Chancellor Boulevard/East Mall Intersection Redesign

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University of British Columbia

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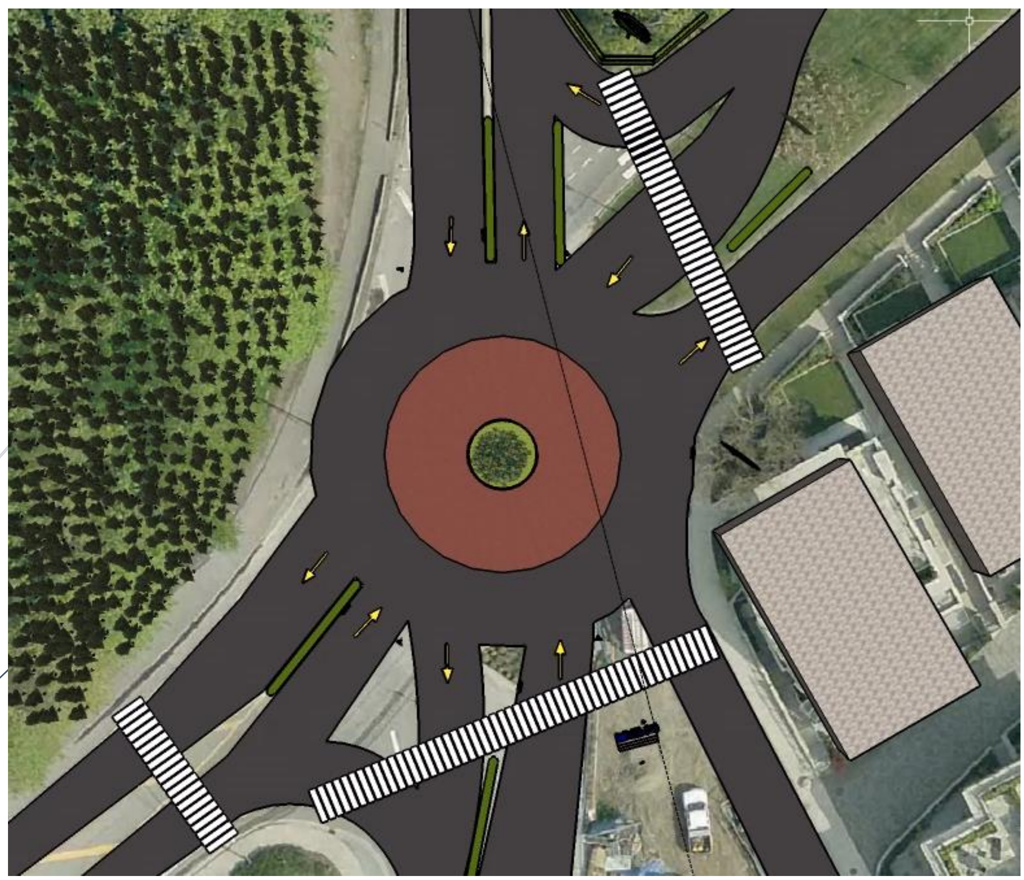
Krista Falkner – University of British Columbia



GUANG CONSULTING – TEAM 6

Aaron Lam, Brahmantyo Hadiprasetyo, Christian Yapari, David Wu, Dominic Lao, Simbo Pyo

1. Executive Summary

The Chancellor Boulevard/East Mall Intersection Redesign project is a restructure of the intersection to align with the *UBC Transportation Plan* promoting a more sustainable environment for the community. The goals accomplished as part of the project include creating a design that meets the projected transportation demands, accommodating varying stakeholder needs, encouraging active transportation modes, constructing a unique pedestrian observation platform, and improving safety and mobility for vehicles, trucks, bicyclists and pedestrians. The final cost of the project is approximately $760,000 CAD, including all construction costs as well as installation of the pedestrian structure. The construction of the roundabout is slated to begin in May 2016 and the completion date is targeting the end of November 2016.

The design of the intersection includes a 33.5-meter diameter single-lane roundabout including a low-profile mountable apron for the use of heavy vehicles. The lanes are approximately 5.0-meters wide with an additional 1.5-meter cyclist lane. The distance from the central median to the curb is 13.7-meters. Bicycle lanes will be implemented on the north and south approaches of the intersection to be consistent with the existing lanes on the east and west approaches. Additionally, the new intersection includes upgraded lane alignment, improved sign placement, as well as the installation of crosswalks on all approaches for an improvement in safety and convenience. The low impact construction of the roundabout considers the preservation of trees and green space. Careful considerations are made such that the construction process does not affect regular traffic flow, especially during the start of the autumn semester.

The proposed design for the pedestrian observation structure is a 350cm wide x 200cm tall x 60cm deep structure of "UBC 100," which will be installed on the island at the southbound approach. The structure sits on a 250cm x 250cm x 50cm square concrete foundation to resist its design loadings and overturning moments. It will incorporate bike racks to align with UBC's goals of promoting sustainable modes of transportation. Behind the "UBC 100" are concrete steps guarded with handrails which allow users to be elevated and provides a better view of the Burrard Inlet. The structure will be located 10 meters away from the edge of the roundabout for safety reasons and to improve sightlines within the roundabout.

The high percolation rate of Quadra sand and topographical location of the roundabout pose great risk of cliff erosion at the cliff located on the north side of the roundabout. To minimize the risk, gutters will be installed along the roadway and inlets will be strategically located around the roundabout to accommodate the system requirements. The storm water inlets will be connected to the existing drainage system and in case of a 100-year storm, the roadway will act as an open channel to accommodate major flows.

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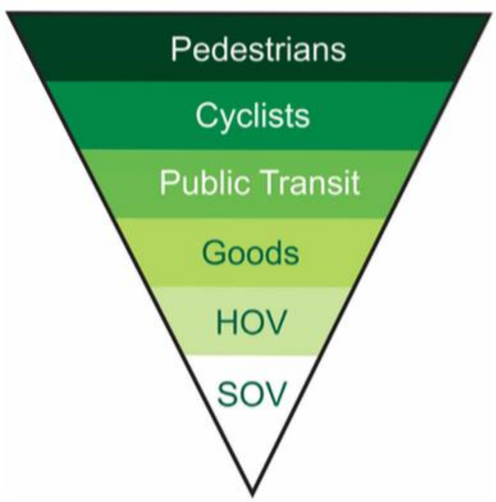
2. Introduction

2.1. Purpose

The Chancellor Boulevard / East Mall Intersection Redesign project will restructure the intersection to align with the *UBC 2014 Transportation Plan* promoting a sustainable and safe environment for the community. Goals for the project include creating a design that meets the projected transportation demands, accommodating varying stakeholder needs, encouraging active transportation modes, constructing a unique pedestrian observation platform, and improving safety and mobility for vehicles, trucks, bicyclists, and pedestrians. The transportation modal priority is illustrated in the figure below with ascending importance.

Figure 1: Transportation Priority Triangle, Bunt & Associates



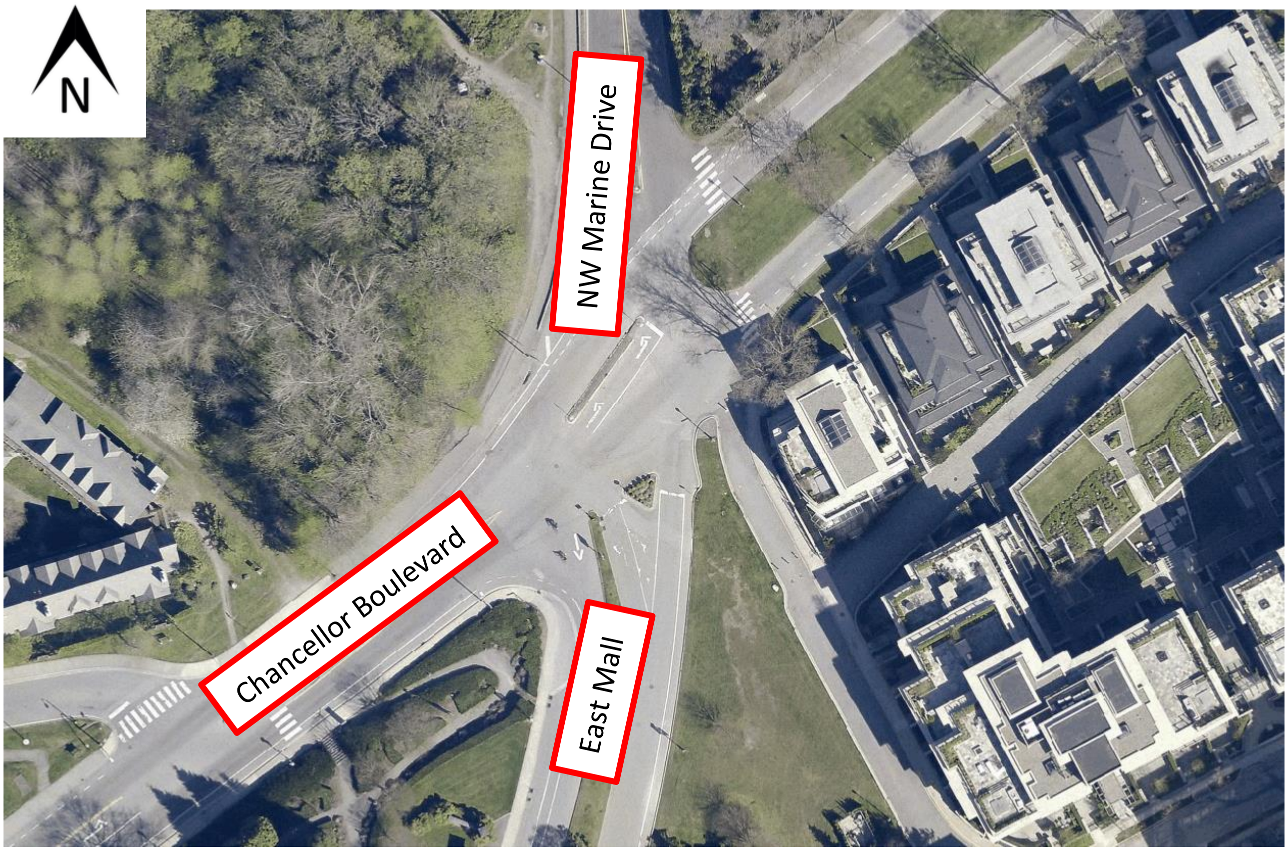
2.2. External Contributions

The detailed design and construction plan was developed in accordance with the client (UBC), the *2014 UBC Transportation Plan*, the BC Ministry of Transportation & Infrastructure (BC MoTI), and key stakeholders, including the Musqueam peoples. The client provided traffic count data, base CAD files of road alignments, and additional input on design preferences and parameters.

2.3. Site Overview

Northwest (NW) Marine Drive is an arterial road that connects Southwest (SW) Marine Drive to Spanish Banks beach while providing access to UBC and residential properties. Chancellor Boulevard is an arterial road that provides access to UBC from West 4th Avenue. East Mall is a collector road that serves the central UBC campus. Features located adjacent to the site include: Cecil Green Park House, Green College, the Rose Garden Parkade and the Chan Centre. The northwest corner of the intersection provides pedestrian access to a trail that connects to the Point Grey foreshore. Chancellor Boulevard and Marine Drive are both owned and operated by the BC Ministry of Transportation and Infrastructure (MoTI) and require that a roundabout be the ultimate design option.

Figure 2: Aerial Photo, adapted from Vanmap



2.4. Individual Contributions

The following table summarizes the breakdown of the individual contribution of each Guang Consulting team member to the final detailed design report.

Table 1: Summary of Contributions

Brahmantyo Hadiprasetyo	**Aaron Lam**
• Construction Work Plan • Schedule • Cost Estimate & Quantity Takeoff	• Pedestrian Structure Design • Geometric Design • Geotechnical Design
Dominic Lao	**Jin Young Pyo**
• Introduction & Conclusion • Background & Project Description • Design Objectives & Constraints • Construction Traffic Management • Formatting & Review	• Sustainability • Stormwater Management • SketchUp Modeling
David Wu	**Christian Yapari**
• AutoCAD Drawings • Detailed Design Standards • Intersection Design	• Compilation and Editting • Design Life & Loadings • Stakeholder Engagement

3. Background and Project Description

3.1. Background

The existing four-way stop-controlled intersection at Chancellor Boulevard and East Mall in the University of British Columbia Vancouver Campus is currently being considered for operational improvement in the near future. The university believes that the intersection is not performing up to the standards of the *2014 UBC Transportation Plan* and with the student population increasing, the intersection is unsafe and not operating at an optimal level. There are currently problems with lack of pedestrian facilities and the intersection has geometric issues that are important considerations as part of the detailed design process.

A preliminary study has been conducted previously by Guang Consulting and the detailed design for the new intersection is produced in the following report. The detailed design was created with data provided by the client (UBC), guidelines from the BC Ministry of Transportation & Infrastructure (BC MoTI) and also input from key stakeholders (Musqueam peoples) and the *2014 UBC Transportation Plan*.

The number one target of the *UBC Transportation* Plan requires that by 2040 at least two-thirds of all trips to and from UBC will be made by walking, cycling or transit. The installation of a roundabout and pedestrian structure in the Chancellor Boulevard / East Mall intersection that accommodates all modes of travel both safely and efficiently is a key priority in reaching that goal.

Figure 3: Sustainable Travel Target, 2014 UBC Transportation Plan

3.2. Scope

The scope of the detailed design of the intersection at Chancellor Boulevard and East Mall include the following items as detailed in the formal project proposal. Not included in this list are items that were completed as part of the preliminary design process.

- Describe key components of the design, including the roundabout and the pedestrian structure.
- Determine and summarize the design criteria, including the adopted design life and design loadings.
- Define the standards and software packages utilized throughout the design process.
- Summarize the technical considerations associated with the design, including aspects of stormwater management, geotechnical engineering, transportation engineering, structural engineering, and sustainable design.
- Draft design drawings and plans detailing the intersection layout as well as spatial solutions.
- Create a draft plan of construction work including requirements, sequencing and anticipated issues relating to existing site conditions.
- Summarize the traffic management strategy in order to allow for safe and efficient travel during critical construction phases of the project.
- Issue requirements and recommendations for the advancement of the project.
- Estimate the total cost of the project including construction, all related works, and all material costs.
- Generate a schedule with respect to specific project timelines.
- Recognize and frequently engage key stakeholders directly affected by the development of the project

3.3. Project Description

The location of the intersection is on the North side of the UBC campus and connects to several hiking trails and also roads leading in and out of the campus. Most of the traffic coming through the area comprises of commuter vehicles leaving and entering the campus and some heavy vehicles. The area surrounding the intersection is a residential neighborhood combined with a number of university buildings, including the Chan Centre for Performing Arts.

Following a site visit conducted by Guang Consulting at the Chancellor Boulevard / East Mall intersection on September 30, 2015, a number of issues and constraints as part of the future redesign have been identified. Generally, the existing site presents geometric irregularities, unconventional laning, spatial issues, obstructed sightlines, and overall safety concerns. During the site analysis, we identified the northwest corner of the intersection to have a wide turning radius and contains a large park area with many trees. Additionally, the southwest corner has a steep turning radius. The south approach has lanes in each direction separated by an irregularly wide raised median. Iona Drive is a separate road adjacent to East Mall and is currently accessible by bicycles only due to the safety bollards. Chancellor Boulevard is at a 45-degree angle as it crosses East Mall. The east approach is single lane in both directions and is separated by a 10-meter-wide raised median. There is a median in the center of the intersection that protects an eastbound left turn bay. Moreover, there are a large amount of signs which may lead to driver confusion and sensory overload.

A number of instances of driver-cyclist conflicts as well as driver-pedestrian conflicts were recorded based on an intersection safety study. This can be attributed to the lack of pedestrian and cyclist provisions throughout the intersection. Pedestrians are only able to cross on one approach of the intersection and are observed to cross at locations without crosswalks. Furthermore, cyclists are observed to use the sidewalks as opposed to the roadway. Sightlines are currently obstructed by large signs on multiple turning movements.

4. Design Criteria

4.1. Design Objectives

In discussions with UBC staff, the goal of the detailed design is to construct a roundabout that would minimize the overall construction impact and meet the following objectives.

1. Create a safe and pleasant intersection to use;
2. Meet existing and projected vehicle, bicycle, and pedestrian demands;
3. Accommodate all stakeholder needs;
4. Encourage active transportation modes; and
5. Include a unique pedestrian observation structure.

4.2. Design Constraints

Due to the overall nature of the project, the site location constraints described in previous sections, as well as objectives set out by our client, we are faced with a number of design constraints. These design constraints mentioned are as follows.

- The existing intersection has an irregular layout with steep turning radii and poor lane alignment;
- The amount of space to work with is limited overall with buildings and vegetation on all four corners of the intersection;
- The design must adhere to BC Ministry of Transportation & Infrastructure guidelines (*BC Supplement to TAC Geometric Design Guide*);
- The sightlines may be affected by existing buildings and vegetation; and
- The lack of pedestrian and cyclist facilities in the existing condition.

4.3. Design Considerations and Key design issues

The detailed design has addressed the following issues of the project.

- Technical
  - Existing and future traffic demands regarding level of service, intersection capacity, and network capacity
  - Limitations of the roundabout design due to existing geometry and safety concerns
  - Pedestrian structure specifications to prevent excessive rotation and settlement
  - Adequacy of drainage and street lighting management

- Economic
  - Detailed project cost estimation of existing intersection removal and implementation of new roundabout
  - Accompanying project cost estimation of topsoil, sod and sidewalk
  - Project cost estimation of pedestrian structure

- Construction Planning
  - Punctuality of project construction beginning on May 2016

- Regulatory
  - Roundabout design compliance with *BC Ministry of Transportation & Infrastructure Guidelines* and *UBC Technical Guidelines*
  - Structural design compliance with *UBC Technical Guidelines*

- Societal
  - Varying concerns of numerous stakeholders
  - Musqueam people's concerns and interests

4.4. Design Life & Loadings

The updated roundabout intersection has been designed with a life of 25 years due to the location of the roundabout. The curbing requirements for the design guidelines states that the pavement structure within the roundabout lane and the truck apron extending beyond the island should be designed to keep a constant elevation over the life of the roundabout. With the increase in capacity of the intersection, the paving has been designed with considerations for higher traffic loads.

According to the traffic volume data provided by the client, the intersection is currently most heavily loaded in the morning peak hours at around 800 vehicles passing through the intersection. The intersection is currently running close to its capacity and will not be able to fully cope with the increase in traffic load that is expected in the future. The width of the entry lanes have not been altered so the entering flow of the intersection will not be changed. By implementing the roundabout, the capacity of the intersection is increased to 1200 vehicles per hour as dictated by the guideline due to the relatively low entry flow of the intersection. This has taken into consideration the recommendation by the guidelines that roundabouts be designed to operate at 85 percent of the capacity instead of the full 100 percent.

The updated capacity of the intersection also takes into account the addition of the pedestrian cross-walks that are being implemented as well as the bike lanes along the approaches of the intersection. These factors affect the entry flow of the intersection and subsequently the circulating flow of the roundabout.

4.5. Stakeholder Engagement

As part of the project strategy, a stakeholder engagement plan was devised to allow interaction with the different communities that are going to be affected by intersection. The main targets for consultation were the Musqueam peoples, the student body, UBC staff, faculty and residents. Information on the detailed design has been distributed through the following different media.

- Newspaper notices
- Letters and flyers
- Setting up public information sessions/ Community open houses
- Supplementary meetings with local residents, interest groups and external agencies
- Online consultation (i.e. Reddit AMA)

Public information sessions and town hall meetings have been conducted on milestone dates of the project as follows:

- PIC No.1 held on November 30th 2015
- PIC No.2 held on January 10th 2016

Additional meetings will continue to be held to provide updates and receive feedback on the intersection itself. There are also meetings scheduled during construction to ensure that the measures taken to re-route traffic are working effectively. The notices for the public information centers will be placed in newspapers and delivered to residents' homes around the campus.

Meetings and surveys have been held with property owners and other interested parties to allow all affected parties to participate in the project. Consultations with the Musqueam peoples have also been conducted to discuss potential issues and observe specific requests. An evaluation process throughout the public consultation process has been completed with the findings that the vast majority of participants were satisfied with the detailed design and their needs were met and carefully considered. We will continue to communicate with the Musqueam people in the future to ensure continued approval of the project.

5. Detailed Design

5.1. Detailed Design Standards

To conceive our detailed design, a number of technical guidelines and codes have been referenced to provide the relevant specifications:

- BC Supplement to TAC Geometric Design Guide 2007
- Vancouver Campus Plan Design Guidelines
- UBC Technical Guidelines
- British Columbia Building Code
- British Columbia Standard Specifications for Highway Construction

Additionally, the following software was used to visualize and analyze our detailed design of the roundabout:

- AutoCAD – Producing design drawings (Overview of roundabout with supporting sectional drawing, and signage plans)
- Trimble Sketchup – Constructing a 3D flythrough that visualizes the design. This was used for our presentation with the client

The roundabout design parameters comply with the design standards of the *BC Supplement to TAC Geometric Design Guide 2007*. The technicalities of the roundabout configuration and drainage management are referenced in section "740 Roundabouts and "1000 Hydrology", respectively. Specifically, the roundabout dimensioning is determined by the turning radius of a WB-20 (large truck). Hence, the inscribed circle diameter and truck apron width allows sufficient room for a WB-20 to maneuver the roundabout. There is currently a transit route that utilizes the intersection, the C20 bus route. However, the transit vehicle is atypical to the WB-20 classification since it is a small capacity shuttle bus. As per Table 430.B of the *BC Supplement to TAC Geometric Design Guide 2007*, the design width of the biking lanes is 1.5m. On the other hand, the hydrology section of the guide establishes the technical specifications and effective uses of the catch basin drainage solution.

Regarding the construction detail drawing that is profiled in Figure 5, the road composition is supplemented by the *BC Supplement to TAC Geometric Design Guide*, while the truck apron and the central island details are supported by the *British Columbia Standard Specifications for Highway Construction*.

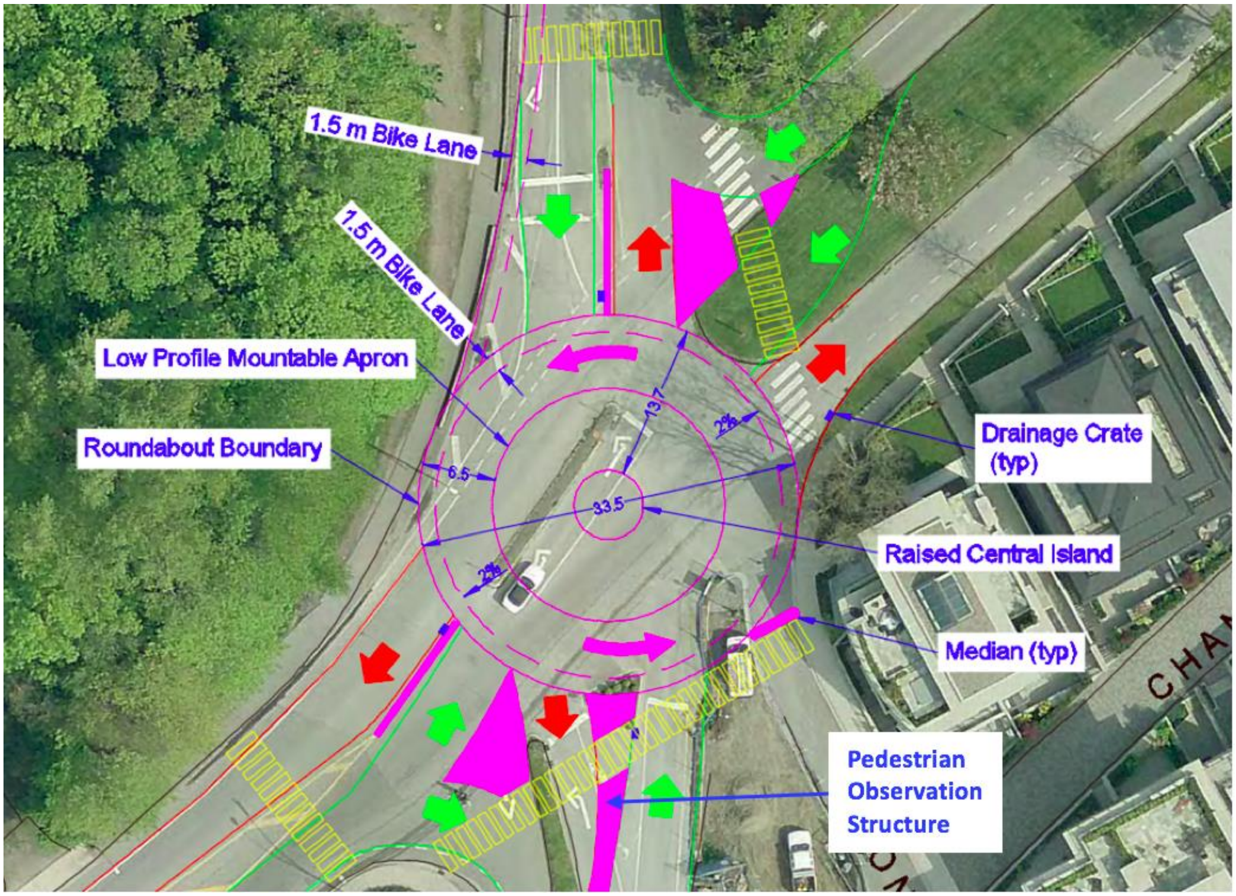
For the “UBC 100” structure, the structural specifications shall conform to the UBC Technical Guidelines in which it is an addendum of the British Columbia Building Code. The code provides the necessary concrete technical requirements and the respective design dead, live, wind, and impact loads. On the other hand, the geotechnical aspect of the structure shall adhere to the British Columbia Building Code.

The guidelines for the biking facility, seating, and street lighting would be in accordance to UBC’s Vancouver Campus Plan Design Guidelines. Spacing and width of both the biking racks and seating are provided by the guidelines. While, for the street lighting, the guideline determines the standardized fixtures.

5.2. Intersection Design

Due to the various physical constraints limiting the size of the roundabout, the inscribed diameter of the single-lane roundabout is selected to be 33.5 metres. The lane width is 5.0m with an additional 1.5m cyclist lane. There is also a 20.5m diameter low-profile mountable apron to allow sufficient room to maneuver for larger trucks. In total, the distance between the raised central island and the edge of the roundabout curb is 13.7m. In addition to the roundabout dimensioning, the following figure depicts the roundabout configuration and the location of the crosswalks.

Figure 4: Overview of Roundabout Configuration, David Wu



While the design diameter meets code regulations as stated in Section 5.1, it is also within the boundary of the existing intersection. Therefore, the roundabout location does not conflict with the neighbouring native land and private properties. Additionally, the placement of the roundabout allows the preservation of the existing trees. To accommodate the implementation of the roundabout and crosswalks, existing road elements that are in positional conflict with the new installations will be removed.

As pedestrians are considered the highest priority according to the Transportation Priority Triangle (Figure 1), the importance of safety of this transportation mode is the most paramount. Consequently, marked crosswalks for pedestrians will be implemented on all approaches of the intersection. This improvement significantly increases the safety and convenience of pedestrians. With clear signage that warns motor vehicles of pending crossings, crosswalks guide pedestrians to only cross the intersection on the indicated pathways. The locations of the crossing signage is displayed on Figure 16 in the appendix.

The next classification of the Transportation Priority Triangle are cyclists. The safety of cyclists can be achieved by improving the functionality of bike lanes. To be consistent with existing bike lanes on other intersection approaches, a new bike lane will be implemented on the north approach of the intersection. Furthermore, the new 1.5 metre bike lane at the roundabout intersection shall tie in to the cyclist lanes on all approaches. These implementations lessen the tendency for cyclists to use the pedestrian crosswalks where it poses a safety hazard to both pedestrians and cyclists. On the south approach, Iona Drive will be used as a dedicated road for cyclists. A median on the roundabout entrance will bar motor vehicles from entry, allowing access to only cyclists. The dedicated lane allows safe passage for cyclists as they do not need to share the road with motor vehicles.

The other classifications are motor vehicles where their priority is less than the pedestrians and cyclists. Nonetheless, the safety for motor vehicles is also important. By installing medians, it guides vehicles that are entering and exiting the intersection. The medians are also safety barriers that divides the entrance and exit lanes on all approaches. Additionally, improved sign placement will increase the safety of motor vehicles. The locations of the roundabout signage is displayed in the appendix.

Figure 5: Roundabout Construction Detail, David Wu

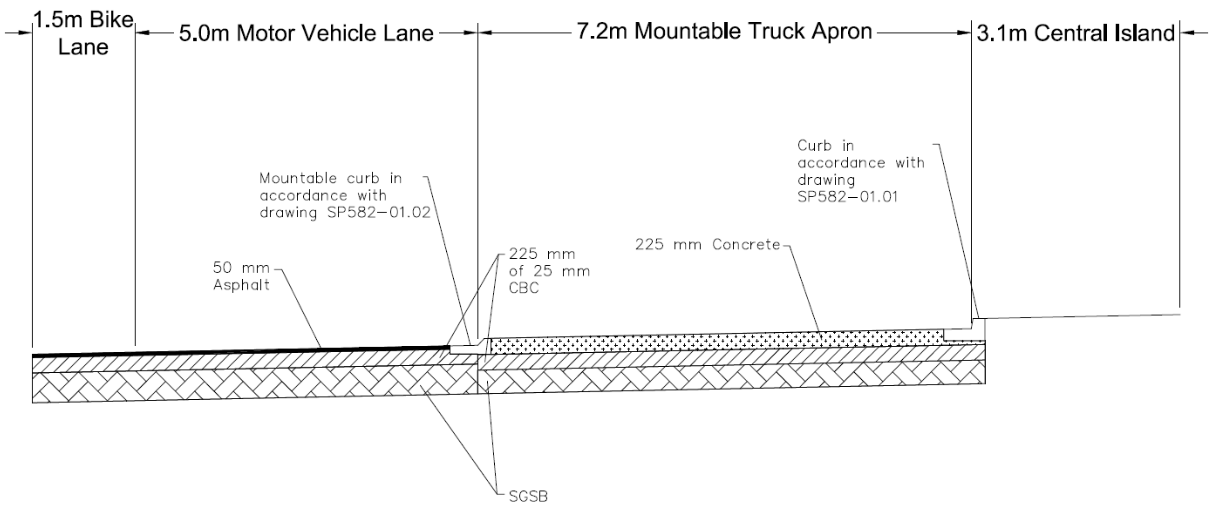


Figure 5 is a detail section drawing depicting the material composition from the edge of the roundabout to the center of the central island. The bike and motor vehicle lane will comprise of asphalt, crushed base course (CBC), and select granular sub-base (SGSB). Meanwhile, the configuration of the truck apron concrete curb and the central island curb is in reference to drawings SP582-01.02 and SP582-01.01 of the *British Columbia Standard Specifications for Highway Construction*, respectively. The specification drawings are attached in the appendix. Underneath the concrete are CBC and SGSB material.

5.3. Pedestrian Structure Design

Figure 6: Pedestrian Observatory Structure

The pedestrian observatory structure was designed with the intention of welcoming both vehicular and pedestrian traffic as a major gateway into the university. In addition to serving as a new landmark, it should contain an elevated platform for pedestrians and align with UBC's official community plan to promote the use of cycling and minimize the impact of single-occupancy vehicles.

The structure is a steel frame structure spells "UBC 100" to celebrate the university's centennial year and commemorate UBC's 100 years of learning, research, and community engagement (as shown in *figure 6)*. The 350cm wide x 200cm tall x 60cm deep steel logo of "UBC 100" will be sitting on a 2500mm x 2500mm x 500mm square concrete foundation. The reinforcement in the concrete foundation will be using 15M@150c/c. The bottom part of the "U" and "C" provides seating for users. Specific dimensions and the front, side, bird's-eye view of the structure are shown in *figure 7* below. Calculations for the design of the foundation, reinforcement requirements, and placement of the reinforcement can be found in the Appendix.

Figure 7: Front View of Structure

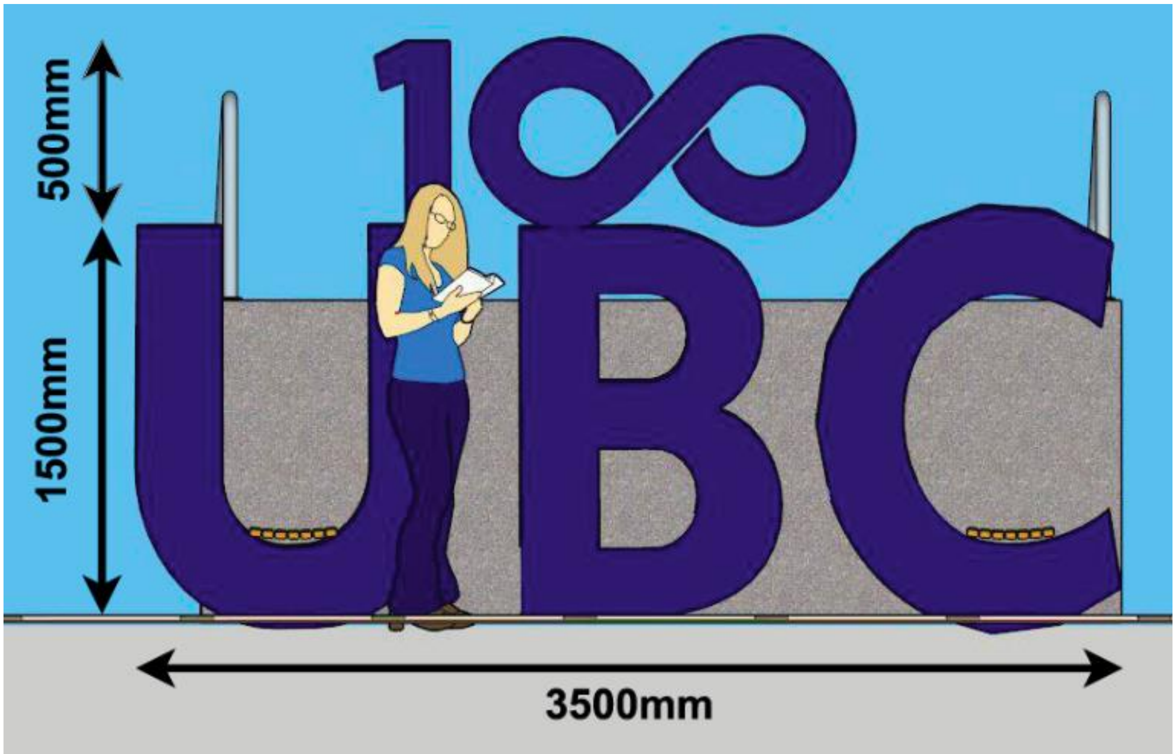


Figure 8: Side View of Structure

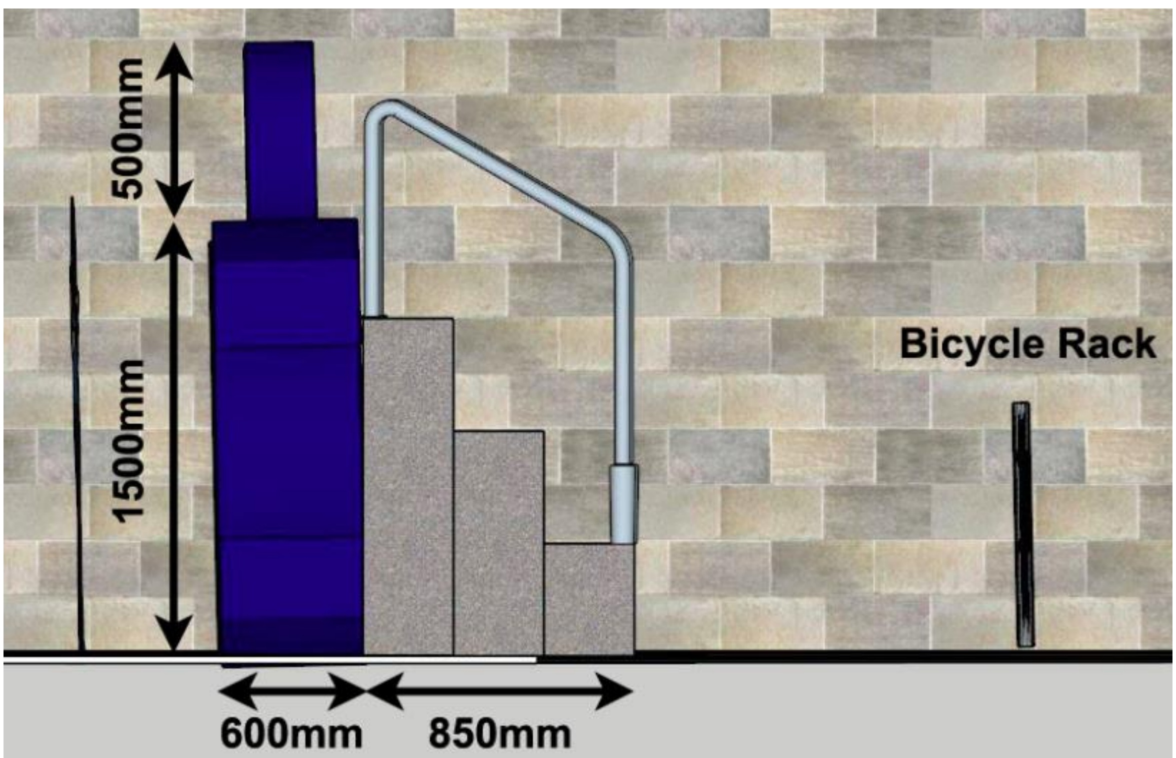
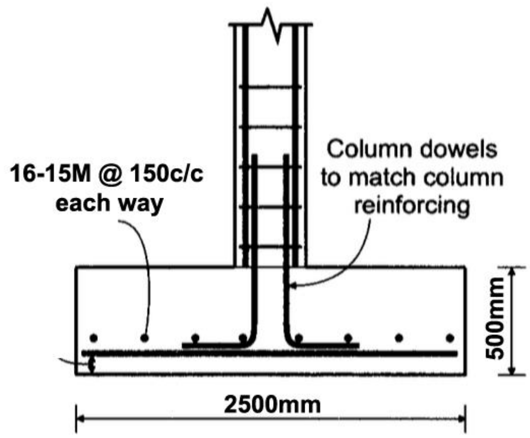


Figure 9: Foundation Reinforcement Drawing (N.T.S.)



The observatory structure is located on the southbound island as shown in *Figure 4.* The pedestrian is located 10-meters from the edge of the roundabout and behind the pedestrian crossing to ensure the sightline from East Mall into the roundabout is unobstructed. The placement will prevent collision between users of the structure and vehicles as there is a pedestrian crossing in front of it which serves as a safety 'buffer'.

Concrete steps are part of the structure but are located behind the "UBC 100" steel frame and provides an elevated platform for users to have a better view of the roundabout intersection. The dimensions of the structure and the foundation is designed to carry a maximum occupancy of 10-people. The steps are guarded with safety handrails for safety reasons.

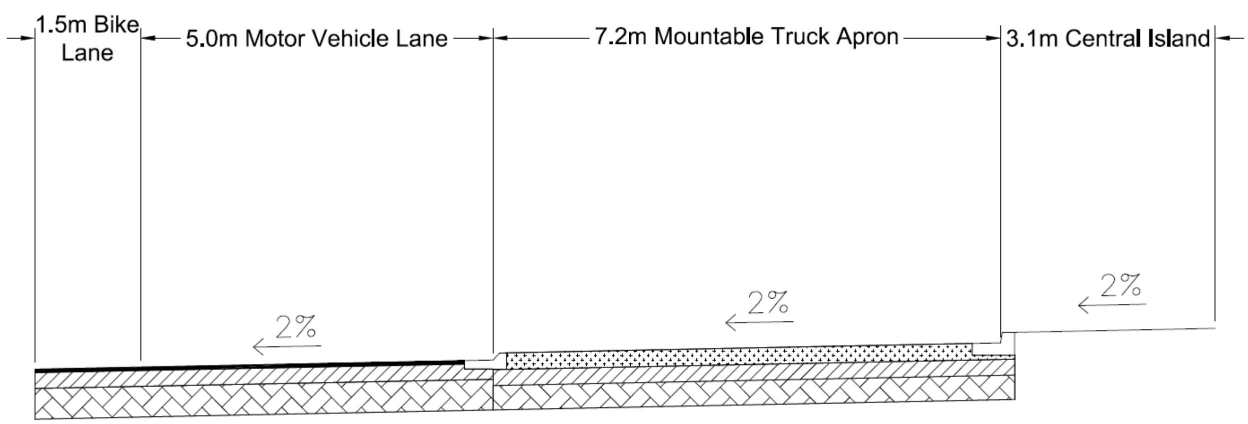
To encourage the use of alternative modes of transportation in accordance with UBC's community plans, bike racks are installed behind the structure to provide safe, secure, and convenient bicycle storage space for users on the northern side of campus.

5.4. Geometric Design

The horizontal alignment of the intersection features a circular roundabout and curved entry and exit roads on all approaches. Curves allow vehicles to easily merge in and out of the roundabout without them having to adjust their speeds significantly.

To guide surface flow, the roundabout is sloped at 2% from the intersection center. The sloping allows surface runoff to flow away from the roundabout and be captured by one of the drainage crates as depicted in Figure 4. The following figure shows the slope from the edge of the roundabout to the center:

Figure 10: Sloping Cross Section



5.5. Geotechnical Design

The design of the foundation of the pedestrian observatory structure is based off of the geotechnical soil logs provided by UBC. Four boreholes were drilled along Westbrook mall and the closest one to the roundabout is borehole BH04. However, our structure and roundabout is located at East Mall and Chancellor Boulevard. Therefore, the geotechnical data from the logs may not accurately portray the geological site conditions on site.

As BH04 is the closest borehole to the intersection, our design conditions are largely based off of the data collected from BH04. After 0.12m of asphalt, the soil is composed of 0.20m of gravel and followed by 1.5m of silt. Therefore, it is safe to assume the foundation will be sitting on silt for the pedestrian structure. Calculations regarding the design of the concrete foundation on silt are provided in Appendix B.

With regards to the geotechnical design of the roundabout, according to a report prepared by AECOM, the roundabout is sitting on top of quadra sand (AECOM, 2013). Quadra sand contains very high percolation rate of 1-8”/hr. The high percolation rate of Quadra sand and topographical location of the roundabout pose great risk of cliff erosion at the cliff located on the north side of the roundabout. To minimize the risk, gutters will be installed along the roadway and inlets will be strategically located around the roundabout to accommodate the system requirements.

5.6. Stormwater Management

The roundabout’s stormwater management plan was created using geotechnical data, BC Supplement to TAC Geometric Design Guide 2007 and UBC’s Integrated Stormwater Management Plan (ISMP).

UBC’s ISMP has two main objectives:

- Reduce the impacts of flows of stormwater off of campus (e.g. cliff erosion), through detention and other methods; and,
- Maintain water quality at its boundaries at a level that meets or exceeds best practices for urbanized municipalities.

The impacts of flows of stormwater off of campus includes cliff erosion: The high percolation rate of Quadra sand and topographical location of the roundabout pose great risk of cliff erosion at the cliff located north side of the roundabout. To minimize the risk, gutters will be installed along the roadway and stormwater inlets will be strategically located around the roundabout to accommodate the minor stormwater system. The gutters and inlets will be designed to the design requirement of 5-year return period (BC MoTI).

The stormwater inlets will be connected to the existing storm sewer system. The storm sewer system discharges into the North catchment outfall (Spiral Drain). UBC has upgraded the area around the Spiral Drain to increase detention capacity in case of heavy outfall. In addition, UBC plans to install additional detention facilities to reduce the impacts of flows of stormwater off of campus.

In case of 100-year storm and the storm sewer system cannot accommodate the overflow, the roadway connected to the roundabout will act as an open channel to accommodate the major stormwater system requirement. The roadway will safely guide the stormwater to the north part of the campus. Precautions must be made for the overflow to not directly discharge off the cliff and cause erosion. Therefore, putting temporary flood protection along the roadway during such event is highly recommended.

Although it is not required, it is recommended to install media filters at stormwater detention tanks to remove the pollutants from stormwater to maintain stormwater quality.

5.7. Sustainability

The design of the roundabout is tied closely with UBC's sustainability plan. UBC's Vancouver Campus Plan sustainability goals are to "achieve more sustainable, efficient, effective and convenient land use distribution patterns; integrated approaches to managing open space, energy and infrastructure systems; a pedestrian and cycling friendly campus and a socially engaging environment that fosters a thriving academic community" (UBC 2014).

The roundabout is preferable than conventional signaled intersection in terms of sustainability when it comes to energy consumption: Since the roundabout does not require signals, it does not require any energy to operate, thus more sustainable.

In terms of construction, the roundabout was designed so that no trees will be harmed during or after construction. In addition, a tree will be planted at the island to improve aesthetics and showcase UBC's interest of having sustainable campus.

6. Construction Management

6.1. Construction Work Plan

Prior to the construction activities, documentation of existing conditions of the intersection was performed. Topographic survey by a licensed surveyor to find geological data of the site was also done, including coordination with the local utility companies to add or relocate existing services due to the intersection redesign. The construction phase will begin on May 2, 2016 and expected to end by November 21, 2016.

For general sequence of the construction, refer to section 7. The construction begins with establishing control lines around the intersection to guide the construction crews. As there are underground utilities passing through the redesign site, relocation of the utilities will be required. The relocation of the underground utilities will take place prior any road works.

After all utility works are completed, the curb, sidewalk, and gutter will be placed. The asphalt paving for the new single-lane roundabout will follow after the concrete curb and sidewalk, and gutter have all been placed and cured sufficiently with the installation of the base layer of asphalt. The roundabout will also be paved with asphalt. Final pavement layer will be installed followed by line paintings and the new island pavements. Landscaping will begin after the base layer of asphalt is installed and is expected to complete before final pavement layer installation. The construction will be completed with final landscaping and site clean-up, which is expected to happen in mid-November.

Some issues are anticipated to happen due to the site conditions and other constraints. First of all, as the site is sitting on top of Quadra sand (high percolation rate), erosion can be an issue, especially on the north cliff area. Silt fences will be erected on the north cliff area to prevent this issue. Specific construction methods to minimize disruption of the soil on the site will also be performed. Heavy rain during the fall season will cause some delays during the later phase of the construction. Rainy weather will result in a muddy site, which will hinder all roadworks. Half of the construction will be done during summer time, thus the weather effects from rains can be minimized. However, as most of the pavement works are scheduled on the later stage of the construction, some delays will be inevitable.

Traffic around the intersection will also be interrupted by the construction process. With regards to traffic issues, Guang Consulting has developed an appropriate traffic management strategy to keep the traffic moving safely and efficiently during the construction process (refer to section 6.2 for Traffic Management). Noises generated from the construction phase will cause disruptions for the residential area around the site. The disruption can be kept to a minimum by not doing the noisy activities (such as works with heavy machineries) later on the day when most people are back in their home.

The UBC graduation ceremony happening on the last week of May will also provide another issue for the construction schedule. To anticipate this, we pushed the schedule for curb, gutter, and sidewalk installation a week later to not conflict with the UBC graduation ceremony. We already implement this delay in our schedule, such that it would not affect the expected completion date of the roundabout construction.

6.2. Construction Traffic Management

To ensure safety and minimize the impacts of the construction of the roundabout, Guang Consulting has developed an appropriate traffic management strategy (TMS). Based on analysis of traffic patterns and flows, suitable detour routes and traffic monitoring will be in place during the construction period. The idea is to keep traffic moving safely and efficiently throughout the construction process.

The figure below outlines the proposed detour route as well as TCP locations, pending approval from UBC and BC MoTI staff. Both cyclists and vehicles will be detoured according to the proposed route and directed by TCP. Detailed road closures as well as road closure dates and full sign placements are included as part of the detailed TMS.

Figure 11: Detour Route, adapted from Google Maps

Through the majority of construction, all approaches and at least one lane will remain open to minimize the inconvenience. In order to facilitate this process traffic control personnel (TCP) will be hired to manage the construction zone. TCP be available to direct the movement of both traffic and construction vehicles to the appropriate locations. Typical construction signs will be erected in the appropriate locations as detailed in the completed TMS.

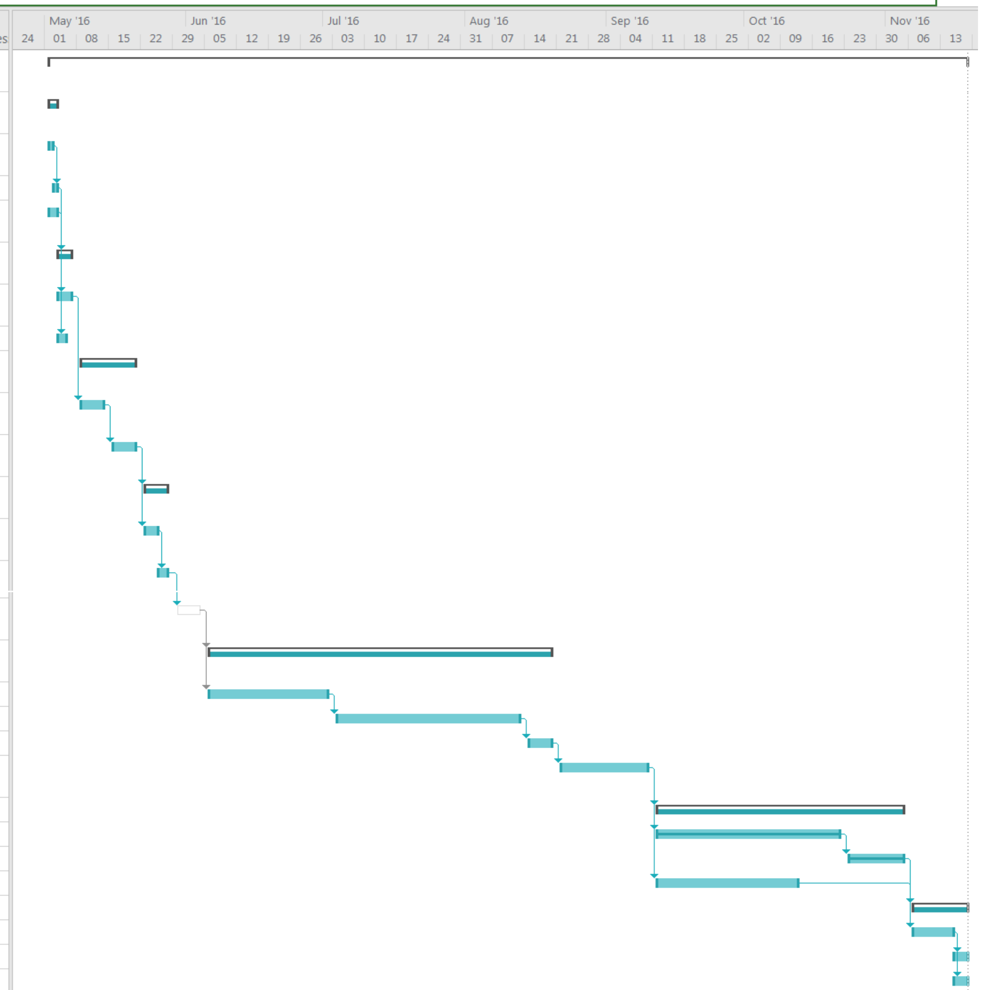
As traffic flows are surveyed to be relatively low throughout weekdays, full intersection closures may be required during short time periods (maximum of 4 hours) to proceed with the critical construction phases of the roundabout. Considering this, intersection closures will be avoided during peak periods and will only be implemented on weekends.

Guang Consulting will also monitor traffic across the detour route and project area during the construction period. Based on the monitored flows, adjustments to the traffic management program may be made. This will allow for continued safe and efficient movement during the construction phase of the project.

7. Schedule

Figure 12: Construction Schedule Gantt Chart

	Task Name	Duration	Start	Finish	Predeces
1	**Construction Start**	**145 days**	**Mon 02/05/16**	**Fri 18/11/16**	
2	**Establish Control Line**	**2 days**	**Mon 02/05/16**	**Tue 03/05/16**	
3	NW Marine Drive	1 day	Mon 02/05/16	Mon 02/05/16	
4	Chancellor Blvd	1 day	Tue 03/05/16	Tue 03/05/16	3
5	East Mall	2 days	Mon 02/05/16	Tue 03/05/16	
6	**Vegetation and Topsoil Removal**	**3 days**	**Wed 04/05/16**	**Fri 06/05/16**	**5,4**
7	Topsoil Removal	3 days	Wed 04/05/16	Fri 06/05/16	4
8	Vegetation Removal	2 days	Wed 04/05/16	Thu 05/05/16	4
9	**Underground Utilities**	**10 days**	**Mon 09/05/16**	**Fri 20/05/16**	
10	Existing Utitities Relocation	5 days	Mon 09/05/16	Fri 13/05/16	7
11	New Utilities Installation	5 days	Mon 16/05/16	Fri 20/05/16	10
12	**Street Lights**	**5 days**	**Mon 23/05/16**	**Fri 27/05/16**	**11**
13	Concrete Bases	3 days	Mon 23/05/16	Wed 25/05/16	11
14	New Street Light Pole Installation	2 days	Thu 26/05/16	Fri 27/05/16	13
15	~~UBC Graduation Ceremonies~~	~~5 days~~	~~Mon 30/05/16~~	~~Fri 03/06/16~~	~~14~~
16	**Curb, Gutter, and Sidewalk Installation**	**55 days**	**Mon 06/06/16**	**Fri 19/08/16**	**15**
17	Curb Installation	20 days	Mon 06/06/16	Fri 01/07/16	15
18	Sidewalk Installation	30 days	Mon 04/07/16	Fri 12/08/16	17
19	Gutter Installation	5 days	Mon 15/08/16	Fri 19/08/16	18
20	Electrical Conduits Installation	15 days	Mon 22/08/16	Fri 09/09/16	19
21	**Asphalt**	**40 days**	**Mon 12/09/1**	**Fri 04/11/16**	**20**
22	Base Layer	30 days	Mon 12/09/16	Fri 21/10/16	20
23	Final Pavement Layer	10 days	Mon 24/10/16	Fri 04/11/16	22
24	Landscaping	23 days	Mon 12/09/16	Wed 12/10/16	20
25	**Cleanup**	**10 days**	**Mon 07/11/1**	**Fri 18/11/16**	**23**
26	Finishing	7 days	Mon 07/11/16	Tue 15/11/16	24
27	Equipment Cleanup	3 days	Wed 16/11/16	Fri 18/11/16	26
28	Site Cleanup	3 days	Wed 16/11/16	Fri 18/11/16	26



The full schedule of the construction can be seen on the Gantt chart provided above. The construction will begin on May 2, 2016 and will take a total of 145 working days. Without delays, the construction is expected to end by November 18, 2016. The roundabout will open to all traffic beginning November 21, 2016.

A point to note is the UBC Graduation Ceremony (typed in red) happening at the last week of May will delay the construction by a week. As access to Chan center from NW Marine Drive is required, constructions will be paused during the graduation times. The traffic in the area will make it impossible to continue the ongoing construction. Construction will resume again on June 6, 2016 with the curb, gutter, and sidewalk installation.

The bulk of the roundabout construction will happen from September 12 to November 11, 2016. During that time, the roundabout will be completed. The figure below is showing the list of critical tasks during the construction. Failure to finish the following tasks on time will result in delays to the construction schedule.

Table 2: Construction Critical Tasks

CRITICAL TASKS

CRITICAL TASKS

A task is critical if there is no room in the schedule for it to slip.
Learn more about managing your project's critical path.

▪ Status: Complete ▪ Status: Future Task

Name	Start	Finish	% Complete	Remaining Work	Resource Names
NW Marine Drive	Mon 02/05/16	Mon 02/05/16	0%	0 hrs	
Chancellor Blvd	Tue 03/05/16	Tue 03/05/16	0%	0 hrs	
East Mall	Mon 02/05/16	Tue 03/05/16	0%	0 hrs	
Electrical Conduits Installation	Mon 22/08/16	Fri 09/09/16	0%	0 hrs	
Finishing	Mon 07/11/16	Tue 15/11/16	0%	0 hrs	
Equipment Cleanup	Wed 16/11/16	Fri 18/11/16	0%	0 hrs	
Site Cleanup	Wed 16/11/16	Fri 18/11/16	0%	0 hrs	

8. Cost Estimate & Quantity Takeoff

The total rounded cost for the single-lane roundabout project is $760,000. The total cost estimate already took design and construction fees into account. The unit price is based on typical unit price for each category of work done in British Columbia. The quantity shown involves all the items and labor associated in the construction process. Details for the cost estimate calculations and the quantity takeoff for each work are included in the table below.

Table 3: Cost Estimates

Description of Work	Quantity	Unit	Unit Price	Total Cost
Asphalt pavement removal	400	s.m.	$5.00	$2,000.00
Topsoil & subsoil stripping	250	s.m.	$5.00	$1,250.00
Asphalt road construction	400	l.m.	$900.00	$360,000.00
Curb & gutter installation	600	m	$138.00	$82,800.00
Concrete median	35	s.m.	$110.00	$3,850.00
Installation of new sidewalk	300	s.m.	$85.00	$25,500.00
Ditching	300	l.m.	$30.00	$9,000.00
Concrete structure (inc. installation)	1	ea.	$8,000.00	$8,000.00
Grading	1000	s.m.	$2.00	$2,000.00
Topsoil & sod	400	s.m.	$10.00	$4,000.00
New signs/ striping	1	ea.	$20,000.00	$20,000.00
Landscaping	250	s.m.	$125.00	$31,250.00
Subtotal Construction Cost				$549,650.00
20% Contingency				$109,930.00
Subtotal				$659,580.00
15% Engineering Cost				$98,937.00
Subtotal Project Cost				$758,517.00
TOTAL (ROUNDED)				**$760,000.00**

9. Conclusion

The Chancellor Boulevard / East Mall Intersection Redesign project is a complete overhaul of the intersection design in order to align with the *UBC Transportation Plan* to promote sustainable modes of travel. Breaking ground for the project is set to begin in May 2016 with final completion expected at the end of November 2016. The total cost of the project is estimated to be $760,000 CAD, inclusive of all associated costs and maintenance.

Moving forward, a number of steps will be taken to ensure due diligence in the completion of the project. Traffic flow during the construction period along the detour route will be monitored closely. In case of any extenuating circumstances, changes may be made to improve traffic congestion with respect to the chosen detour route. Additionally, peak hour traffic counts will be completed proceeding the completion of the project to monitor the traffic flows and mode splits. Stream-flow measurements will be collected moving forward in order to determine the effect of development on erosion or sediment deposition on the north cliff of the university campus. Finally, key stakeholders will be engaged through the construction process until completion such that potential issues are avoided and minim

Appendix A

Figure 13: Central Island Curb Detail Drawing, British Columbia Standard Specifications for Highway Construction

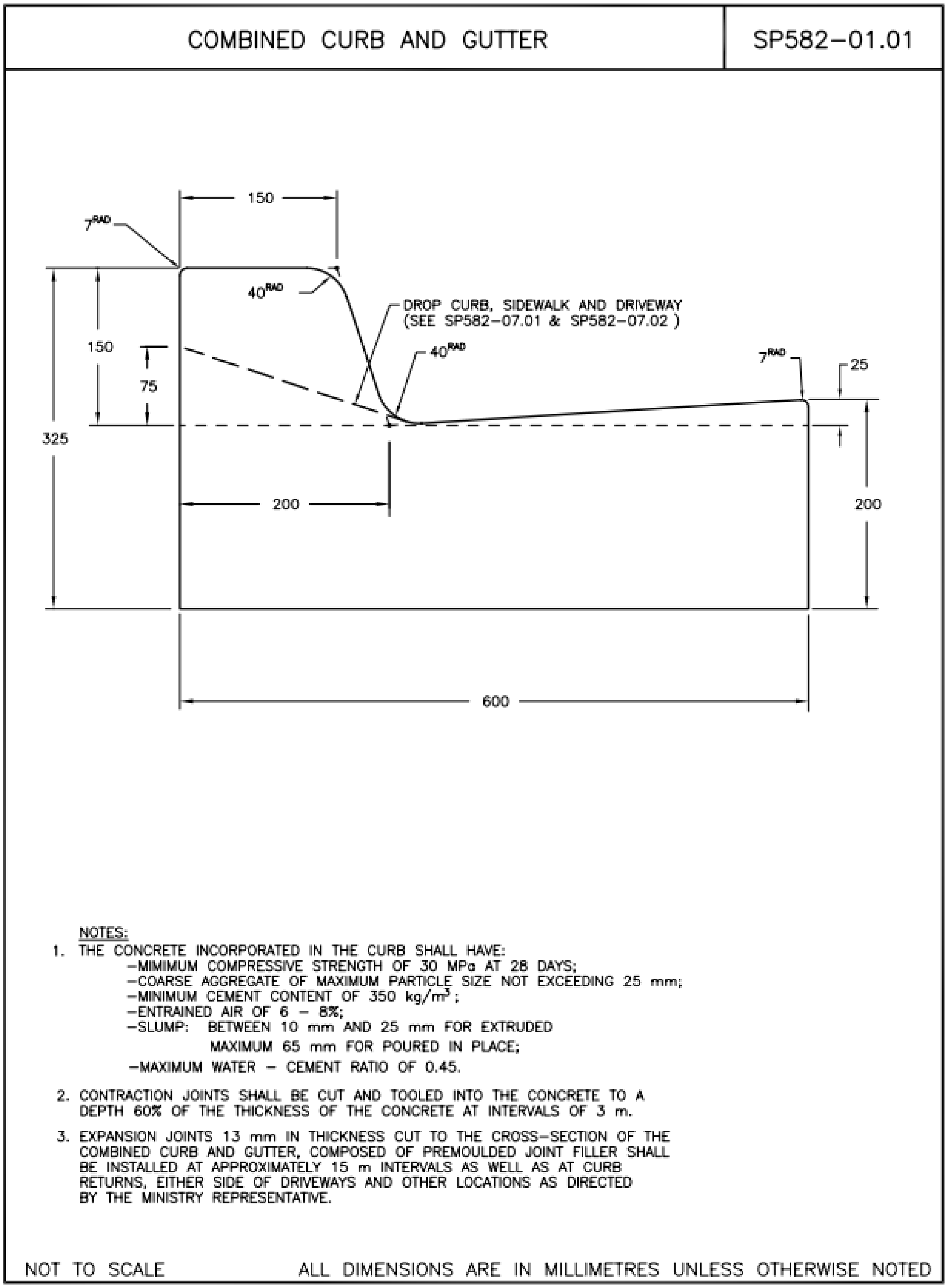
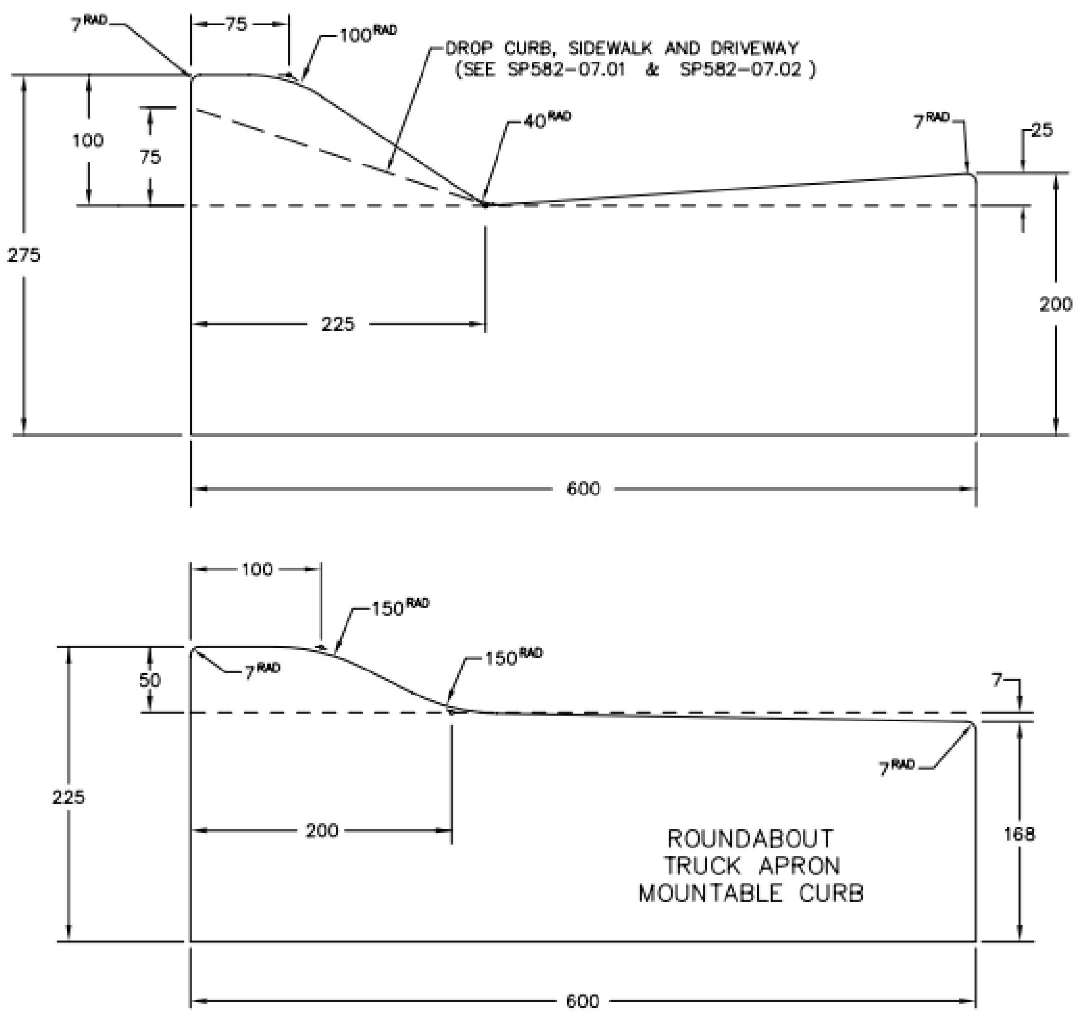


Figure 14: Truck Mountable Curb, British Columbia Standard Specifications for Highway Construction

MOUNTABLE CURB AND GUTTER	SP582–01.02



NOTES:

1. THE CONCRETE INCORPORATED IN THE CURB SHALL HAVE:
   - –MIMIMUM COMPRESSIVE STRENGTH OF 30 MPa AT 28 DAYS;
   - –COARSE AGGREGATE OF MAXIMUM PARTICLE SIZE NOT EXCEEDING 25 mm;
   - –MINIMUM CEMENT CONTENT OF 350 kg/m^3;
   - –ENTRAINED AIR OF 6% to 8%;
   - –SLUMP: BETWEEN 10 mm AND 25 mm FOR EXTRUDED, MAXIMUM 65 mm FOR POURED IN PLACE;
   - –MAXIMUM WATER/CEMENT RATIO OF 0.45.
2. CONTRACTION JOINTS SHALL BE CUT AND TOOLED INTO THE CONCRETE TO A DEPTH 60% OF THE THICKNESS OF THE CONCRETE AT INTERVALS OF 3 m.
3. EXPANSION JOINTS 13 mm IN THICKNESS CUT TO THE CROSS–SECTION OF THE COMBINED CURB AND GUTTER, COMPOSED OF PREMOULDED JOINT FILLER SHALL BE INSTALLED AT APPROXIMATELY 15 m INTERVALS AS WELL AS AT CURB RETURNS, EITHER SIDE OF DRIVEWAYS AND OTHER LOCATIONS AS DIRECTED BY THE MINISTRY REPRESENTATIVE.

NOT TO SCALE ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED

Figure 15: Pedestrian Crossing Signage (by David Wu)

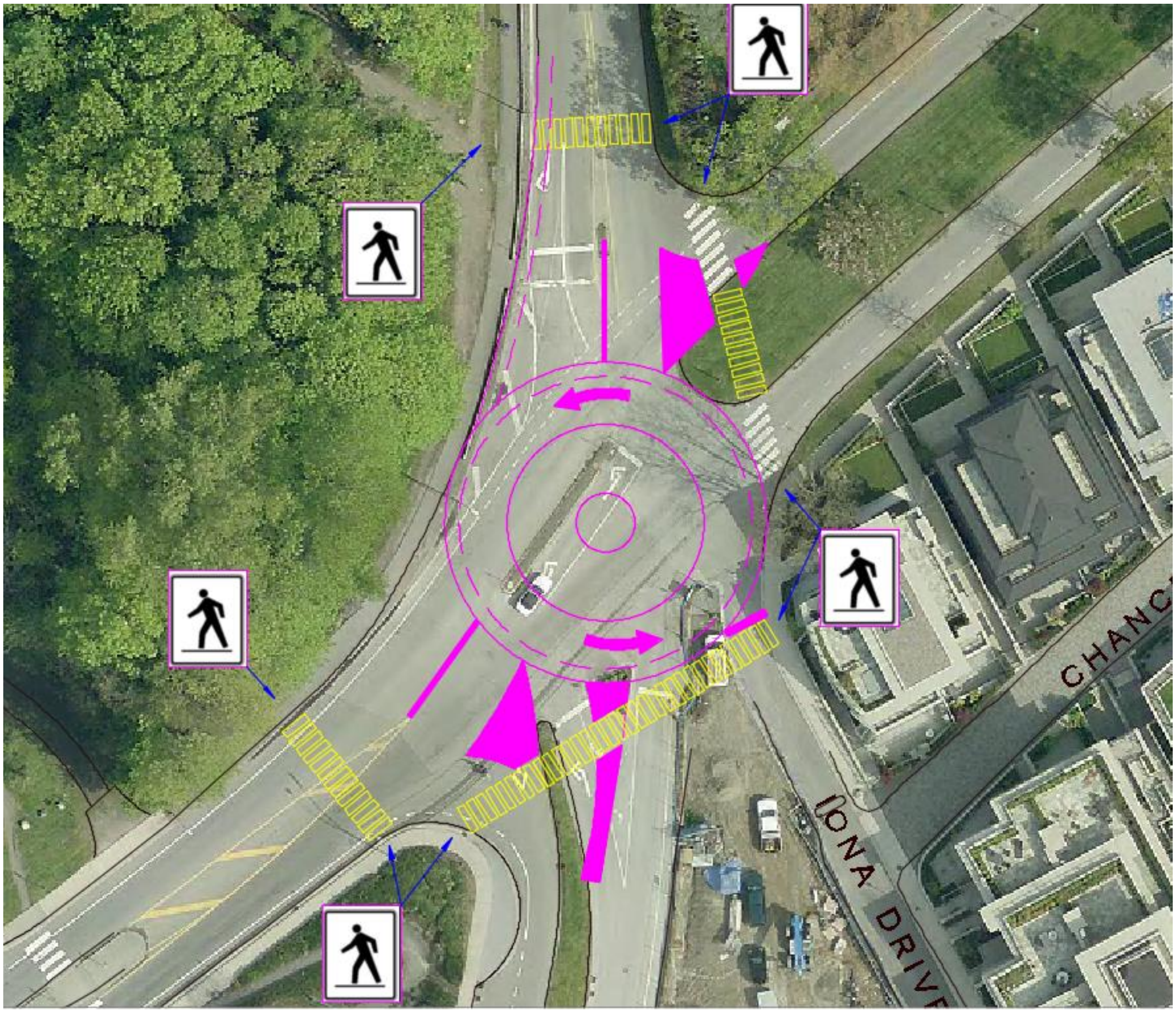
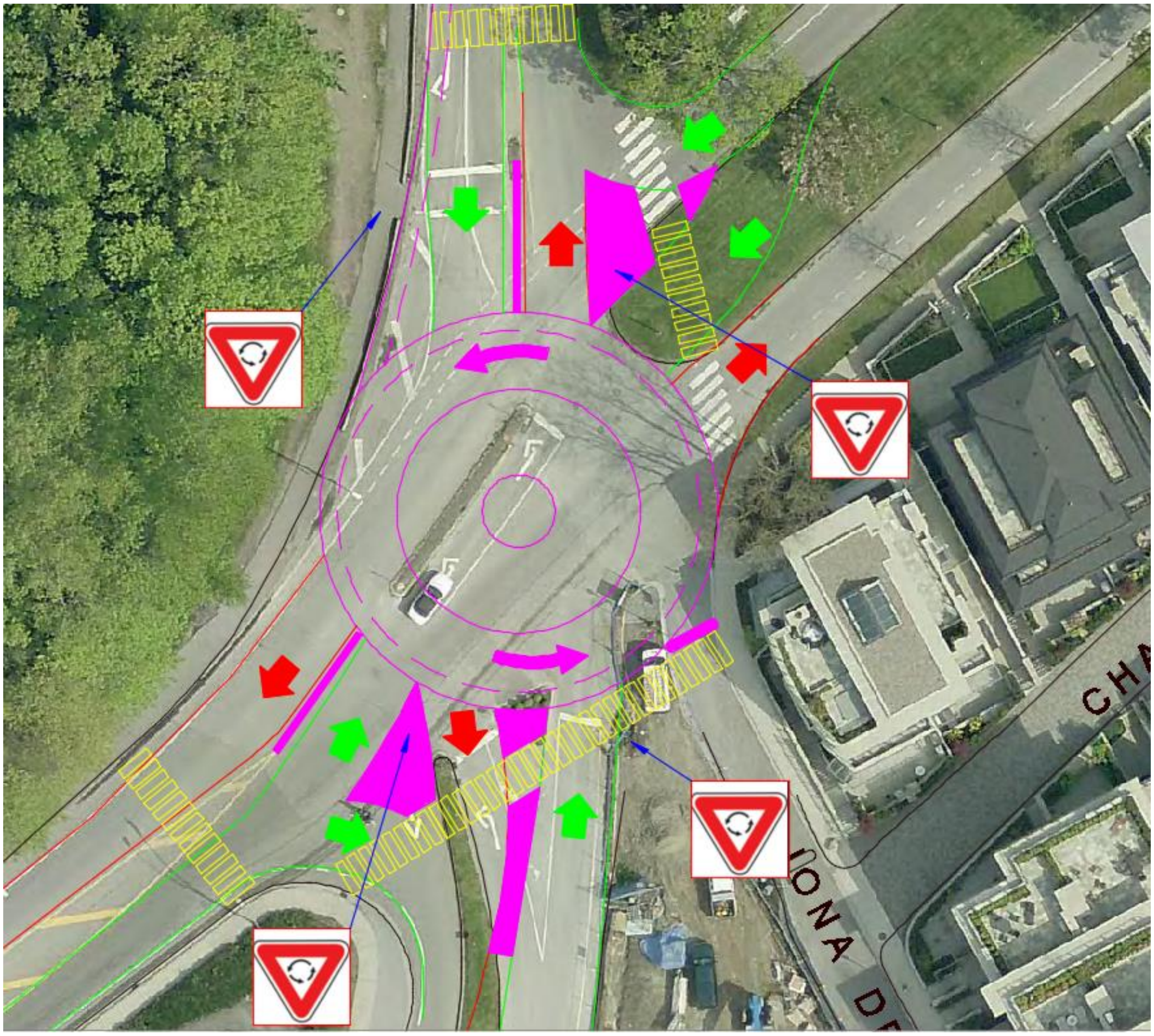


Figure 16: Roundabout Signage (by David Wu)



Appendix B: Calculations

According to the geotechnical report, borehole BH04 is the nearest drilled borehole to the Chancellor Boulevard/East Mall Intersection. Due to a lack of geotechnical data available at the intersection, the data from BH04 will be assumed to be similar to the geotechnical data at the intersection and be used for the following calculations:

Ultimate Bearing Capacity of Soil:

$$q_u = N_c S_u (S_c d_c)$$

$$q_u = Ultimate\ Net\ Bearing\ Capacity$$

$$N_c = Ultimate\ Net\ Bearing\ Capacity\ Factor = 5.14$$

$$S_u = Undrained\ Shear\ Strength\ of\ Soil\ (Assume\ S_u = 30kPa)$$

$$S_c = Shape\ Factor$$

$$= 1 + 0.2\frac{B}{L} = 1 + 0.2\left(\frac{2.5}{2.5}\right) = 1.2$$

$$d_c = Depth\ Factor$$

$$= 1 + 0.33\left(\frac{D_f}{B}\right) = 1 + 0.33\left(\frac{0.5}{2.5}\right) = 1.067$$

$$D_f = Depth\ of\ Footing = 0.5m$$

$$B = L = 2.5m\ (Square\ Footing)$$

$$q_u = N_c S_u (S_c d_c)$$

$$= (5.14)(30)(1.2)(1.067)$$

$$= 164.5kPa$$

$$q_{ult} = \frac{q_u}{FOS} + gD_f$$

$$q_{ult} = Ultimate\ Gross\ Bearing\ Capacity$$

$$FOS = Factor\ of\ Safety\ = 1.5$$

$$g = Effective\ Unit\ Weight\ of\ Soil\ = Assume\ g = 18kN/m^3\ for\ Gravel$$

$$q_{ult} = \frac{q_u}{FOS} + gD_f$$

$$q_{ult} = \frac{164.5}{1.5} + (18)(0.5)$$

$$= 118.67kPa » 120kPa$$

Factored Axial Load (Weight of Structure):

Dead Load of 'UBC 100':

Assume the weight of "UBC 100" is one solid concrete wall. This assumption is conservative considering the structure will be a steel frame that would weigh considerably less.

$$Dead\ Load\ of\ 'UBC\ 100':$$

$$V = (3.50m)(0.60m)(2.00m) = 4.2m^3$$

$$F = (r_{concrete})(V) = (24.5kN/m^3)(4.2m^3) = 102.9kN$$

Dead Load of Concrete Steps:

$$V = (3steps)(3.50m)(0.30m)(0.90m) = 2.835m^3$$

$$F = (r_{concrete})(V) = (24.5kN/m^3)(2.835m^3) = 69.5kN$$

Live Load of Structure:

Assume average person shoulder width = 45cm.

Approximately 8 people will fit on a 3.50m platform.

For conservative design, the structure will be designed for an occupancy of 10 people.

Assume average body weight per person as 80kg.

$$F = (10people)(80kg)(9.81) = 7.85kN \approx 7.9kN$$

Total Factored Load:

$$\begin{aligned} U &= 1.4DL + 1.6LL \\ &= 1.4(102.9kN + 69.5kN) + 1.6(7.9kN) \\ &= 254kN \end{aligned}$$

Shallow Foundation Design - UBC 100 Pedestrian Structure

Data:

Concrete grade, f'c	30	MPa
Steel grade, fy	400	MPa
Factored axial load, kN	257	kN
My, kNm	100	kNm
Mz, kNm	0	kNm
Column size, b	600	mm
Column size, d	600	mm
Allowable Bearing Capacity, q_a	120	kN/m^2
Factor of Safety, FOS	1.5	

Pressure:

Factored axial load, kN	257	kN
Total weight	257	kN
Area of footing required	2.14	m2
size of footing, Bf	2.5	m
size of footing, Df	2.5	m
Projection, b1	0.950	m
Projection, d1	0.950	m

Since, 2.5 > 2.14, size of footing is appropriate.

Footing Pressure,

Pmax = P/A + My/Zy + Mz/Zz

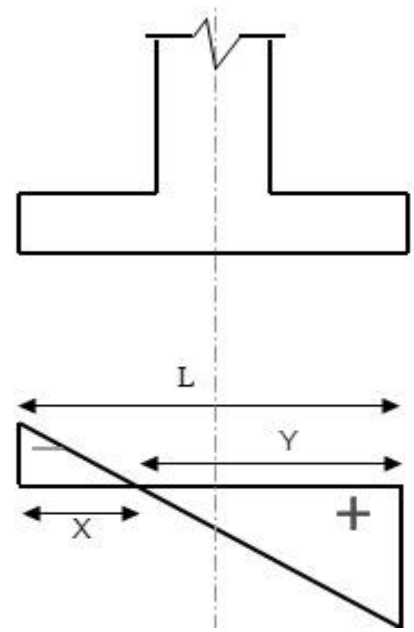
Pmax	79.52	kPa

Pmin = P/A - My/Zy - Mz/Zz

Pmin	2.72	kPa

Eccentricity:

Y	2.42	m
X	0.08	m
L	2.5	m
2/3 L	1.67	m
b	2.5	m
qu	61.68	kN/m^2
Eff. qu	79.52	kN/m^2



Shear Check

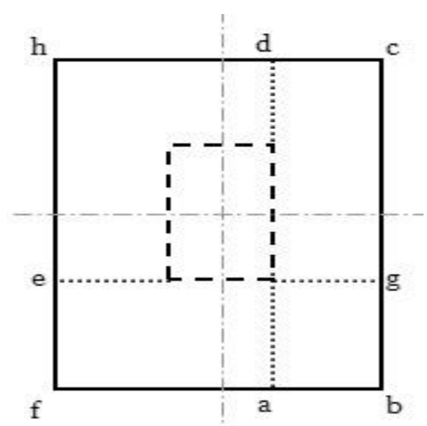
One way Shear : At distance d from face of column.

pt assumed	0.25	%
Designed shear stress	0.37	N/mm^2
vu	78.3336	
d=	168.05	mm
d provided	442.00	mm

(assume 50mm cover)

Flexure design:

For section efbg		
pressure@f	79.52	kN/m^2
pressure@b	79.52	kN/m^2
Moment@eg. Meg	35.88	kNm
Mu	53.83	kNm
d provided	442.00	mm
Mu/bd2	0.28	N/mm^2
pt	0.120	%
pt provided	0.250	
Ast_required	1,105.0	mm^2/m width
provide	15M	@150c/c
Ast_provided	**1333**	**mm^2/m width**



Since Ast Provided > Ast_required, rebar arrangement is sufficient (15M@150c/c)

Appendix C: References

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