30mm$ — Max Aggregate Size

$b := 1000mm$ — Slab Unit Width

$d := t_{slab} - cover - \frac{d_b}{2} = 254.8 \cdot mm$ — Effective Depth

Design Slab for Moment:

$$A_s := \frac{(\alpha_1 \cdot \phi_c \cdot f_c \cdot b)}{\phi_s \cdot f_y} \cdot \left(d - \sqrt{d^2 - \frac{2 \cdot M_f}{\alpha_1 \cdot \phi_c \cdot f_c \cdot b}} \right) = 896.668 \cdot mm^2$$

$s_s := b \cdot \frac{A_b}{A_s} = 334.572 \cdot mm$ — Bar spacing for Slab

$A_{smin} := 0.002 \cdot b \cdot t_{slab} = 609.6 \cdot mm^2$ — Minimum Slab Reinforcement

$s_{min} := \min\left[3.t_{slab}, \frac{(b \cdot A_b)}{A_{smin}}, 500mm, s_s\right] = 334.572 \cdot mm$ — Minimum Spacing for Reinforcement in Slab

$s_{des} := 250mm$

$$A_{sdes} := \frac{(b \cdot A_b)}{s_{des}} = 1.2 \times 10^3 \cdot mm^2$$

$$\rho_b := 0.022$$

Balanced Reinforcement Ratio for 25 MPa Conc.

$$\rho := \frac{A_{sdes}}{b \cdot d} = 4.71 \times 10^{-3}$$

$$BalancedRatio := \begin{cases} \text{"Good"} & \text{if } \rho_b \geq \rho \\ \text{"Not Good"} & \text{otherwise} \end{cases}$$

$$BalancedRatio = \text{"Good"}$$

20M Long. Bars @ 250 mm c/c

Design Slab for Shear:

$$d_v := \max(0.9 \cdot d, 0.72 \cdot t_{slab}) = 229.32 \cdot mm$$

Effective Shear Depth

$$\beta := \frac{230mm}{1000mm + d_v} = 0.187$$

Section Contains No Shear Reinforcement

$$V_c := \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{f_c} \cdot b \cdot d_v \cdot \left(\sqrt{MPa}\right) = 139.44 \cdot kN$$

Shear Resistance of Concrete

$$ShearReinforcement := \begin{cases} \text{"Not Needed"} & \text{if } V_c \geq V_f \\ \text{"Needed"} & \text{otherwise} \end{cases}$$

$$ShearReinforcement = \text{"Not Needed"}$$

Project: Chancellor Blvd. and West Mall Intersection
Client: UBC
Designer: Lyndon Martell
Date: Feb 27, 2017

DESIGN OF COLUMN

Concrete and Steel Specs:

$\gamma_c := 24\frac{kN}{m^3}$

$f_c := 25MPa$

$f_y := 400MPa$

$\phi_c := 0.65$

$\phi_s := 0.85$

$\lambda := 1$ Normal Concrete

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$d_b := 20mm$ Bar Diameter

$A_b := 300mm^2$ Bar Area

$d_{tie} := 10mm$ Tie Diameter

$cover := 40mm$ Exterior Slab Cover Exposed to Freeze Thaw

$a_{max} := 30mm$ Max Aggregate Size

Column Dimensions:

$b_{col} := 400mm$ Square Column

$l_{col} := 10ft + 2ft = 3.658 \cdot m$ Length of Column, (2 ft below ground)

$A_g := b_{col}^2 = 1.6 \times 10^5 \cdot mm^2$ Gross Area

Slab Dimensions + Load:

$l_n := 9ft$ Clear Span of Cantilever

$t_{req} := \frac{l_n}{10} = 274.32 \cdot mm$ Required Cantilever Thickness

$t_{slab} := 12in = 304.8 \cdot mm$ Design Thickness of Slab

$w_{slab} := 4ft = 1.219 m$ Width of Slab

$P_{slab} := (l_n + b_{col}) \cdot t_{slab} \cdot w_{slab} \cdot \gamma_c = 28.033 \cdot kN$ Dead Load of Slab

Wall and Letters Dimensions + Loads:

$t_{wall} := 6in = 152.4 \cdot mm$ Thickness of Walls

$t_{let} := 6in = 152.4 \cdot mm$ Thickness of Letters

$h_{wall} := 3.5ft = 1.067 \cdot m$ Height of Wall

$h_{let} := 2.75ft = 0.838 \cdot m$ Height of Letters

$L_{wall} := l_n + b_{col} = 3.143 \cdot m$ Total Length of Wall

$L_{let} := 26in = 0.66 m$ Length of a Letter

$P_{wall} := t_{wall} \cdot h_{wall} \cdot L_{wall} \cdot \gamma_c = 12.265 \cdot kN$ Dead Load of Wall

$P_{let} := \frac{3}{2} t_{let} \cdot h_{let} \cdot L_{let} \cdot \gamma_c = 3.037 \cdot kN$ Dead Load of Letters

Dead Load:

$P_{DL} := P_{slab} + P_{wall} + P_{let} = 43.335 \cdot kN$ Total Dead Load

Snow Loads:

Snow drift should be considered since wall obstructions at rear and side of slab

$SL_0 := 2.45kPa$ Snow Load at x = 0 m

$SL_3 := 1.82 kPa$ Snow Load at x = 3 m

$SL_1 := SL_0 - (SL_0 - SL_3) \cdot \left(\frac{0.61m}{3m}\right) = 2.322 \cdot kPa$ Snow Load at x = 0.61 m

$SL := \frac{(SL_0 + SL_1)}{2} = 2.386 \cdot kPa$ Equivalent Design Snow Load

$P_{SL} := SL \cdot (l_n + b_{col}) \cdot w_{slab} = 9.143 \cdot kN$ Total Snow Load

Factored Loads:

$P_f := 1.25 \cdot P_{DL} + 1.5 \cdot P_{SL} = 67.884 \cdot kN$ Factored Axial Load

$M_f := 74.11 kN \cdot m$ Factored Moment

Check Slenderness of Column:

ψ.top = infinity

$E_c := 4500 \cdot \sqrt{f_c} \cdot \sqrt{MPa} = 2.25 \times 10^4 \cdot MPa$

$I_g := \frac{b_{col}^4}{12} = 2.133 \times 10^9 \cdot mm^4$

$I_c := 0.7 \cdot I_g = 1.493 \times 10^9 \cdot mm^4$

$q_{all} := 100 kPa$ Conservative Allowable Bearing Pressure for Sand from table 14.1 Concrete Textbook (pg. 832)

$k_s := 30000 \frac{kN}{m^3}$ Coefficient of Subgrade Reaction From Concrete Design Code

$b_{foot} := 2.5m$ Square Footing Width

$I_{foot} := \frac{b_{foot}^4}{12} = 3.255 \times 10^{12} \cdot mm^4$

$k_f := k_s \cdot I_{foot} = 9.766 \times 10^4 \cdot kN \cdot m$

$$\psi_{bot} := \frac{\left[\frac{(4 \cdot E_c \cdot I_c)}{l_{col}}\right]}{k_f} = 0.376$$

Using Nomograph, Considering an Unbraced Frame

$k := 2.05$

$r := 0.3 \cdot b_{col} = 120 \cdot mm$

$$\frac{(k \cdot l_{col})}{r} = 62.484$$

$$\frac{(25 - 10 \cdot 1)}{\sqrt{\frac{P_f}{(f_c \cdot A_g)}}} = 115.143$$

$$Slenderness := \begin{cases} \text{"OK"} & \text{if } \frac{(k \cdot l_n)}{r} \le \frac{(25 - 10 \cdot 1)}{\sqrt{\frac{P_f}{(f_c \cdot A_g)}}} \\ \text{"Re-design"} & \text{otherwise} \end{cases}$$

Slenderness = "OK"

Slenderness need not be Considered

Design Longitudinal Reinforcement:

$$\gamma := \frac{(b_{col} - 2cover - 2d_{tie} - d_b)}{b_{col}} = 0.7$$

Use interaction diagram from concrete design manual

$$\frac{M_f}{A_g \cdot b_{col}} = 1.158 \cdot MPa$$

$$\frac{P_f}{A_g} = 0.424 \cdot MPa$$

$\rho_t := 0.01$ Chosen from Interaction Diagram

$A_{st} := \rho_t \cdot A_g = 1.6 \times 10^3 \cdot mm^2$ Required Tension Reinforcement

$n := \frac{A_{st}}{A_b} = 5.333$ Required # of bars

Use 8-20M Long. bars

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DETERMINATION OF PAD FOOTING DIMENSIONS AND SPECS

Monument Dimensions:

$h_{ag} := 10ft = 3.048\,m$	Height of Monument Above Grade
$d_{bg} := 2ft$	Depth of Monument Below Grade
$h := h_{ag} + d_{bg} = 3.658\,m$	Total Height of Monument
$L_{foot} := 2.5m = 2.5\,m$	Pad Footing Dimension
$b_{col} := 400mm$	Column Dimension

Loading:

$\gamma_c := 24\frac{kN}{m^3}$	Unit Weight of Concrete
$\gamma_s := 19\frac{kN}{m^3}$	Unit Weight of Soil
$P_{col} := \gamma_c \cdot h \cdot b_{col}^2 = 14.045 \cdot kN$	Dead Load of Column
$P_{DL1} := 43.34kN$	Dead Load from Slab, Wall, and UBC letters
$P_{SL} := 9.14kN$	Snow Load
$P_{soil} := \left(L_{foot}^2 - b_{col}^2\right) \cdot d_{bg} \cdot \gamma_s = 70.537 \cdot kN$	Dead Load from Soil Above Footing
$P_{DL} := P_{DL1} + P_{col} + P_{soil} = 127.922 \cdot kN$	Total Dead Load on Footing
$P_s := 1.0P_{DL} + 1.0P_{SL} = 137.062 \cdot kN$	Service Load

$M_s := 57kN \cdot m$

Service Moment

$$e_c := \frac{M_s}{P_s} = 0.416\,m$$

Eccentric Effect of Combined Axial Load and Moment on Footing

$P_f := 1.25 \cdot P_{DL} + 1.5P_{SL} = 173.613 \cdot kN$

Max Factored Axial Moment

1. PAD FOOTING SIZE

$q_{all} := 100kPa$

Allowable Soil Bearing Pressure

$L_{foot} = 2.5\,m$

Pad Footing Dimension

$A_{foot} := L_{foot}^{\,2} = 6.25\,m^2$

$$\frac{L_{foot}}{6} = 0.417\,m$$

$$LargeEcc := \begin{vmatrix} \text{"Yes"} \quad \text{if } e_c \geq \dfrac{L_{foot}}{6} \\ \text{"No"} \quad \text{otherwise} \end{vmatrix}$$

Large Eccentricty Should be Avoided, (which is met here) Design For Small Eccentricity

LargeEcc = "No"

$$q_{max} := \frac{P_s}{A_{foot}}\left(1 + \frac{6 \cdot e_c}{L_{foot}}\right) = 43.818 \cdot kPa$$

Maximum Bearing Pressure from Combined Load and Moment at Edge of Footing

$$BearingCapacity := \begin{vmatrix} \text{"OK"} \quad \text{if } q_{all} \geq q_{max} \\ \text{"Re-design"} \quad \text{otherwise} \end{vmatrix}$$

BearingCapacity = "OK"

$$q_{fmax} := \frac{P_f}{A_{foot}}\left(1 + \frac{6 \cdot e_c}{L_{foot}}\right) = 55.503 \cdot kPa$$

Factored Bearing Pressure from Combined Load and Moment at Edge of Footing

$$L_{short} := \frac{L_{foot}}{2} - \frac{b_{col}}{2} = 1.05\,m$$

Length from Column Face to Edge of Footing

$$q_f := q_{fmax} - \left[q_{fmax}\frac{(L_{short})}{L_{foot}}\right] = 32.192 \cdot kPa$$

q.f @ Face of Column

$$V_f := q_f \cdot L_{short} \cdot L_{foot} + \frac{(q_{fmax} - q_f)}{2} \cdot L_{short} \cdot L_{foot} = 115.099 \cdot kN$$

Factored Design Shear Force in Footing

2. ONE WAY SHEAR REQUIREMENTS

$\phi_c := 0.65$ — Resistance Factor

$f_c := 25MPa$ — Normal Strength Concrete

$cover := 75mm$ — Permanently Cast Against Earth

$d_b := 15mm$ — 15M reinforcement bars

$h_{min} := 12in$ — Thickness of the Footing

$$d := h_{min} - cover - \frac{d_b}{2} = 222.3 \cdot mm$$

Effective Depth

$$d_v := \max(0.9 \cdot d, 0.72h_{min}) = 219.456 \cdot mm$$

Effective Shear Depth

$$\beta := \frac{230mm}{1000mm + d_v} = 0.189$$

$\lambda := 1$ — Normal Density Concrete

$$V_c := \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{\frac{f_c}{MPa}} \cdot MPa \cdot L_{foot} \cdot d_v = 336.304 \cdot kN$$

Shear Strength of Concrete

$$OneWayShear := \begin{cases} \text{"OK"} & \text{if } V_c \ge V_f \\ \text{"Re-design"} & \text{otherwise} \end{cases}$$

$OneWayShear = \text{"OK"}$ No need for Shear Reinforcement

3. FLEXURAL REINFORCEMENT

$M_f := P_f \cdot e_c = 72.2 \cdot kN \cdot m$ Total Factored Moment

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$\phi_s := 0.85$

$f_y := 400MPa$

$$A_s := \frac{\alpha_1 \cdot \phi_c \cdot f_c \cdot L_{foot}}{\phi_s \cdot f_y} \cdot \left[d - \sqrt{d^2 - \frac{(2 \cdot M_f)}{\alpha_1 \cdot \phi_c \cdot f_c \cdot L_{foot}}} \right] = 977.752 \cdot mm^2$$

$A_g := L_{foot} \cdot h_{min} = 7.62 \times 10^5 \cdot mm^2$ Gross Area

$A_{smin} := 0.002 \cdot A_g = 1.524 \times 10^3 \cdot mm^2$ Min. Area of Steel Required by Code

$A_{15} := 200mm^2$ Area of 15 M bars

$$s_{min} := L_{foot} \cdot \frac{A_{15}}{\max(A_{smin}, A_s)} = 328.084 \cdot mm$$

$space := \min(s_{min}, 3 \cdot h_{min}, 500mm) = 328.084 \cdot mm$

$s_{des} := 300mm$ Design Spacing

$$n_{long} := \frac{L_{foot}}{s_{des}} = 8.333$$

# of longitudinal bars in footing

$$n_{trans} := \frac{L_{foot}}{s_{des}} = 8.333$$

# of transverse bars in footing

Min 9-15M long. bars and 9-15M trans. bars

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DETERMINATION OF DETENTION TANK WALLS

Wall Dimension Checks:

$d_{bg} := 0.5m$ Depth Below Grade

$L_n := 6m$ Length of Detention Tank

$W_n := 6m$ Width of Detention Tank

$D_n := 2.5m$ Depth of Detention Tank

$\frac{D_n}{W_n} = 0.417$ Depth to Width Ratio

$\frac{D_n}{L_n} = 0.417$ Depth to Length Ratio

$$DesignAs := \begin{vmatrix} \text{"OneWaySlab"} & \text{if } \left(0.5 \geq \max\left(\frac{D_n}{W_n}, \frac{D_n}{L_n}\right)\right) \\ \text{"TwoWaySlab"} & \text{otherwise} \end{vmatrix}$$

DesignAs = "OneWaySlab"

$t_{req} := \frac{D_n}{20} = 125 \cdot mm$ Required Simply Supported Slab Thickness

$t_{wall} := 250mm$ Detention Tank Wall Thickness

Side Walls of Detention Tank:

$\gamma_c := 24 \frac{kN}{m^3}$ Unit Weight of Concrete

$\gamma_s := 19\frac{kN}{m^3}$ Unit Weight of Soil

$S_s := 1.9kPa$ Snow Surcharge for Vancouver

$\phi := 38deg$ Friction Angle for Sand of Nearby Site

$k_a := \tan\left(45deg - \frac{\phi}{2}\right)^2 = 0.238$ Active Earth Pressure Assuming Rankine Theory

$P_s := k_a \cdot S_s = 0.452 \cdot kPa$ Active Pressure

$P_{a3} := \gamma_s \cdot (d_{bg} + D_n) \cdot k_a = 13.559 \cdot kPa$ Pressure at Bottom of Tank

$P_{a05} := \gamma_s \cdot (d_{bg}) \cdot k_a = 2.26 \cdot kPa$ Pressure at Top of Tank

$P_{eq} := \frac{(P_{a3} + P_{a05})}{2} = 7.91 \cdot kPa$ Equivalent Distributed Presure (for simplification purposes)

$q_{DL} := P_{eq} \cdot 1m = 7.91 \cdot \frac{kN}{m}$

$q_{SL} := P_s \cdot 1m = 0.452 \cdot \frac{kN}{m}$

$q_{f1} := 1.4 q_{DL} = 11.073 \cdot \frac{kN}{m}$ Factored Uniform Load Case 1

$q_{f2} := 1.25 \cdot q_{DL} + 1.5 \cdot q_{SL} = 10.565 \cdot \frac{kN}{m}$ Factored Uniform Load Case 2

$q_f := \max(q_{f1}, q_{f2}) = 11.073 \cdot \frac{kN}{m}$ Factored Load

$M_f := \frac{\left(q_f \cdot D_n^{\,2}\right)}{8} = 8.651 \cdot kN \cdot m$ Max Factored Moment

$V_f := \frac{(q_f \cdot D_n)}{2} = 13.842 \cdot kN$ Max Factored Shear Force

Concrete and Steel Specs:

$f_c := 25MPa$

$f_y := 400MPa$

$\phi_c := 0.65$

$\phi_s := 0.85$

$\lambda := 1$ Normal Concrete

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$d_b := 15mm$ Bar Diameter

$A_b := 200mm^2$ Bar Area

$cover := 75mm$ Cast Against Earth

$a_{max} := 30mm$ Max Aggregate Size

$b := 1000mm$ Slab Unit Width

$d := t_{wall} - cover - \frac{d_b}{2} = 167.5 \cdot mm$ Effective Depth

Design Wall One-Way Slab for Moment:

$$A_s := \frac{(\alpha_1 \cdot \phi_c \cdot f_c \cdot b)}{\phi_s \cdot f_y} \cdot \left(d - \sqrt{d^2 - \frac{2 \cdot M_f}{\alpha_1 \cdot \phi_c \cdot f_c \cdot b}} \right) = 153.753 \cdot mm^2$$

$s_s := b \cdot \frac{A_b}{A_s} = 1.301 \times 10^3 \cdot mm$ Bar spacing for Slab

$A_{smin} := 0.002 \cdot b \cdot t_{wall} = 500 \cdot mm^2$ Minimum Slab Reinforcement

$s_{min} := \min\left[3.t_{wall}, \frac{(b \cdot A_b)}{A_{smin}}, 500mm, s_s\right] = 400 \cdot mm$ Minimum Spacing for Reinforcement in Slab

$s_{des} := 400mm$

$$A_{sdes} := \frac{(b \cdot A_b)}{s_{des}} = 500 \cdot mm^2$$

$$\rho_b := 0.022$$

Balanced Reinforcement Ratio for 25 MPa Conc.

$$\rho := \frac{A_{sdes}}{b \cdot d} = 2.985 \times 10^{-3}$$

$$BalancedRatio := \begin{cases} \text{"Good"} & \text{if } \rho_b \geq \rho \\ \text{"Not Good"} & \text{otherwise} \end{cases}$$

$$BalancedRatio = \text{"Good"}$$

15M Long. Bars @ 400 mm c/c E/W for Walls of Detention Tank

Design Wall Slabs for Shear:

$$d_v := \max(0.9 \cdot d, 0.72 \cdot t_{wall}) = 180 \cdot mm$$

Effective Shear Depth

$$\beta := \frac{230mm}{1000mm + d_v} = 0.195$$

Section Contains No Shear Reinforcement

$$V_c := \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{f_c} \cdot b \cdot d_v \cdot \left(\sqrt{MPa}\right) = 114.025 \cdot kN$$

Shear Resistance of Concrete

$$ShearReinforcement := \begin{cases} \text{"Not Needed"} & \text{if } V_c \geq V_f \\ \text{"Needed"} & \text{otherwise} \end{cases}$$

$$ShearReinforcement = \text{"Not Needed"}$$

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DETERMINATION OF DETENTION TANK WALLS

Dimension Checks:

$d_{bg} := 0.5m$ Depth Below Grade

$L_n := 6m$ Length of Detention Tank

$W_n := 6m$ Width of Detention Tank

$D_n := 2.5m$ Depth of Detention Tank

$\frac{D_n}{W_n} = 0.417$ Depth to Width Ratio

$\frac{D_n}{L_n} = 0.417$ Depth to Length Ratio

$$DesignAs := \begin{cases} \text{"OneWaySlab"} & \text{if } \left(0.5 \geq \max\left(\frac{D_n}{W_n}, \frac{D_n}{L_n}\right)\right) \\ \text{"TwoWaySlab"} & \text{otherwise} \end{cases}$$

$DesignAs = \text{"OneWaySlab"}$

$t_{req} := \frac{D_n}{20} = 125 \cdot mm$ Required Simply Supported Slab Thickness

$t_{wall} := 250mm$ Detention Tank Wall Thickness

Top of Detention Tank:

$\gamma_c := 24\frac{kN}{m^3}$ Unit Weight of Concrete

$\gamma_s := 19\frac{kN}{m^3}$ Unit Weight of Soil

$S_s := 1.9kPa$ Snow Surcharge for Vancouver

$q_{SL} := S_s \cdot 1m = 1.9 \cdot \frac{kN}{m}$ Unit Width Distributed SL on Top of Tank

$q_{DL} := \gamma_s \cdot d_{bg} \cdot 1m = 9.5 \cdot \frac{kN}{m}$ Unit Width Distributed load from Soil on Top

$q_f := 1.25 \cdot q_{DL} + 1.5 \cdot q_{SL} = 14.725 \cdot \frac{kN}{m}$ Factored Uniform Load

$M_f := \frac{\left(q_f \cdot W_n^{\,2}\right)}{8} = 66.263 \cdot kN \cdot m$ Factored Moment

$V_f := \frac{\left(q_f \cdot W_n\right)}{2} = 44.175 \cdot kN$ Max Factored Shear Force

Concrete and Steel Specs:

$f_c := 25MPa$

$f_y := 400MPa$

$\phi_c := 0.65$

$\phi_s := 0.85$

$\lambda := 1$ Normal Concrete

$\alpha_1 := 0.8$

$\beta_1 := 0.9$

$d_b := 25mm$ Bar Diameter

$A_b := 500mm^2$ Bar Area

$cover := 75mm$ Cast Against Earth

$a_{max} := 30mm$ Max Aggregate Size

$b := 1000mm$ Slab Unit Width

$d := t_{wall} - cover - \frac{d_b}{2} = 162.5 \cdot mm$ Effective Depth

Design Top One-Way Slab for Moment:

$$A_s := \frac{(\alpha_1 \cdot \phi_c \cdot f_c \cdot b)}{\phi_s \cdot f_y} \cdot \left(d - \sqrt{d^2 - \frac{2 \cdot M_f}{\alpha_1 \cdot \phi_c \cdot f_c \cdot b}}\right) = 1.345 \times 10^3 \cdot mm^2$$

$s_s := b \cdot \frac{A_b}{A_s} = 371.783 \cdot mm$ Bar spacing for Slab

$A_{smin} := 0.002 \cdot b \cdot t_{wall} = 500 \cdot mm^2$ Minimum Slab Reinforcement

$s_{min} := \min\left[3.t_{wall}, \frac{(b \cdot A_b)}{A_{smin}}, 500mm, s_s\right] = 371.783 \cdot mm$ Minimum Spacing for Reinforcement in Slab

$s_{des} := 300mm$

$A_{sdes} := \frac{(b \cdot A_b)}{s_{des}} = 1.667 \times 10^3 \cdot mm^2$

$\rho_b := 0.022$ Balanced Reinforcement Ratio for 25 MPa Conc.

$\rho := \frac{A_{sdes}}{b \cdot d} = 0.01$

BalancedRatio := | "Good" if $\rho_b \geq \rho$
| "Not Good" otherwise

BalancedRatio = "Good"

25M Long. Bars @ 300 mm c/c E/W for Top Slab of Detention Tank

Design Top Slab for Shear:

$d_v := \max(0.9 \cdot d, 0.72 \cdot t_{wall}) = 180 \cdot mm$ — Effective Shear Depth

$\beta := \dfrac{230mm}{1000mm + d_v} = 0.195$ — Section Contains No Shear Reinforcement

$V_c := \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{f_c} \cdot b \cdot d_v \cdot \left(\sqrt{MPa}\right) = 114.025 \cdot kN$ — Shear Resistance of Concrete

$$\text{ShearReinforcement} := \begin{cases} \text{"Not Needed"} & \text{if } V_c \geq V_f \\ \text{"Needed"} & \text{otherwise} \end{cases}$$

ShearReinforcement = "Not Needed"

APPENDIX E – COST BREAKDOWN

Item #	Description	QUANTITY TAKEOFF					
		No of Pieces	Area	Depth/Height	Sub-Total	Total Quantity	Units
1	Sidewalk	3	100	0.275	27.5	82.5	m^3
2	Roundabout	1	176.714587	0.275	48.5965114	48.59651136	m^3
3	Tank	2	132	0.2	26.4	26.4	m^3
3	Monument	2	9.59	0.4	3.836	3.836	m^3
4	Foundation	2	6.25	0.3	1.875	1.875	m^3
	Concrete Total	10	424.55	1.45	108.21	163.21	m^3

METHOD						LABOR		
Crew Code	Crew Size	Worker-Hours (WHr/Unit)	Daily Output (Units/day)	Duration (days)	Total Worker-Hours	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost
C-20	8	0.523	45.88	1.80	43.16	$79.33	$41.50	$3,423.75
C-20	8	0.523	45.88	1.06	25.42	$79.33	$41.50	$2,016.76
C-20	8	0.523	45.88	0.58	13.81	$79.33	$41.50	$1,095.60
C-20	8	0.523	45.88	0.08	2.01	$79.33	$41.50	$159.19
C-20	8	0.523	45.88	0.04	0.98	$79.33	$41.50	$77.81
C-20	8	2.62	229.4	3.56	85.37	$396.67	$207.50	$6,773.11

MATERIAL		EQUIPMENT		TOTAL COST	
Unit Cost	Total Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
$122.00	$10,065.00	$16.20	$1,336.50	$179.70	$14,825.25
$122.00	$5,928.77	$16.20	$787.26	$179.70	$8,732.79
$122.00	$3,220.80	$16.20	$427.68	$179.70	$4,744.08
$122.00	$467.99	$16.20	$62.14	$179.70	$689.33
$122.00	$228.75	$16.20	$30.38	$179.70	$336.94
$610.00	$19,911.32	$81.00	$2,643.96	$898.50	$29,328.39

Table 9: Cost estimate of total concrete

Item #	Description	QUANTITY TAKEOFF					
		No of Pieces	Area	Depth/Height	Sub-Total	Total Quantity	Units
1	Asphalt	1	2000	0.125	250	250	m^3
	Asphalt	1	2000	0.125	250	250	m^3

METHOD						LABOR		
Crew Code	Crew Size	Worker-Hours (WHr/Unit)	Daily Output (Units/day)	Duration (days)	Total Worker-Hours	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost
C-20	8	0.523	45.88	5.45	130.78	$79.33	$41.50	$10,375.00
C-20	8	0.52	45.88	5.45	130.78	79.33	41.5	10375

MATERIAL		EQUIPMENT		TOTAL COST	
Unit Cost	Total Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
$122.00	$30,500.00	$16.20	$4,050.00	$179.70	$44,925.00
122	30500	16.2	4050	179.7	$44,925.00

Table 10: Cost estimate of total asphalt

Item #	Description	QUANTITY TAKEOFF				
		No of Pieces	Area	Sub-Total	Total Quantity	Units
1	Sidewalk Formwork	3	11.7	35.1	105.3	m^2CA
2	Roundabout Formwork	1	7.07	7.07	7.07	m^2CA
3	Tank Formwork	1	264.00	264.00	264.00	m^2CA
3	Monument Formwork	1	24.40	24.40	24.40	m^2CA
4	Foundation Formwork	1	9.25	9.25	9.25	m^2CA
	Formwork Total	7	316.42	339.82	410.02	m^2CA

METHOD						LABOR		
Crew Code	Crew Size	Worker-Hours (WHr/Unit)	Daily Output (Units/day)	Duration (days)	Total Worker-Hours	Unit Labor Pricing ($/WHr)	Unit Labor Cost ($/Units)	Total Labor Cost
C-2	6	0.487	49.24	2.14	51.32	$68.73	$33.50	$3,527.55
C-2	6	0.487	49.24	0.14	3.45	$68.73	$33.50	$236.80
C-2	6	0.487	49.24	5.36	128.68	$68.73	$33.50	$8,844.00
C-2	6	0.487	49.24	0.50	11.89	$68.73	$33.50	$817.40
C-2	6	0.487	49.24	0.19	4.51	$68.73	$33.50	$309.88
C-2	6	$2.44	$246.20	$8.33	$199.85	$343.65	$167.50	$13,735.62

MATERIAL		EQUIPMENT		TOTAL COST	
Unit Cost	Total Cost	Unit Cost	Cost	Total Unit Cost ($/Units)	Total Cost
$18.75	$1,974.38	$0.00	$0.00	$52.25	$5,501.93
$18.75	$132.54	$0.00	$0.00	$52.25	$369.33
$18.75	$4,950.00	$0.00	$0.00	$52.25	$13,794.00
$18.75	$457.50	$0.00	$0.00	$52.25	$1,274.90
$18.75	$173.44	$0.00	$0.00	$52.25	$483.31
$93.75	$7,687.85	$0.00	$0.00	$261.25	$21,423.47

Table 11: Cost estimate of total formwork

Other Costs Summary

Item #	Description	Total Cost
1	Solar Pedestrian Signs	$14,034
2	Sign Install	$3,000
3	Road Paint	$300
4	Road Reflectors	$50
5	Road Reflectors Install	$500
6	Street Lights	$48,000
7	Street Light Install	$18,000
8	Steel Rebar	$5,000
9	Excavation	$148,325
10	Soil Removal	$59,330
11	Manholes/Catch Basins	$4,500
12	Fill Material	$5,200
13	Waste Removal	$10,000
14	Sprinkler System	$20,000
14	Landscaping	$5,000
	Total	$341,238.90

Table 12: Cost estimate of other materials and services

APPENDIX F – DETAILED DESIGN DRAWINGS

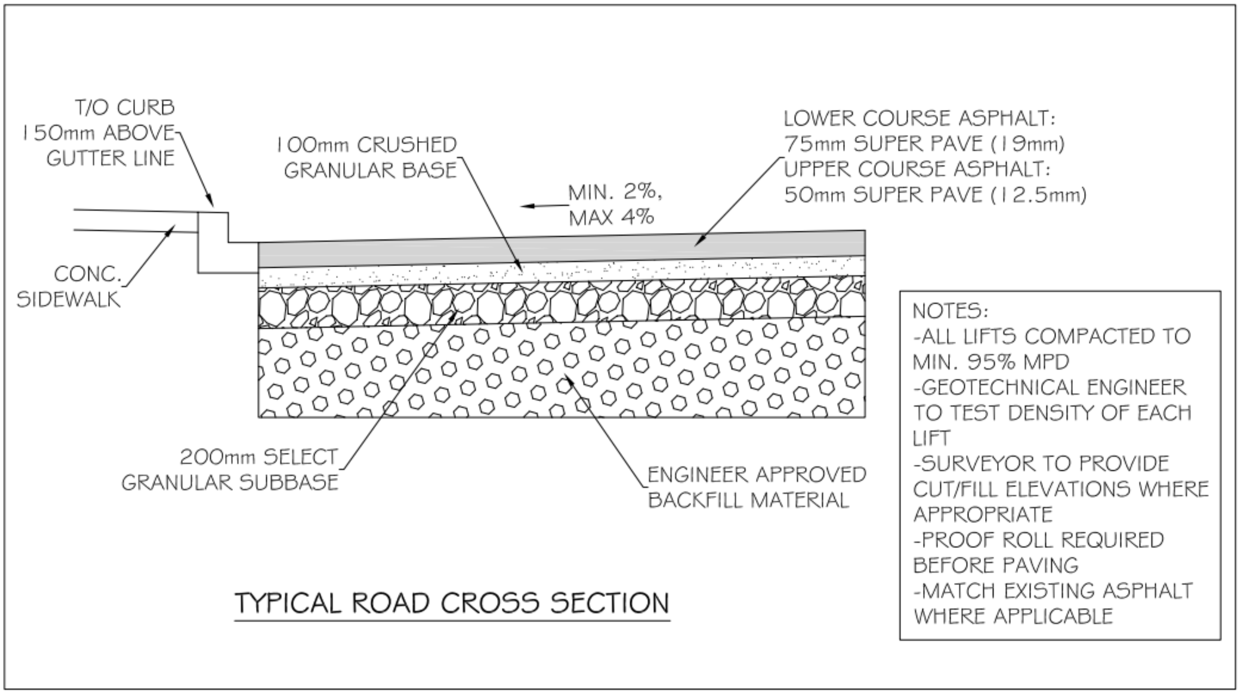

Figure 33: Typical road cross section

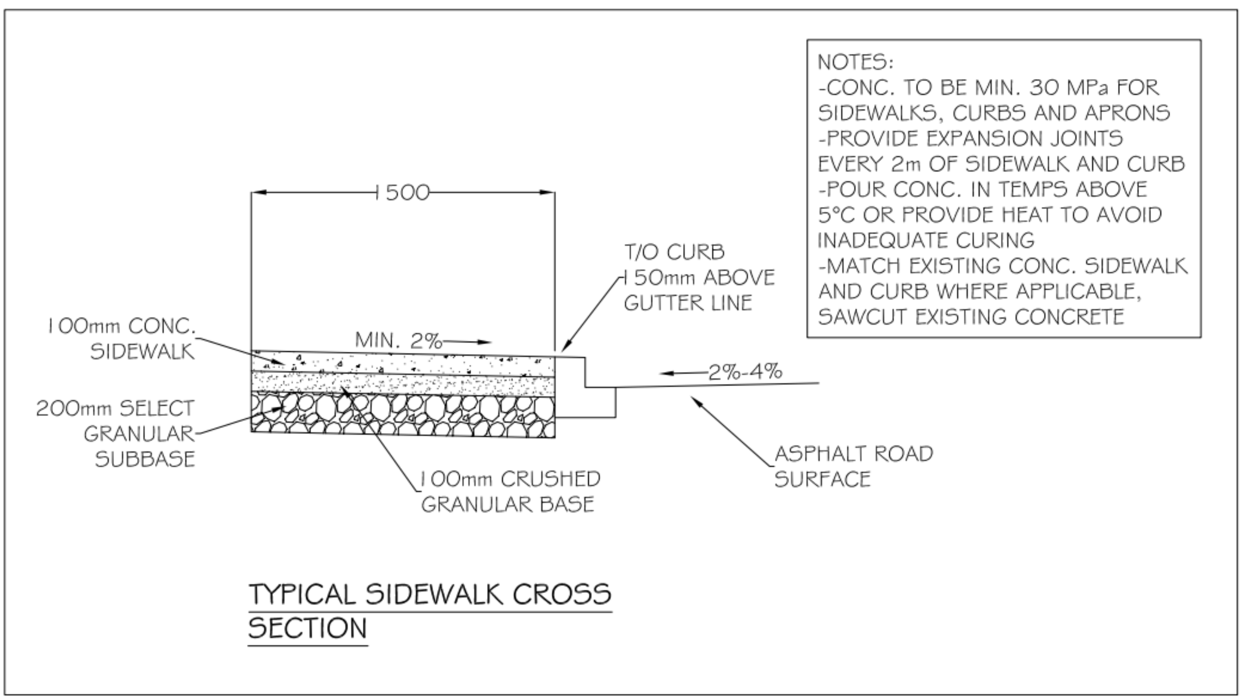

Figure 34: Typical sidewalk cross section

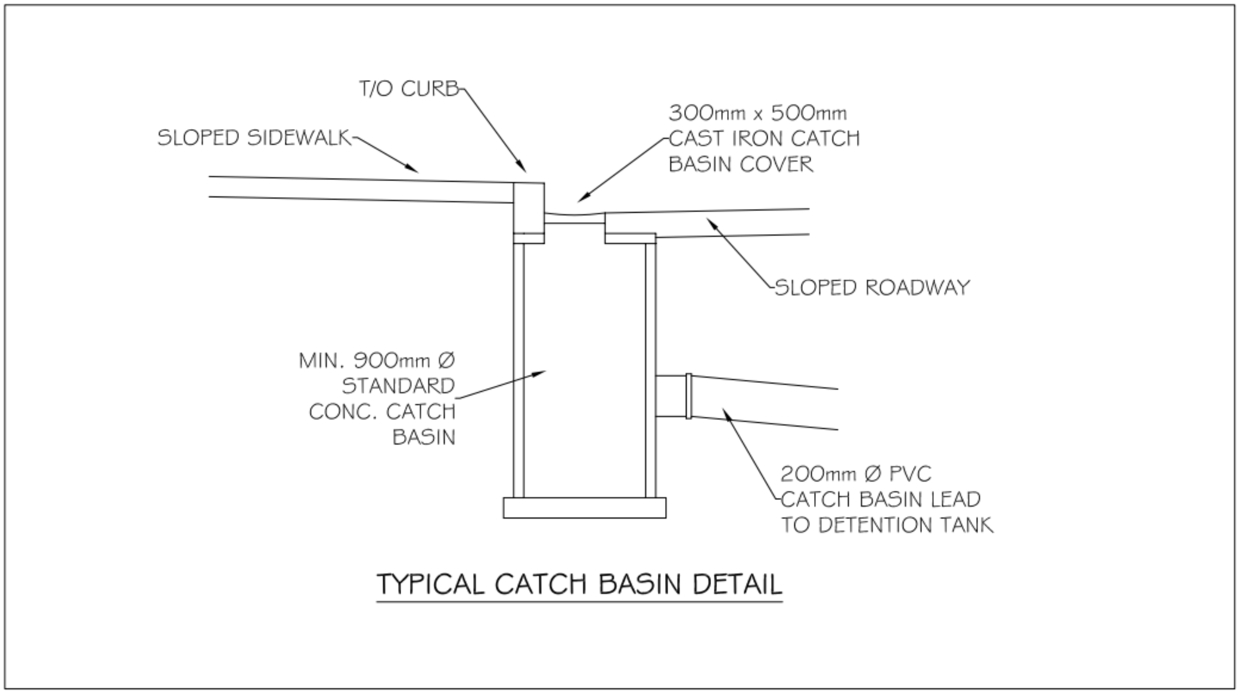

Figure 35: Typical catch basin detail

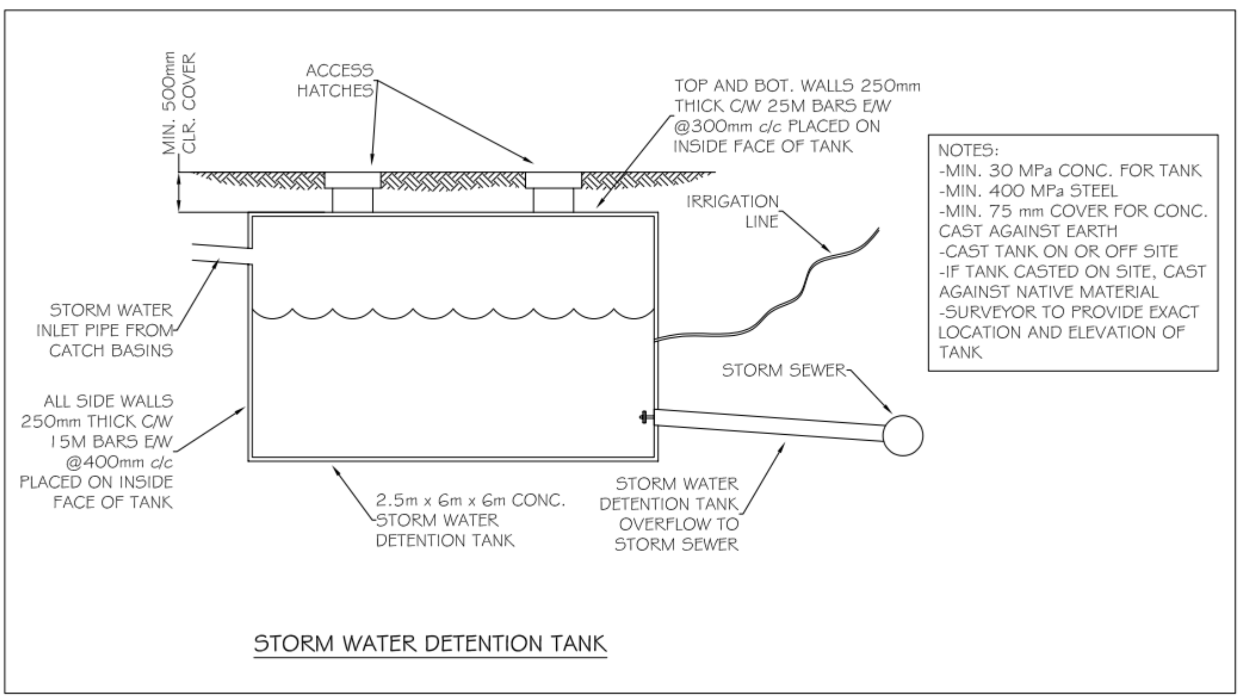

Figure 36: Strom water detention tank

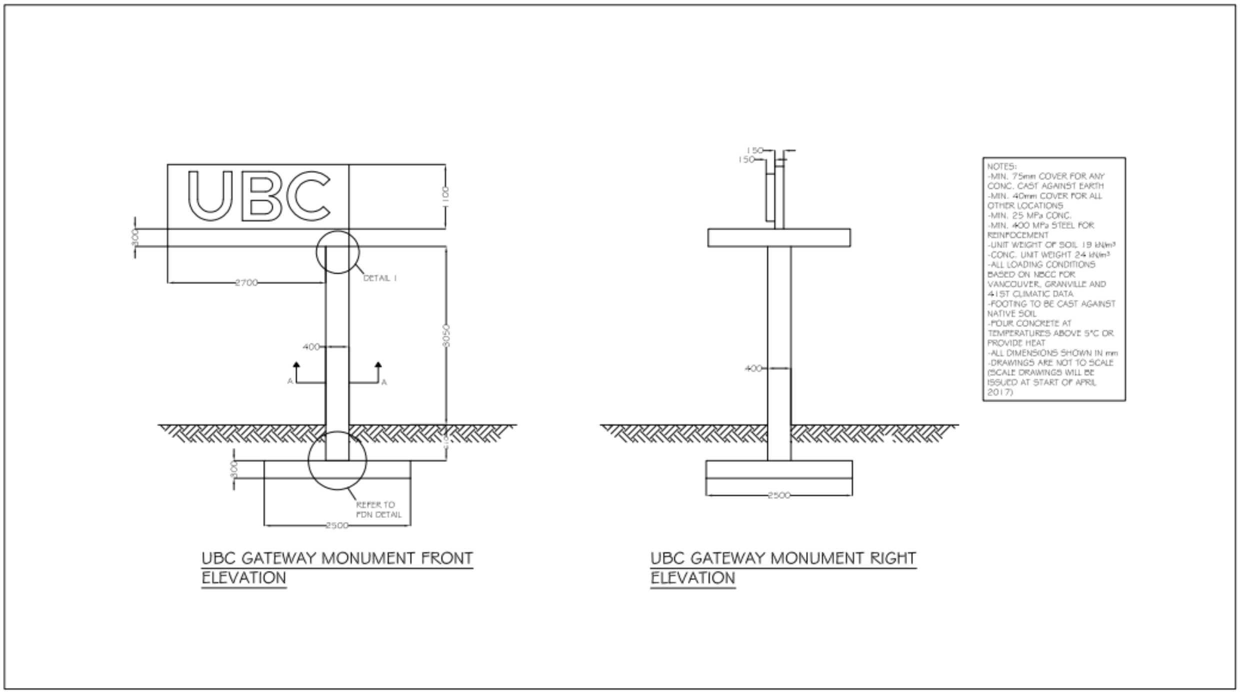

Figure 37: Monument details

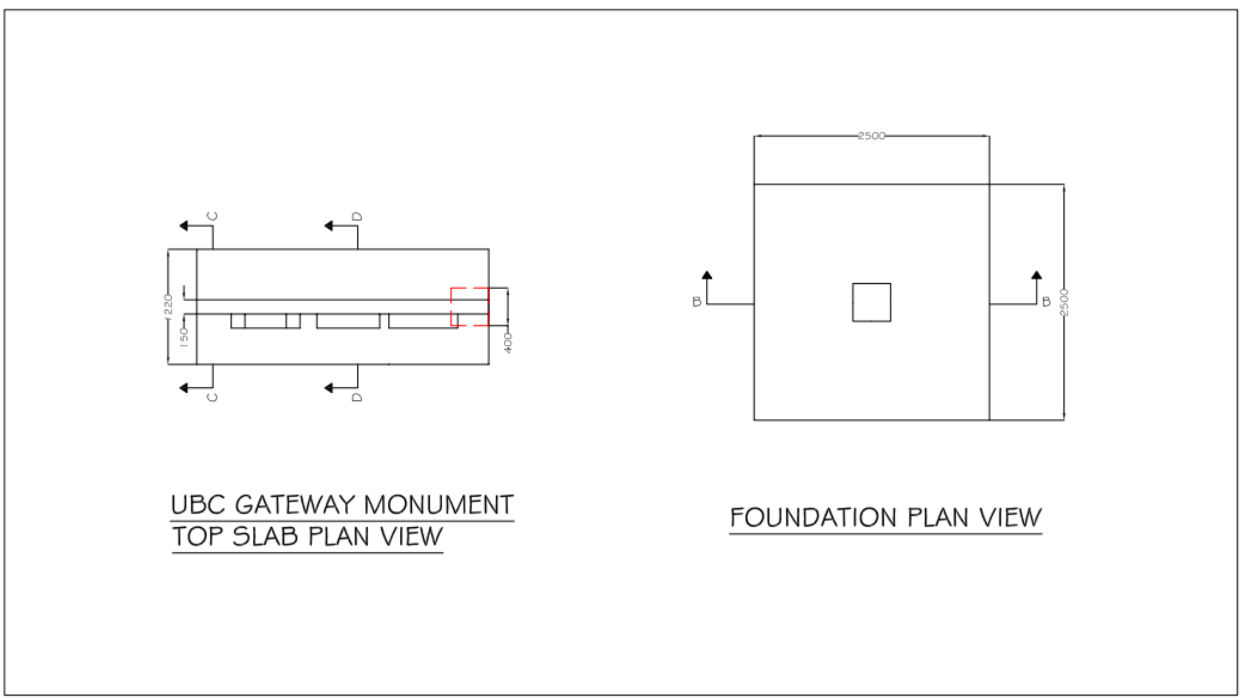

Figure 38: Foundation details

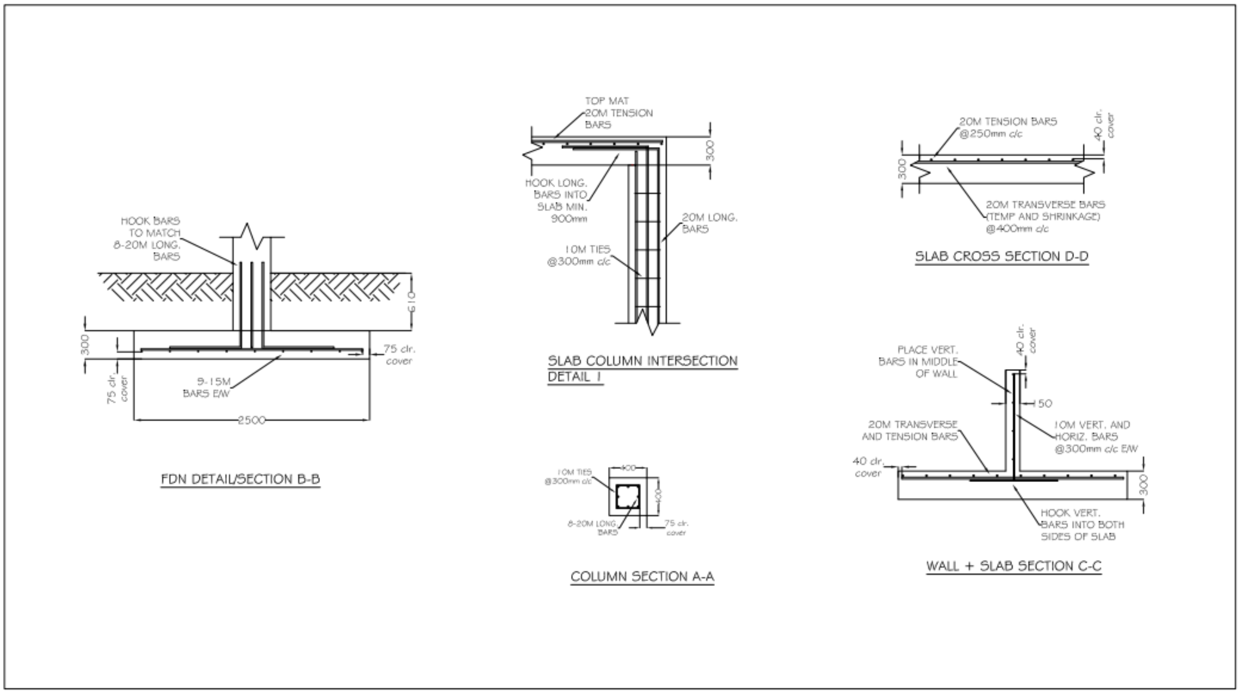

Figure 39: Connection details

APPENDIX G - REFERENCES

1. Department of Transportation and Infrastructure. (2010, September 13). Transportation and infrastructure: Single-lane Roundabouts. Retrieved November 01, 2016, from Transportation and Infrastructure, http://www.gov.pe.ca/tir/singlelane

2. City of Vancouver. (2016, September 01). Planning & Development and Community Services. Retrieved November 13, 2016, from City of Vancouver, http://vancouver.ca/files/cov/csg-fees-2013.pdf

3. Province of British Columbia. (2016, August 2). Geometric design guidelines for B.C. Roads - province of British Columbia. Retrieved November 10, 2016, from Geometric Design Guidelines for B.C. Roads, http://www2.gov.bc.ca/gov/content/transportation/transportation-infrastructure/engineering-standards-guidelines/highway-design-survey/tac-bc