UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

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University of British Columbia

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Themes: Water, Climate, Land

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DESIGN FINAL REPORT

Detention Facility for UBC CCM

University of British Columbia - UBC SEEDS Sustainability Program

April 8th, 2019

Group 12

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Exuective Summary

The TTG Consulting Ltd. has been contracted with UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program to design a detention facility for UBC Center for Comparative Medicine (CCM). By following the requirements of the client and the Integrated Stormwater Management Plan (ISMP), a detention facility will be developed adjacent to the UBC CCM. The purpose of building this facility is to minimize the erosion of the surrounding cliffs, eliminate the flooding concerns due to large storms, and improve the quality of stormwater leaving campus. The final design includes a 100m*50m*4.5m detention pond and a 3-story multi-functional green building.

This report summarizes the design progress and critical outcomes after the preliminary design. Some of the highlights are as follows: the detention pond storage capacity is 20700 m^3; the 100-year pre-development rainfall flow rate is 1579 L/s; the walls of the building will be constructed of large panels of glass; the building's first floor is designed to be completely submerged underwater; there is a 265.25-m^2 transparent solar panel installed onto the building; the total retainable floor area of the building is 1162.25 m^2. More details can be found in the attached report.

The total cost estimation of the whole project is $4.4 million which includes $0.4 million of environmental protection and permitting cost, $1.6 million of detention pond system construction, $1.3 million of building structure construction and $1.1 million of

operation and maintenance cost combined with contingency cost as well as GST and PST in BC. The project will be constructed on May 1st, 2019, and the substantial completion will be achieved on May 11th, 2020, with the full operation coming up on Aug 6th, 2020 .

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1. Introduction

The final report is prepared on behalf of the TTG Consulting Ltd. and will present the detailed final design of a detention facility adjacent to UBC CCM. The report will begin with an introduction to the project and followed by detailed information of design components, design criteria, design specifications, construction specifications and a draft plan of construction work. Detailed construction drawings, cost estimate, schedule and sample calculations will be attached in the Appendixes.

1. 1 Project Overview

The major objective of the multi-use stormwater detention facility adjacent to UBC CCM is to imitate a complete detention pod to control the water flowing leaving and improve the stormwater quality. The major concerns of this project include the erosion of the surrounding cliffs in Point Grey, potential flooding due to large storms, and the quality of water leaving campus. As a result, the designed detention pond will mainly focus on solving these problems. In the creative part, a multi-purpose green building will be developed in the middle of the detention pond, integrating with the detention pond to provide an opened public community to nearby people.

TTG Consulting team develop the design based on many constraints and criteria, including existing infrastructure, soil geology, standards, cost, community impact, environmental protection and sustainability. The final design report aims at developing structural details design based on the technical design criteria.

1. 2 Site Overview

The construction will span around 5,000 square meters at its intersection of South West Marine Drive and Wesbrook Mall. UBC CCM is adjacent and UBC Farm is at the Northwest where is 200 meters away to the proposed site. The following figure shows the detailed project construction site.

Figure 1: Construction Site (Google Earth)

1. 3 Scope of Work

The project scope as presented in the report includes the following:

- Review the technical and non-techincal design constrains
- Detailed design of the detention pond and building structure
- Structural loading conditions and design of the whole detention facilty
- A construction plan highlighting the construction timeline and key tasks
- A maintenance plan over the design life
- An uploaded cost estimate and construction schedule
- Detailed structural drawings issued for construction

1. 4 Task Distribution

The following table indicate each team members' contributions to this final design.

Table 1: Team List & Task Distribution

Team Member	Report Contribution
Guan XinYan	Executive Summary Introduction Foundation Design Construction Plan Updated Schedule Proof Reading Formatting
Wang YanLi	Design Criteria and Constraints Pump Design Slab Design Proof Reading
Wang ZhenNing	Buidling Enclosure Design
Peng Harry	Detention Pond Design Overview Building Structure Design Overview Detention Pond Design Beam Design Updated Cost Estimate(Detention Pond) Proof Reading
Yang YaXing	Construction Plan Maintenance Specification and Plans Updated Cost Estimate (Building Structure) Detailed Drawings Proof Reading

2. Design Criteria and Constraints

The project is developed under the regulations of UBC SEEDS Sustainability Program, and each phase during the project follows all rules set by the UBC Infrastructure and Serving Planning. The location of the project is selected by UBC Campus and Community Planning. Minimum requirements of infrastructure design in the Nation Building Code of Canada (NBCC), British Columbia Building Code and British Columbia Master Municipal Construction Documents (MMCD) are used and adhered throughout the entire design. In consideration of the local geotechnical and climatic conditions, British Columbia Building Code and City of Vancouver Bylaws are also consulted. In addition, the minimum requirements of Metro Vancouver should be reached for all design criteria and construction methods of water mains. The resistance force of structural components of slabs, beams, columns and foundations will be checked according to the CSA code of concrete.

A detention pond is designed surrounding the central building structure; since the collected stormwater will be used to provide potable water for the building, the water, after filtration phase, should meet the requirements of BC Water Quality Guidelines: Drinking Water Sources. The redundant water will be discharged to the UBC Management network, thus, the quality of water should reach the standards of Fisheries Act in Canada, Canadian Environmental Protection Act, Water Act and Environmental Management Act that are required by UBC Integrated Stormwater Management Plan (ISMP).

Some constraints are included which mainly come from the underground and overground infrastructures associating with the entire project. Sewer, water and gas networks exist below the ground, therefore, any further excavation work should minimize the impact on the underground treatment system. In addition, UBC Farm, numerous trees, buildings and pathways are located near to the proposed construction site, so avoiding reposition of these structures and cutting the minimum number of trees are important in this project. Some other site restrictions such as land availability, dimensions, local precipitation and accessibilities are also included and will be addressed as well.

2.1 Design Capacity

The proposed detention pond in UBC is used for water management during the stormwater events and to provide a space for temporary storage of rainwater runoff. Taking account of the design criteria shown above, the detention facility is designed to serve for 75 years and should have the ability to store the water throughout 100-year storm conditions. The building structure design is based on the design load which contains design moment, design shear and design column axial load. All loads are determined by SAP2000; after analysis, the slab and beam of design moment are 157.9 kN*m and 308.2 kN*m respectively, the slab and beam of shear force are 31.7 kN/m and 128.8 kN/m, and the total sustained load of column axial load is calculated as 23,416.0 kN.

2.2 Economic

Economic analysis for is necessary for the outlook and performance of a project. The primary goal for the detention pond construction is sustainability, which includes non waste, construction practicability as well as economic efficiency so that the project can acquire adequate investment, and the owners will accept the design. Both of the construction and maintenance sectors are considered, thus, a long-term economic analysis is more effective and appropriate. The larger volume of the structure, the more construction cost is incurred in terms of the foundation excavation and the material use. Typical costs that should be considered include as follows:

- Initial Costs: purchase, acquisition, design and installation of equipment
- Energy Costs: for any product that consumes energy, fuel rates and equipment efficiencies
- Operation, Maintenance and Repair Costs: for the incorporated material and system
- Replacement Costs: for any product which have a life span shorter than the construction design life
- Residual Values: similar with the resale or salvage value for products with remaining life expectancy
- Financial Variables: project-related interest expenses and inflation rates

A water reuse system is included, in order to provide the daily use of water in the building, and the usage of generators, turbines at the end of the pond, as well as solar panels on the roof of building, can significantly fulfill the building's daily power needs. In addition, the traditional rectangular-shaped pond is used, and this is relatively cheap and will require fewer labour hours.

2.3 Environemntal Considerations

The construction undergoing usually has a significant impact on the environment, both on local and global issues. Therefore, fully understanding of the construction impacts becomes important, in order to measure the potential influence on the environment and to provide possible solutions for minimizing the adverse impacts. Some possible environmental effects are considered as follows:

- Energy Efficiency: during the construction process, using old machines or low-efficiency equipment can largely reduce the productivity and requires more energy consumption to complete the work. One of the better ways to improve energy efficiency is to use high-efficiency machines which have the regular repair and update.
- Construction Materials: the wasted construction materials have become one of the major environmental issues caused by construction. Using green material instead of traditional one can be a viable solution since the green material can be recycled and degraded easily.
- Material Wastes: The wastes will be delivered from the construction site regularly, and a detailed waste management plan will be provided before the construction begins.
- Dust and Diesel Emission: a large amount of dust and diesel can be produced, during the construction phase, which significantly impact the local air quality and climate change. Thus, the related construction rules should be followed, and the wind fencing or a fence filter may be installed in order to control the dust and diesel emission.
- Construction Noise: the increased traffic and construction operation will cause noise pollution to the local stakeholders as well as the surrounding wildlife. Thus, the Noise Control Bylaw specifying the hours and days that can make construction-related noise should be followed.

- Soils: in this project, a large part of the structure will be constructed underground. The uncertainties include soil composition, contaminated soil in the existing conditions and soil transportation.

2. 4 Sustainability Approach

The primary goal of this project is sustainability which represents that the environmental, financial and social impacts should meet the requirements and needs for sustainable development in Vancouver. The detention pond combined with a unique structure should comply with the green building standards as an open public community; a green roof will be added to the building, multiple accessories will be provided to the building to ensure the self-sufficient, and a layer of greenery will be designed along the outer edge of the detention pond. In addition, the on-site construction will use more of the natural, recyclable and less waste produced materials, such as wood, recycled plastic and bamboo.

Waste disposal on-site is also a significant issue for the sustainable requirement; the construction waste includes insulation, nails and the waste from site preparation phase, including tree stumps, dredging materials and rubble. A new construction can create five percent of all construction and demolition material in total, so the waste management for recycling and disposing those wastes is necessary. A detailed waste management plan should be provided before the project starting.

2.5 Stakeholder Engagement

TTG Design Team will collaborate with involved stakeholders to ensure the success of this project, and all of the stakeholders are listed as follows:

- SEEDS Sustainability Program (Social Ecological Economic Development Studies): a program with the aim of advancing campus sustainability strategies and projects, and this is the main client of the project
- Musqueam First Nation: the traditional territory is occupied in Vancouver and the surrounding areas
- UBC AMS (Alma Mater Society): the student-led and nonprofit organization at UBC
- UBC Staff: including all staff working in UBC
- CCM: the University of British Columbia Center for Comparative Medicine where is near to UBC campus and will be directly influenced by the project
- the Public: including the nearby residence, pedestrians and the Minister of Community who are responsible for long-range planning of the project design, and needs to manage sustainability, land use and community building programs.
- UBC Farm: near to the construction

A stakeholder engagement is the key for the entire project accomplishment, and the strategies must be held and followed during the project proceeding. The design should consider the satisfaction and requirements from all of the stakeholders. The engagements will be performed by being open-minded, cooperative and willing to listen to the public. Moreover, substantive discussion and reasonable changes for the design needs to be considered in order to accommodate the requests and concerns from the involved stakeholders.

3. Detention Pond Design Overview

TTG designed the detention pond based on the EPA SWMM model developed to sustain 100-year storm events. The dimension of the detention pond is 100 x 60 x 4.5 m, with a total storage capacity of 21,000 cubic meters even in the event of 100% valve blockage.

3.1 Methodology

To design the detention pond, TTG used the following methods. Firstly, an EPA SWMM model is developed from the GIS data to obtain the hydrographs and the maximum flow rates. After this step, the detention pond is then sized in excel after exporting all tables. The size and depth of the detention pond is determined in this step. The final step to ensure that the sizing of the detention pond is sufficient is by adding a detention pond into the SWMM model and set the designed parameters. The model is then analyzed to ensure that the water will not overflow.

3.1.1 Software Used for Design

The software used within TTG's detention pond design are EPA SWMM, Autodesk Revit Architecture, Autodesk Revit Structure, Sap2000, Navisworks, and Microsoft Project.

EPA SWMM

EPA SWMM is used to generate a model for the entire study area. The model is then analyzed to obtain the 100-year maximum flow rates as well as the hydrographs. After obtaining the previous information, the detention pond and the orifice could then be sized.

Autodesk Revit Architecture & Structure

The two Autodesk Revit software are used in modeling the detention pond with sizing obtained from EPA SWMM. The architecture drawings exported from Autodesk Revit Architecture as well as the detailed structural drawings exported from Autodesk Revit Structure are combined to obtain a final model.

Sap2000

Sap2000 is used by TTG to analyze the detention pond in the case of earthquake loading. The detention pond is considered as a one-story building.

Navisworks & Microsoft Project

TTG uses Microsoft Project to construct a detailed schedule for the construction of the detention pond. Then Navisworks is used to animate and analyze the entire construction process.

3.1.2 Key Components of Design

The key components of TTG's detention pond design are the inner four walls of the detention pond, the outer sedimentation basin that surrounds the interior storage pond, and a pump that discharges water in the case of valve blockage.

Interior Walls of the Detention Pond

The interior storage pond walls are designed based on the NBCC. The width of the storage pond is consisted of two walls of 60 m x 4.5 m with a thickness of 300 mm. The cover is 45mm, the longitudinal and horizontal rebars are 20M @ 400mm spacing. The confinements are 10M @ 600 mm.

Sedimentation Pond

Team TTG incorporated a sedimentation pond into the surrounding of the interior detention pond. The total length of the sedimentation pond is 328 meters with a width of 6 meters. The height of water is kept as 1.2 meters. Therefore, with a discharge of 1.53 m^3/s, the flow time is 1543.5 seconds, and the settling percentage is 100%.

Pump

The pump used by TTG in the detention pond to discharge water in the event of valve blockage. The pump has an inner diameter of 410 mm and a wall thickness of 3.6 mm. It provides a maximum flow of 25.5 L/min and is only activated in when valve blockage is detected.

3.1.3 Technical Considerations

To prevent the water within the pond from freezing during low temperature seasons, heating pads is to be added at the bottom of the detention pond. These heating pads will cause the water to stay above 0 degree Celsius.

Also, to prevent the concrete from freezing during setting, TTG uses low slump, air-entraining concrete. Similarly, accelerators will be added as well to decrease the setting time.

3.2 Construction Plan of Detention Pond

The main sections for the construction of the detention pond are site excavation, installation of soil anchors, underground piping, concrete forming, concrete pouring, and backfill & compacting. Following chronological order, the detention pond excavation takes a total of 35 days, starting on May 10th, 2019 and ends on June 27th, 2019. The installation of the soil anchors occurs at the same time as the excavation and lasts 35 days in total. The forming of the detention pond is scheduled to happen the day after the excavation completes and takes a total of 30 days, starting from June 28th, 2019 and ending on August 8th, 2019. On the day that the forming finishes, the pouring of concrete starts, and lasts for a total of 35 days, from August 8th, 2019 to September 25th, 2019. The final construction step for the detention pond is backing filling and compacting, which lasts for a total of 15 days, starting on September 26th, 2019 and ending on October 16th, 2019.

4. Building Structure Design Overview

The building structure in the middle of the detention pond is partially submerged underwater. The building is of 25 m in length and 16 m in width. It is a three-story building and has an overall height of 11.5 m measured from the datum at the bottom of the detention pond.

4.1 Methodology

To design the building structure, TTG used the following methods. At the start of the design process, a basic conceptual building design was created, along with simple drawings. Then, TTG built a first model in Autodesk Revit Architecture. After obtaining the favorable exterior design and dimensions, TTG started working on the structural designs. TTG designed four main sections for the structure of the building. Firstly, TTG designed the reinforced concrete slabs for each of the three stories. Then, TTG moved on to designing the reinforced concrete beams after obtaining the weight of the slabs. The columns that supports the beams are designed next, from the top floor down. Finally, after designing the columns on the first floor, the foundation of the building is designed. After designing all these components in Autodesk Revit Structural, the finalized construction drawings are extracted, and is provided in Appendix A of this report.

4.1.1 Software Used for Design

Similar to the detention pond design, the TTG also uses the same software to design the building structure. The software that the TTG used are within the design of the building (Sub-Mizu) are Autodesk Revit Architecture, Autodesk Revit Structure, Sap2000, Navisworks, and Microsoft Project.

Autodesk Revit Architecture & Structure

Similar to the detention pond, the design of the building uses the programs Autodesk Revit Architecture and Structure in the same way. First, a fully architecture model is developed. Then, a fully structural model is developed. Finally, the two models are combined to generate the final model that is included in the Appendix.

Sap2000

Compared to the detention pond, Sap2000 is used more thoroughly in the design of the building. First a simple 3D three-story model is created in Sap2000 to represent our building. Then, the model is analyzed using Linear-Modal, SRSS from the first mode to the third mode.

Navisworks & Microsoft Project

Similar to the design of the detention pond, TTG uses Microsoft Project to construct a detailed schedule for the construction of the building structure. Then Navisworks is used to animate and analyze the entire construction process.

4.1.2 Key Components of Design

The key components of design for the building Sub-Mizu are the interior slabs, beams, columns, and foundation. All designs are based on the NBCC and CSA Codes.

Interior Slab Design

The slab system for this building is consisted of only one type of one-way slab. The slab is of 240 mm thick and has tension reinforcement of 15M@200 mm to withstand a maximum moment of 63.36 kN.m. The thermal and shrinkage reinforcements are of 15M@400mm. There is no need for shear reinforcements due to the fact that the concrete shear strength is higher than the maximum shear loading.

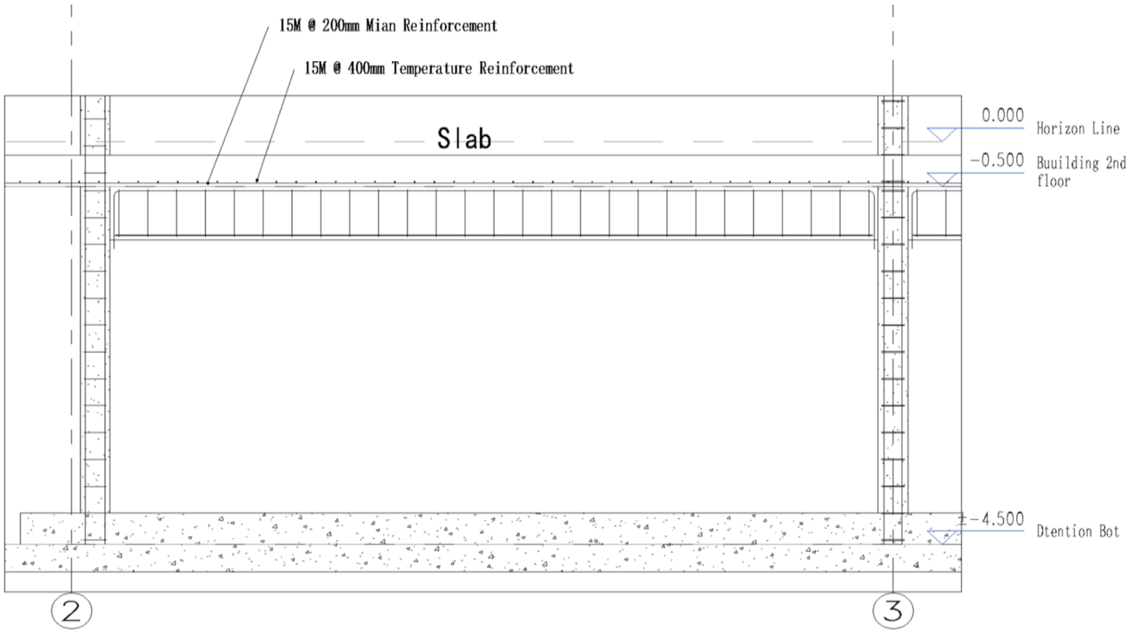


Figure 2: Slab Specifications

Interior Beam Design

TTG designed a one size fits all beam for this building. The size of the beam is 600 x 300 mm. The longitudinal reinforcements for tension are 8-20M in a two-layer layout. The shear reinforcement specification for this beam is 2-legged 10M@300mm spacing with 2-135-degree hooks at the top. The maximum moment this beam can withstand is 343.0 kN.m and the maximum shear force this beam can withstand is 235.9 kN.

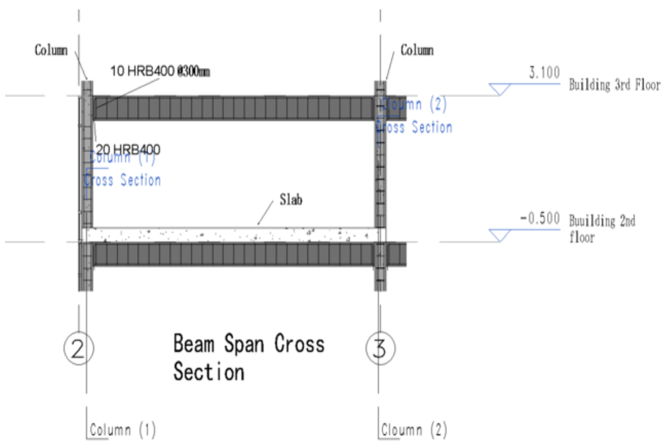


Figure 3: Longitudinal Beam Layout

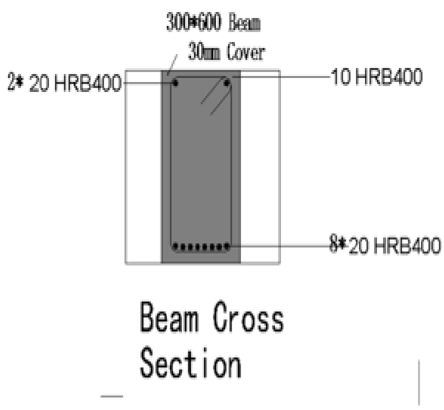


Figure 4: Beam Cross-section

Interior Column Design

TTG designed three types of columns for the building structure. The following figure shows the column layout. Columns 1, 2, 3, and 4 are Type I, columns 5, 6, 7, 8, 9, and 10 are Type II, and columns 11, and 12 are Type III.

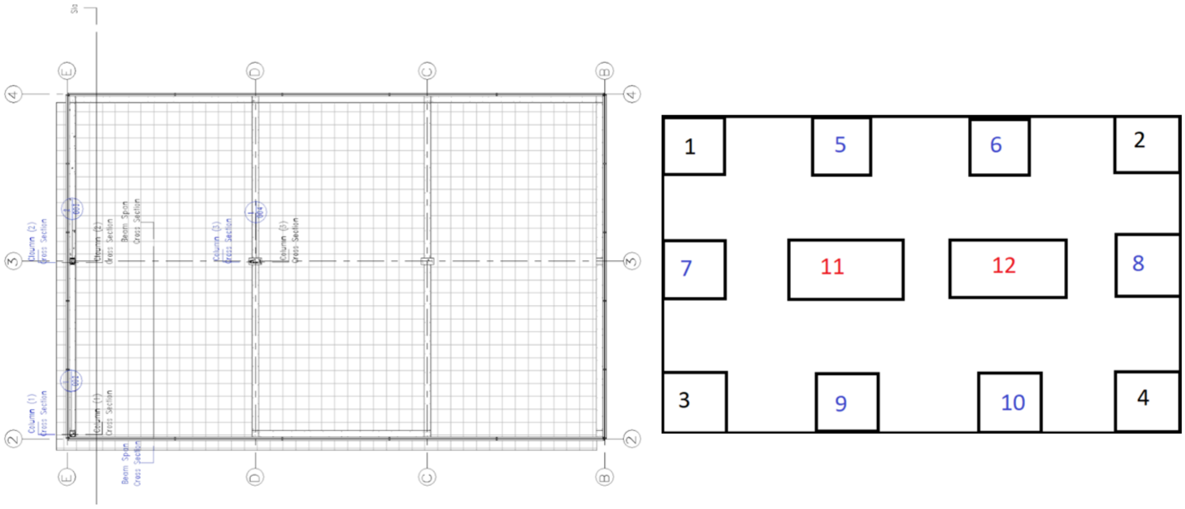


Figure 5: Column Layout

Type I Column: Type I columns have a size of 300 x 300 mm. The longitudinal steel reinforcements are 4-20M with stirrups of 10M@ 300 mm spacing. Type I columns can sustain a vertical load of 1057 kN.

Type II Column: Type II columns have a size of 300 x 300 mm. The longitudinal steel reinforcements are 6-35M with stirrups of 10M@ 300 mm spacing. Type II columns can sustain a vertical load of 2049 kN.

Type III Column: Type III columns have a size of 600 x 300 mm. The longitudinal steel reinforcements are 8-35M with stirrups of 10M@ 300 mm spacing. Type III columns can sustain a vertical load of 3923 kN.

Foundation Design

TTG designed four types of foundations for the building structure. The specification of each are given below.

Foundation I: Foundation I is to be connected to the bottom of columns 1,2,3 and 4. It has a size of 2.00 x 2.00 x 0.45 m. The rebar reinforcement within this type of foundation is 6-20M at a spacing of 300 mm with a clear cover of 75mm.

Foundation II: Foundation II is to be connected to the bottom of columns 5,6,8 and 10. It has a size of 2.00 x 2.00 x 0.65 m. The rebar reinforcement within this type of foundation is 6-25M at a spacing of 300 mm with a clear cover of 75mm.

Foundation III: Foundation III is to be connected to the bottom of columns 7 and 8. It has a size of 2.50 x 2.50 x 0.65 m. The rebar reinforcement within this type of foundation is 5-20M at a spacing of 450mm with a clear cover of 75mm.

Foundation IV: Foundation IV is to be connected to the bottom of columns 11 and 12. It has a size of 3.00 x 3.00 x 0.90 m. The rebar reinforcement within this type of foundation is 6-35M at a spacing of 450 mm with a clear cover of 75mm.

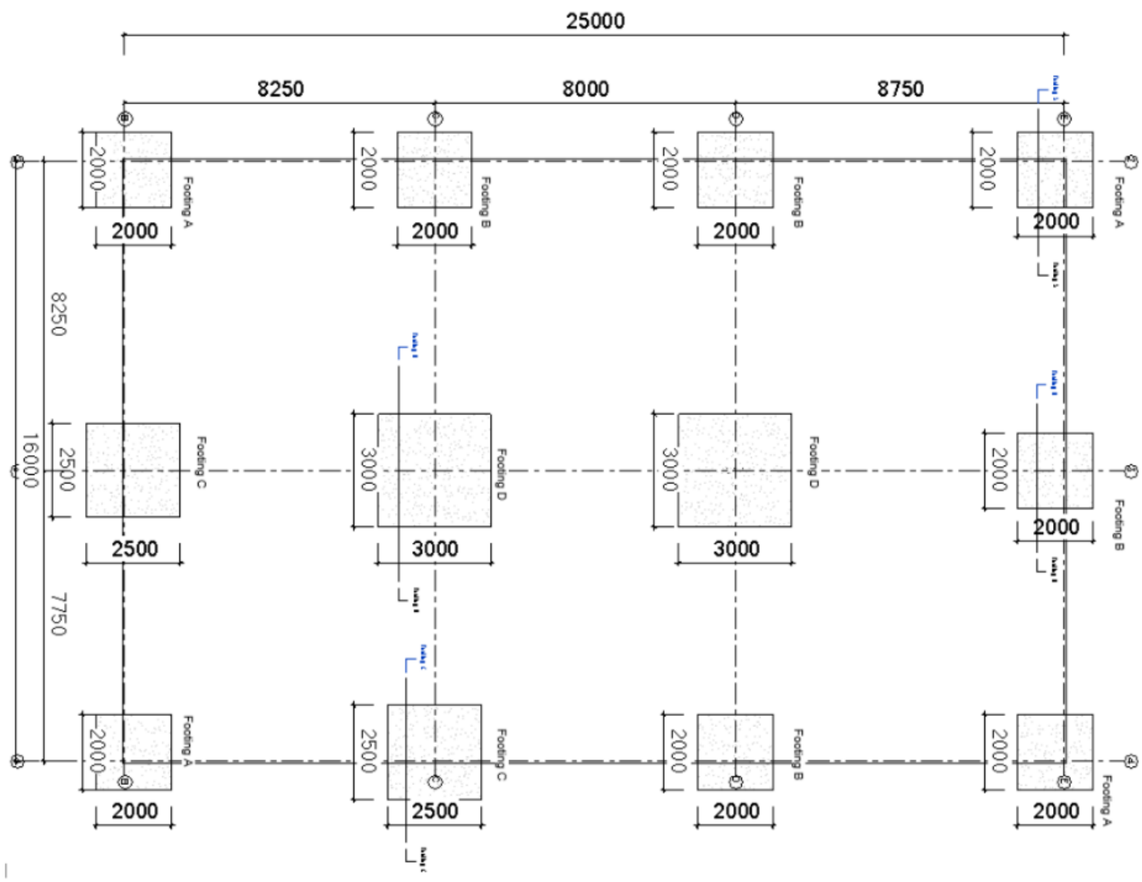


Figure 6: Footing Layout

4.1.3 Technical Considerations

To prevent the water within the pond from freezing during low temperature seasons and cause a high compressive stress at the first floor of the building, thermal pads are placed at the bottom of the detention pond.

At the same time, leakage prevention and monitoring on the first floor will be a continuing process, with sensors at the bottom of every glass window to detect any first signs of leakage.

4.2 Structural Design of the Building

The accuracy of load combination has a direct impact on the safety and economic efficiency of the structural design. So, it is important to reasonably select probable loads in this part. The load analysis in this project consists of vertical dead load, vertical live load, snow load, and wind load.

4.2.1 Vertical Dead Load

The vertical dead load mainly refers to the self-weight of the structure. Several assumptions are made in this part to obtain the estimated dead loads. Firstly, the main material used in the structural system in the Sub-Mizu building is concrete, and the density varies between 2400-3000 kg/m^3. Therefore, the assumed concrete density in this project is the average of these numbers, which is 2700 kg/m^3. Secondly, the slab thickness and column section are 250 mm and 300x300 mm respectively in this project. Finally, the beam section 300x600 mm is used in this project. After taking these assumptions into account, the dead load of the building Sub-Mizu is 11830.36 kN. Sample calculations are provided in Appendix D-4 Load Analysis.

4.2.2 Vertical Live Load

There are many types of vertical live loads, which includes all service loads. For this project, the vertical live load is estimated according to NBCC Table 4.5.1.3, specified uniformly distributed live loads on an area of floor or roof. By checking the museums' requirement, the live load is 4.8 KPa. Therefore, the total live load in the Sub-Mizu is 5578.8 kN. Sample calculations are provided in Appendix D-4 Load Analysis.

4.2.3 Snow Load

Snow load is a vertical load that acts upon roofs. According the NBCC 2010 4.1.6.2, the snow load is calculated from the equation: S=Is[Ss(CbCwCsCa)+Sr]. By checking NBCC, the importance factor Is=1, Ss=1.1 kPa, and Sr=0.2 kPa. Assuming all "C" factors are 1, the calculated snow load is 1.3 kPa.

4.2.4 Wind Load

Wind load is a lateral load mainly acting on the windward side of the building. The load equation is P=Iw·q·Ce·Cg·Cp according to NBCC 2010 4.1.7.1. By checking the NBCC 2010 Table C-2, q=0.57 for 1/50 years. Assuming P=2.6q, so the calculated wind load is 1.482 kPa.

4.2.5 Load Combination Analysis

By checking the NBCC 2010 Table 4.1.3.2A, TTG calculated all cases to find the governing case. After calculation, the governing load combination is found to be 1.25D+1.5L+0.5S, and the factored total vertical load is 23416.15 kN.

4.3 Building Enclosure Design

The primary function of building enclosure is to physically separate the interior and exterior environments, providing a comfortable indoor living environment. Four control mechanisms are used to control the energy flows, including water, thermal, air and vapour control.

4.3.1 Water Control

Due to constant rainfall events in Vancouver, water control is the primary concern for both the building construction and operation. Inadequate design may cause serious damage to the wall, which reduces the service life of the whole building. The control mechanisms include deflection, drainage, drying and durable materials. Since curtain walls are used for the entire first floor, the glass can effectively control the water. For the second and third floors, sheet metal flashings are used to deflect the water around windows. Shingles are used on the cladding to act as the first layer to deflect water for the exterior wall. Two additional drainage planes are designed to avoid water penetration. The first plane is between the structure wall and the insulation layer, and the second plane is between the insulation layer and the cladding.

4.3.2 Heat Control

A proper heat control can minimize the energy losses and gains through the enclosure, which reduces the load on building space conditioning systems and reduces the capital cost of unnecessary heating and cooling. The insulation layer is put out of the vapour control layer to avoid the condensation in the wall. Several insulation materials are compared, including stone wool, fibreglass and polyurethane foam. Finally, the 2-pound high density closed-cell polyurethane foam is chosen for this project because it has fairly higher thermal resistance, and it can be used for both wet and dry locations. It can also be used for both the attics below sheathing and the below-grade wall.

4.3.3 Vapour and Air Control

Due to the distinct nature of this project that the building is surrounded by a detention pond filled with water throughout the year, the temperature change will generate vapour which may intangibly diffuse into the wall. Several effective vapour barrier materials are compared, including polyethylene sheet, external paints and self-adhesive membranes. For this project, polyethylene sheet is chosen because it is not only a reliable material commonly used for similar projects, but it is also used as air barrier.

4.3.4 Materials and Damage Functions

During winter, the local temperature in Vancouver may sometimes drop below zero degree, so the damages caused by constant freeze-thaw cycles need to be prevented. Also, water with salts and minerals in the pond will evaporate, and the residual salts can cause the spalling of the foundation structure. Therefore, special treated brick and concrete are used to avoid being deteriorated. In addition, fasteners and any other steel components need to be coated with zinc to prevent corrosion.

4.3.5 Assembly

For the connections between the exterior cladding and the inner wall, isolated galvanized clips are used for this project because they have low thermal conductance, which reduces the thermal bridging effect and saves a lot of heat energy. This roof for this project is a traditional low-slope roof with 2% slope to provide drainage. On top of the control layers, filter fabric and ballast are designed to protect the roof.

4.4 Construction Plan of the Buidling

The main sections for the construction of the building structure are slab construction, beam construction, column construction, wall construction, glass wall construction, roof construction, stair forming, and entrance connection construction. Following chronological order, the slab construction takes a total of 50 days, starting on October 21th, 2019 and ends on December 27th, 2019. The beam construction takes a total of 50 days, starting on October 21th, 2019 and ends on December 27th, 2019. Similar to the slab and beams, the column construction takes a total of 50 days, starting on October 21th, 2019 and ends on December 27th, 2019. The concrete wall construction takes a total of 45 days, starting on December 30th, 2019 and ends on February 28th, 2019. The glass wall installation takes a total of 20 days, starting on December 30th, 2019 and ends on January 24th, 2020. The roof construction takes a total of 50 days, starting on March 2nd ,2020 and ends on May 8th, 2020. The stair forming takes a total of 15 days, starting on May 11th, 2020 and ends on May 29th, 2020. Finally, the entrance connection construction takes a total of 40 days, starting on October 17th, 2020 and ends on December 11th, 2020.

5. Maintenance Specification and Plans

5.1 Planning and Design Phase

Operation and Maintenance (O&M) activities should start at the planning and design phase and continue through the building life cycle. During this stage, professional maintenance persons should get involved and identify maintenance requirements. For example, it is necessary to identify equipment access requirements, monitor construction conditions, and check electrical and mechanical connections. In addition, an independent (O&M) team should be involved, and the team can represent the project development team so that specific problems related to O&M can be delivered and fixed on time.

5.2 Construction Phase

For the purpose of ensuring efficient O&M, it is highly recommended that the O&M team develop official and accurate maintenance documentations related to the building and update in a timely manner. Furthermore, a detailed manufacturer manual should be established in order to install and maintain equipment accurately. The manual should be reviewed by the owner as well as the consultant team, and it should be updated in different construction phases.

5.3 Life-Cycle Operation and Maintenance

Due to the reason that the O&M includes structure elements of the building and detention pond, a knowledgeable and well-organized management team should be hired. Moreover, to maintain a specific equipment or structure element, well- trained and skilled workers are also needed. The purpose of the hired O&M team include operating, maintaining, and improving the equipment or facilities to achieve reliable, safe, and energy efficient performance. By doing this, the designated usage life can be accomplished. Additionally, O&M management team should apply and manage day-to-day maintenance activities in order to keep the facilities running normally.

6. Cost Estimation

Based on the final design detailed in the previous section, a Class B(Substantive) cost estimate was prepared. The total cost of the project is comprised of the first costs, including permitting, project management, construction, contingency, PST, GST and the annual operating and maintenance fees. A breakdown of these costs is summarized in Table 2 below. A detailed list of cost estimation has been provided in Appendix B Class B Cost Estimation Detail

Table 2: Life-Cyle Cost Estimation

Cost Item	Contingency	Yearly Cash Flow	Total Cost 75-year lifecycle
Captial Cost			
Environmental Considerations	25%	N/A	$25,000
Permitting & Planning	20%	N/A	$19,000
Construction	15%	N/A	$2,772,000
Operation & Maintenance Cost			
Dentention Pond	25%	$9,375	$703,000
Building Structure	25%	$5,625	$422,000
		Subtotal	$3,941,000
		GST(5%)	$197,000
		PST(7%)	$2,75,000
		Total Lifecycle Project Cost	$4,413,000

6.1 Capital Cost Estimation

Table 3 and 4 summarize the contractor costs to fully implement the proposed design of the reservoir and distribution system. The costs are broken into majo divisions as per specified in the Master Municipal Construction Documents(MMCS). All estimates are exclusive of PST(7%), GST(5%).

Table 3: Detention Pond Cost Estimation

CSI Division	Estimated Cost
01 General Requirements	$292,000
03 Concrete	$104,000
31 Earthwork	$1,135,000
33 Utilities	$5,000
Subtotal	**$1,536,000**

Table 4:Building Structural Cost Estimation

CSI Division	Estimated Cost
01 General Requirements	$359,000
03 Concrete	$46,000
05 Metals	$2,000
12 Equipment	$26,000
21 Fire Suppression	$52,000
23 Heating Ventilating and Air Conditioning	$100,000
26 Electrical	$141,000
33 Utilities	$554,000
Subtotal	**$1,280,000**

6.2 Operation & Maintenance Cost Estimation

The lifespan of the project is anticipated to be 75 years. Therefore, the operating and maintenance costs are estimated based on the approximate costs on a one-year span. Table 5 lists the detailed estimates of each component including contingency, GST and PST.

Table 5:Operation & Maintenance Cost Estimation

Item	Cost over 1-year	Cost over Lifecycle
Detention Pond	$ 9,375	$ 703,125
Building Structure	$ 5,625	$ 421,875
Total Operation & Maintenance Cost:		**$ 1,125,000**

7. Construction Schedule

A final schedule has been developed for the entire project based on a start day on May 1st, 2019 and a work schedule of 5 days a week. The detailed project schedule is provided in Appendix C Project Schedule Detail

A summary of the construction milestone date is as follow:

- Starting May 1st, 2019, site preparation on
- Foundation excavation is estimated to be started on May 10th, 2019 and be finished in 114 workdays. This phase is expected to be finished on Oct 16th, 2019.
- Building construction is expected to be started on Oct 17th, 2019 and to finish in 162 workdays on May 29th,2020.
- Detention pond construction is expected to be started at the same time with building construction and finished construction within 40 workdays on Dec 16th, 2019.
- Finishing is estimated to be started after roof construction on May 11th, 2020 and to be finished in 63 workdays. The expected commission date is August 6th, 2020.

The schedule was made under the assumption that all the phases can start on time.

8. Conclusion

The primary goal of this design is to present a potential solution to the erosion of the UBC CCM surrounding cliffs, flooding caused by large storms, and the quality of stormwater leaving campus. The main objective of this project is to scope and design a multi-use detention facility for UBC Center for Creative Medicine. The design decision is made by doing a geotechnical investigation and data collection.

The final design is to build a detention pond with partially submerged green building. The total storage capacity is approximately 20700 m^3 which are able to hold the entire 100-year storm event precipitation. The building is fully self-sufficient and always partially submerged under water.

Computer software such as SWMM is used to develop the stormwater management; Revit and SAP2000 are used to develop models and run simulations during the design process to generate a better image of the future implementation.

Furthermore, the total estimated span of this project construction is 15 months which is scheduled to start from May 1st, 2019 to August 6th, 2020. The life-cycle cost of the project is estimated to be $4.4 million.

Appendix A Construction Drawings

Appendix A Construction Drawings

Appendix A-1 Architectural Drawings

General Notes:

1. READ ALL ARCHITECTURAL/STRUCTURAL DRAWINGS IN CONJUNCTION WITH ALL CONTRAT DOCUMENTS, INCLUDING REFERENCED VENDOR DRAWINGS AND SPECIFICATIONS.

2. THE CONTRACTOR FOR ANY PORTION WORK SHALL VISIT THE SITE AND SHALL BE THOROUGHLY FAMILIAR WITH ALL THE PHICAL FEATURES THAT MAY AFFECT THE WORK IN ANY WAY.

3. FIELD MEASURE AND MAKE ADJUSTMENTS TO SUIT EXISTING CONDITIONS.

4. THE CONTRACTOR SHALL KEEP WORK SITES CLEAN AND FREE OF ALL CONSTRUCTION DEBRIS DURING THE PROCESS OF CONSTRUCTION AND LEAVE THE SITE CLEAN UPON COMPLETION OF WORK OR PORTIONS OF THE WORK.

5. CONSULTANT MUST APPROVE ALL DEVIATIONS FROM THE WORKING DRAWINGS. THE CONTRACTOR MUST KEEP AN ACCURATE RECORD OF ALL CHANGES FROM THE ORIGINAL INFORMATION SHOWN ON THE CONSTRUCTION DRAWINGS.

6. ALL CONSTRUCTION SHALL CONFIRM TO THE LATEST EDITION OF THE FOLLOWING:
   OCCUPATIONAL HEALTH AND SAFETY ACT;
   THE BC BUILDING CODE AND THE NATIONAL BUILDING CODE.

7. IF DISCREPANCIES EXIST BETWEEN THESE DRAWINGS. AND THE SPECIFICATIONS, CONTRAT ENGINEER FOR REVIEW AND APPROVAL PRIOR TO PROCEEDING.

8. FEATURES OF CONSTRUCTION NOT FULLY SHOWN ARE OF THE SAME CHARACTER AS THOSE NOTED FOR SIMILAR CONDITIONS.

9. DO NOT SCALE THESE DRAWINGS.

GENERAL MATERIALS:

1. DELIVER MATERIALS TO JOB SITE IN DRY CONDITION. KEEP MATERIALS DRY AND CLEAN UNTIL USE.

2. ALL CEMENT TO BE PORTLAND BLAST FURNACE SLAG CEMENT TO CAN-A326 BLENDED HYDRAULIC CEMENTS CONSISTING 75% NORMAL TYPE 10 PORTLAND CEMENT AND 25% CEMENTITIOUS HYDRAULIC SLAG.

3. ALL REINFORCING STEEL TO BE GRADE 400 DEFORMED BARS TO CAN/CSA G30.18.

4. DISPOSAL OF ALL EXCAVATED MATERIAL SHALL BE OFF-SITE OTHER THAN APPROVED BACKFILL.

ABBREVIATIONS:

Col A ---COLUMN A

Ba ---BEAM A

Fa ---FOOTING A

W ---WINDOW

D ---DOOR

FOUNDATIONS:

1. BEARING SURFACES MUST BE APPROVED BY THE SOILS ENGINEER IMMEDIATELY PRIOR TO CONSTRUCTION.

2. REFER TO FUNDATION SAMPLE CALCULATIONS FOR OTHER SPECIFIC DESIGN REQUIREMENTSFOR FOOTING, SOIL SLOPES, FROST PROTECTION, MINIMUM COVER, ETC.

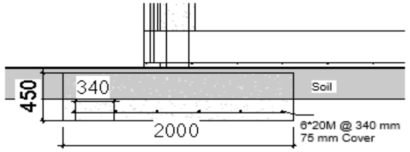
3. UNLESS OTHERWISE SHOWN, CENTER FOOTINGS BELOW COLUMNS AND WALLS.

4. FOOTING ELEVATIONS, IF SHOWN, ARE FOR BIDDING PURPOSES ONLY, ARE NOT FINAL, AND MAY VARY ACCORDING TO SITE CONDITIONS OR AS REQUIRED BY SERVICES. ALL FOOTINGS MUST BE TAKEN TO A BEARING LAYER APPROVED BY THE SOIL ENGINEER.

5. BEARING SURFACES MUST BE PROTECTED FROM FREEZING BEFORE AND AFTER FOOTINGS ARE POURED.

6. CONCRETE PLACED UNDER WATER SHALL CONFIRM TO CAN/CSA-A23.1.

7. FOOTINGS CAST DIRECTLY INTO EXCAVATIONS (WITHOUT SIDE FORMS) SHALL NOT BE LARGER THAN SHOWN BELOW:



CONCRETE:

1. ALL CONCRETE SHALL CONFIRM TO CSA STANDARD A23.A (LATEST EDITION) HAVING A MINIMUM COMPRESSIVE STRENGTH AS SHOWN BELOW (UNLESS NOTED OTHERWISE).

2. ALL CAST-IN-PLACE CONCRETE SHALL CONFIRM TO THE LATEST EDITION OF CSA STANDARD A23.1, 'CONCRETE MATERIALS AND METHODS OF CONCRETE CONSTRUCTION'.

3. SUBMIT CONCRETE MIX DESIGN TO ENGINEER PRIOR TO PRODUCTION. NO WATER SHALL BE ADDED TO THE CONCRETE AT THE SITE.

4. THE OWNER WILL EMPLOY A TESTING COMPANY TO CONDUCT STRENGTH, SLUMP, MATERIAL AND AIR ENTRAINED TESTS ONCE FOR EVERY DAY CONCRETE IS POURED. STRENGTH TEST SHALL INCLUDE THREE CYLINDERS, ONE TESTED AT 7 DAYS AND TWO TESTED AT 28 DAYS IN ACCORDANCE WITH CAN3-A23.2. SLUMP AND AIR CONTENT TESTS SHALL CONSIST OF ONE SAMPLE EACH IN ACCORDANCE WITH CAN3-23.1 AND CAN3-A23.2.

5. ALL CONCRETE THAT WILL BE EXPOSED TO WEATHER SHAA HAVE A 5 TO 7% AIR ENTRAINMENT AT TIME OF PLACING.

6. BULL FLOAT CONCRETE SURFACES AND PROVIDE A LIGHT THOWEL FINISH TO PRODUCE A SMOOTH NON-SLIP SURFACE FREE FROM RIDGES, VOIDS AND MACHINE MARKS. EXTERIOR CONCRETE WALKING SURFACES SHALL HAVE A LIGHT BROOM FINISH TO CONCRETE A NON-SLIP SURFACE. PROVIDE ROUGH SURFACE AT COLD JOINTS.

7. KEEP CONTINUOUSLY MOIST ALL EXPOSED NON-FORMED SURFACES FOR A MINIMUM OF SEVEN CONSECUTIVE DAYS AFTER PLACEMENT OF CONCRETE UNLESS NOTED OTHEREWISE.

8. ALL EXPOSED CONCRETE EDGES ARE TO HAVE THREE-QUARTER (3/4") CHAMBER UNLESS NOTED OTHERWISE.

9. WHERE NEW CONCRETE IS TO BE PLACED AGAIST EXISTING CONCRETE, EXISTING CONCRETE MUST BE THOROUGHLY CLEANED TO REMOVE OIL, GREASE AND DIRTAND BE SURFACE 'CHIPPED' A MINIMUM OF ONE-HALF (1/2") INCH PRIOR TO PLACEMENT OF NEW CONCRETE UNLESS NOTED OTHERWISE ON DRAWINGS. APPLICATION OF AN APPROVED BONDING AGENT SHALL BE APPLIED AT ALL INTERFACES BETWEEN NEW AND OLD CONCRETE.

10. PROVIDE HOT OR COLD WEATHER PROTECTION WHEN REQUIRED AS SPECIFIED IN CAN3-A23.1.

11. VIBRATE ALL CONCRETE. ENSURE ALL CONCRETE IS DENSE, FREE OF HONEY COMBINING, AND THAT NO SEGREGATION OCCURS.

12. ENSURE ALL REBAR IS CLEAN SECURELY HELD IN CORRECT LOCATION DURING PLACING.

CONCRETE PROPERTIES

ELEMENT	COMPRESSIVE STRENGTH (MPa) 28 DAYS U.N.O.	EXPOSURE CLASS
FOOTINGS	30 MPa	N
SLAB-ON-GRADE (INTERIOR)	30 MPa	N
SLAB-ON-GRADE (EXTERIOR)	30 MPa	C-2
RETATINING/ FOUDATION WALLS	30 MPa	F-2
GRADE BEAMS	30 MPa	N

REINFORCING STEEL:

1. LAP ALL REINFORCING AS PER RSIO MANUAL, CLASS "B" TENSION LAP.

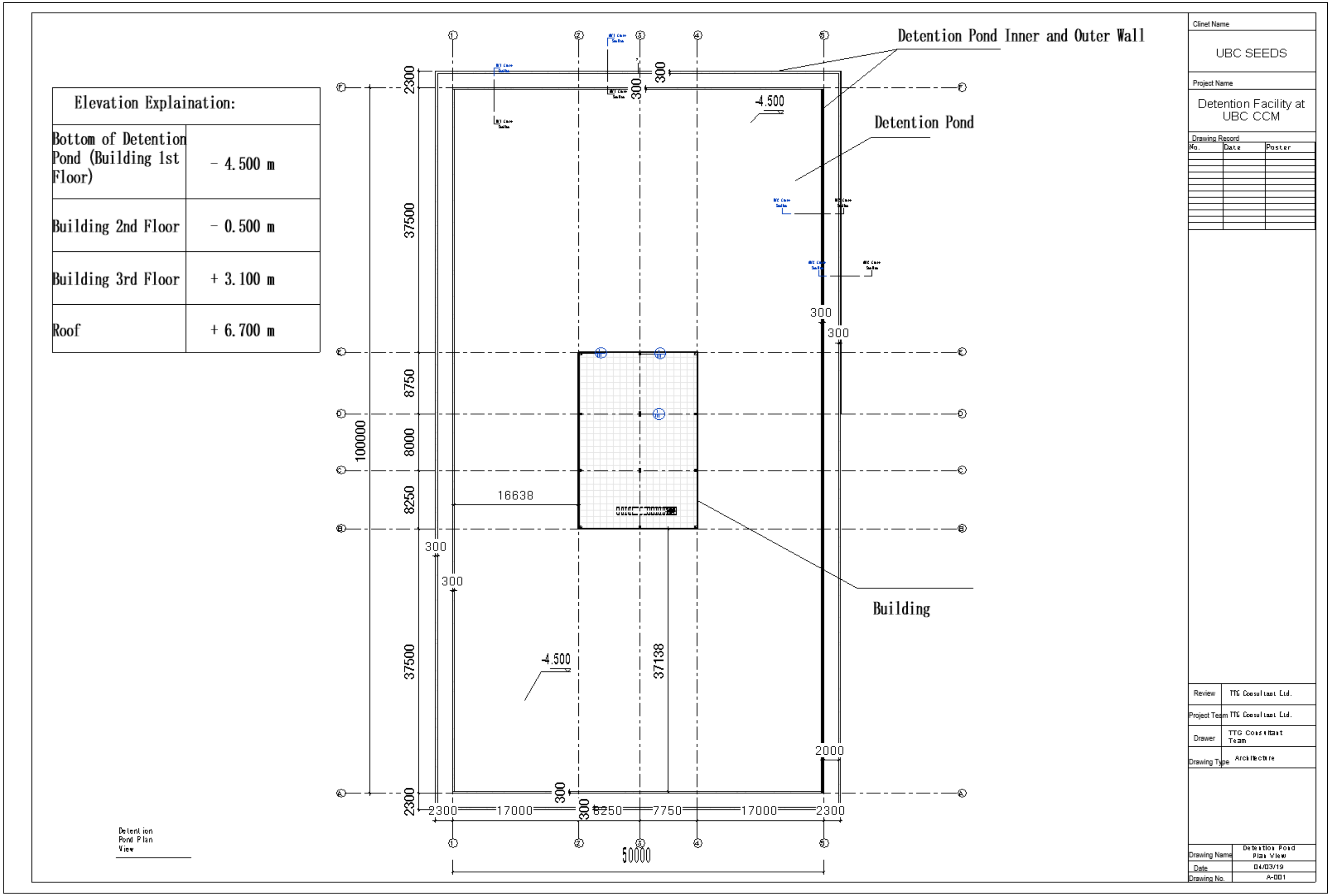
2. INTERSECTING REBAR SHALL BE TIED TOGETHER USING NO.16 U.S. WIRE GAUGE OR HEAVIER ANNEALED WIRE OR AN APPROVED PATENTED TYING SYSTEM.

Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

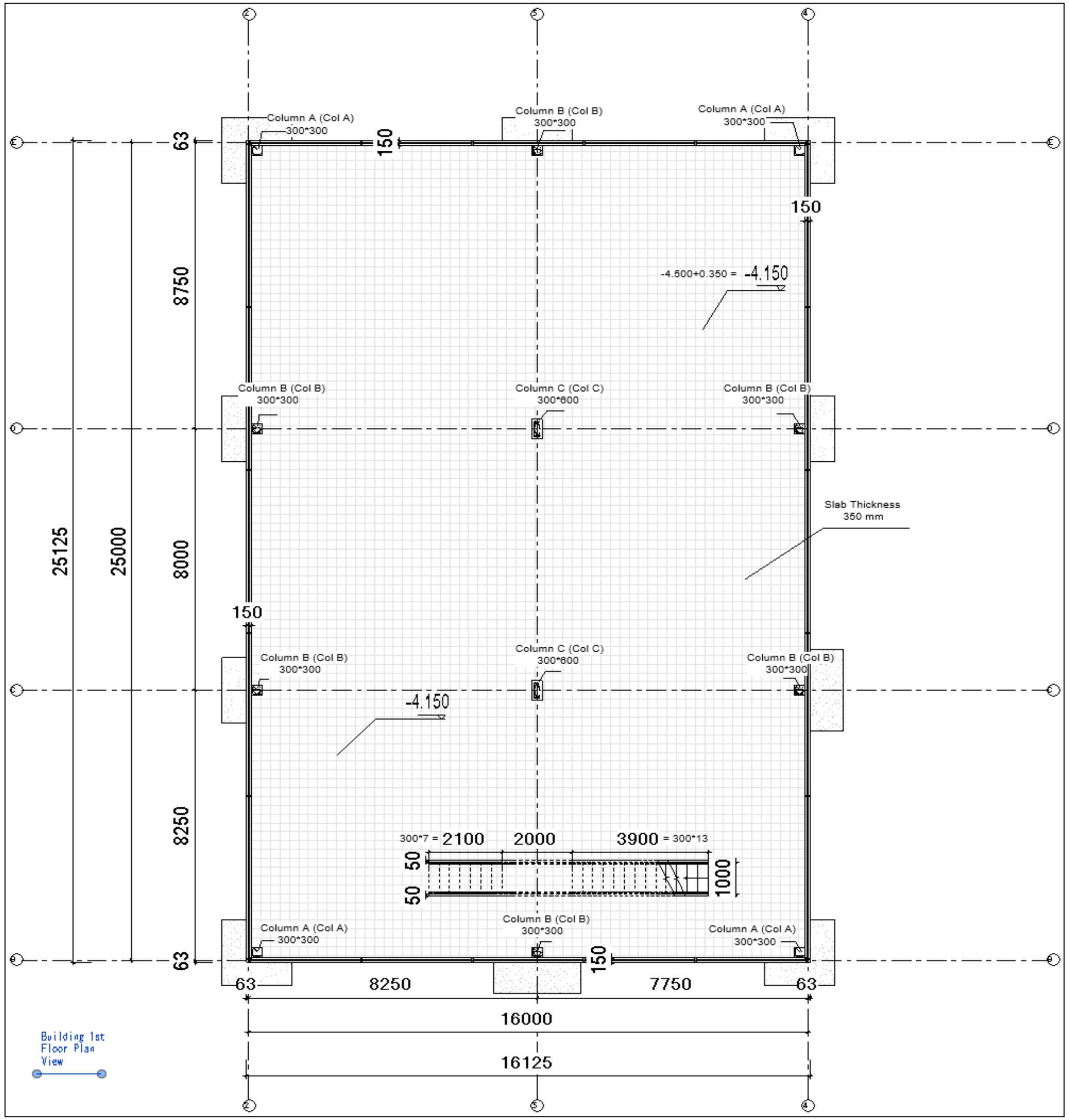
Drawing Record

No.	Date	Poster

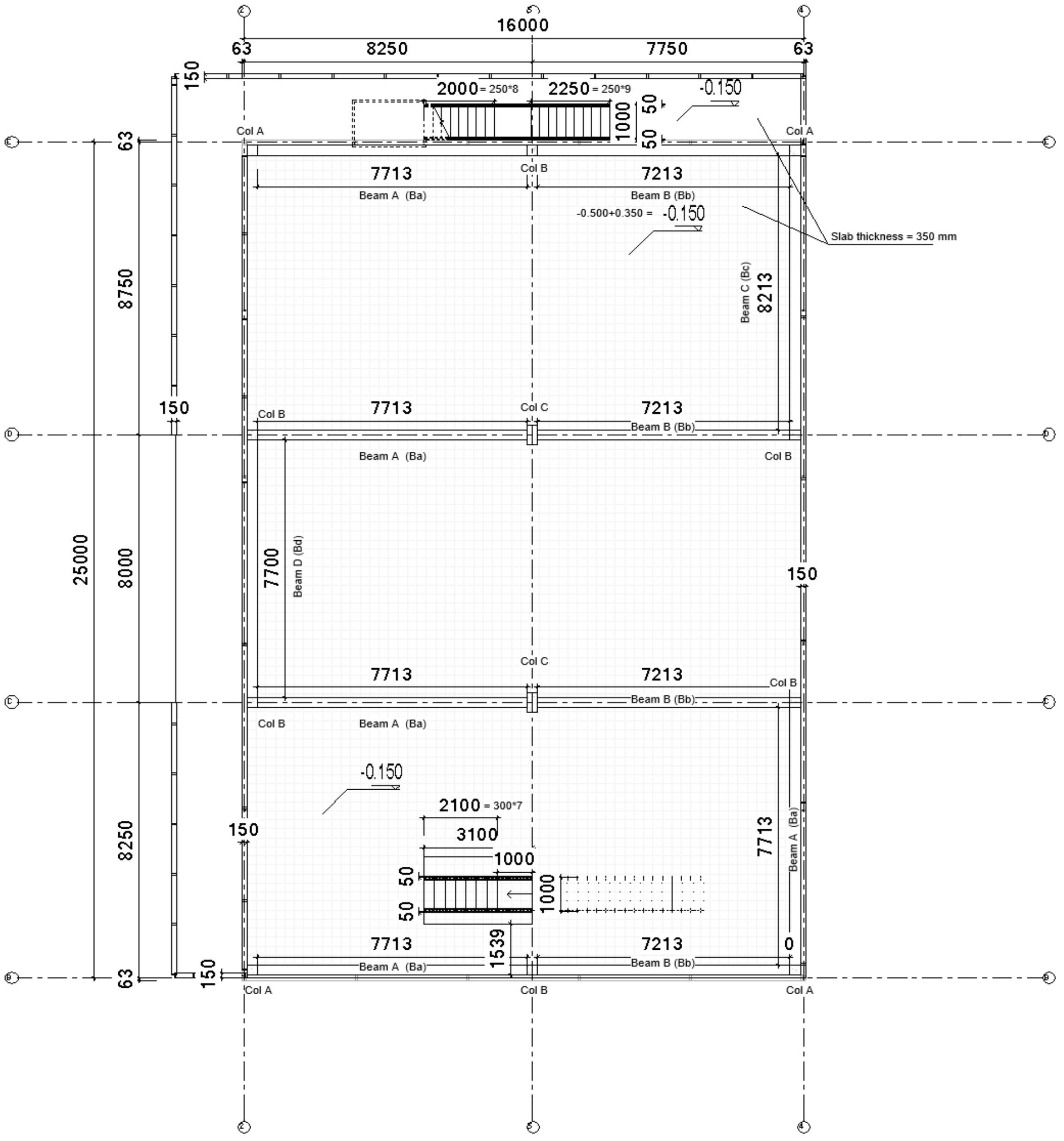
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	General Requirement
Date	04/03/19
Drawing No.	000



Elevation Explaination:	
Bottom of Detention Pond (Building 1st Floor)	－ 4.500 m
Building 2nd Floor	－ 0.500 m
Building 3rd Floor	＋ 3.100 m
Roof	＋ 6.700 m



Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM
Drawing Record	
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building 1st Floor
Date	04/05/19
Drawing No.	A-002



Clinet Name

UBC SEEDS

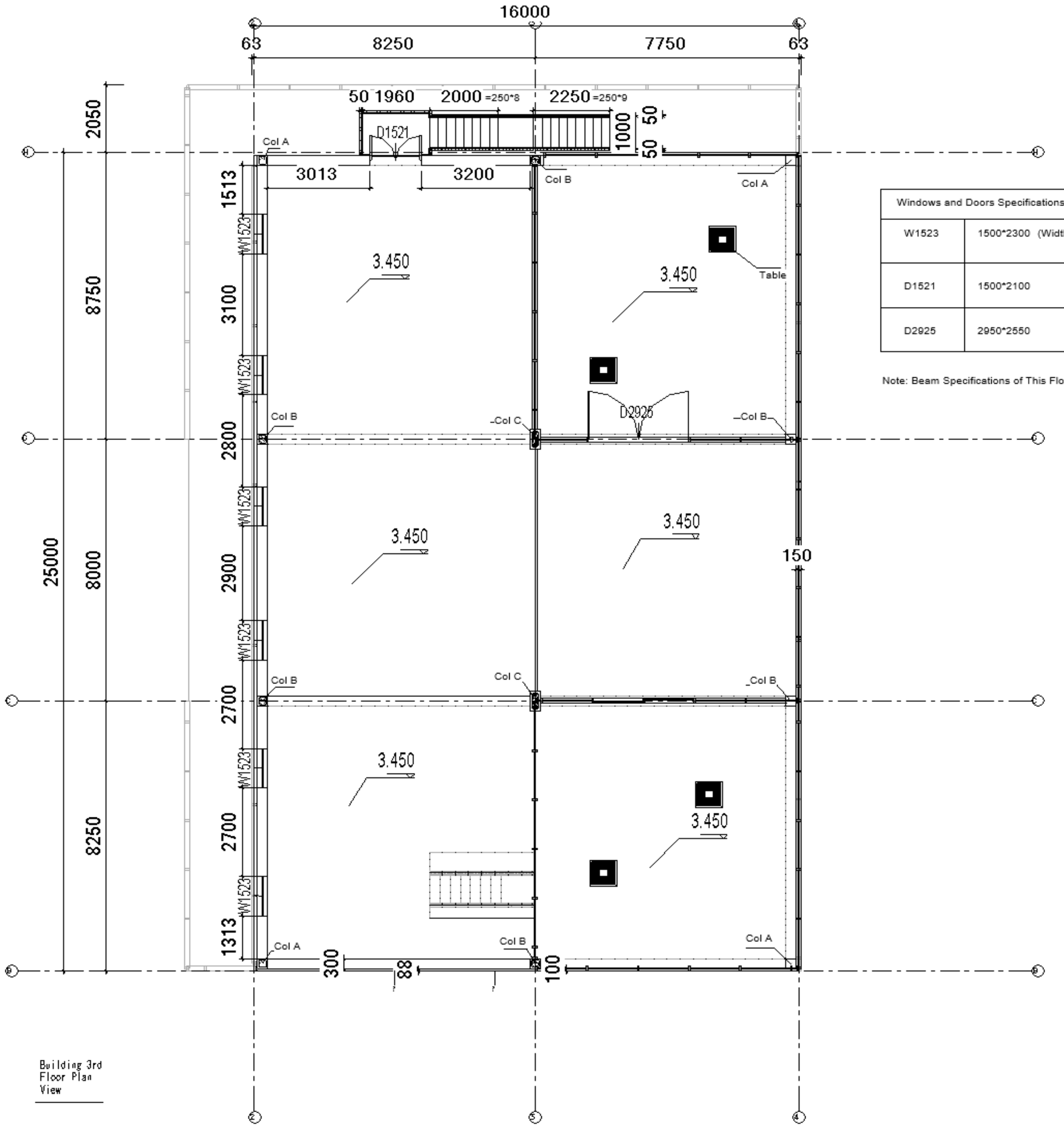
Project Name

Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building 2nd Floor
Date	04/06/19
Drawing No.	A-003



Building 3rd Floor Plan View

Windows and Doors Specifications		
W1523	1500*2300 (Width*Height)	Bottom height:608 mm Top hieght:2708 mm
D1521	1500*2100	Bottom height:0 mm Top hieght:2100 mm
D2925	2950*2550	Bottom height:0 mm Top hieght:2550 mm

Note: Beam Specifications of This Floor will be Shown in the Structure Drawing.

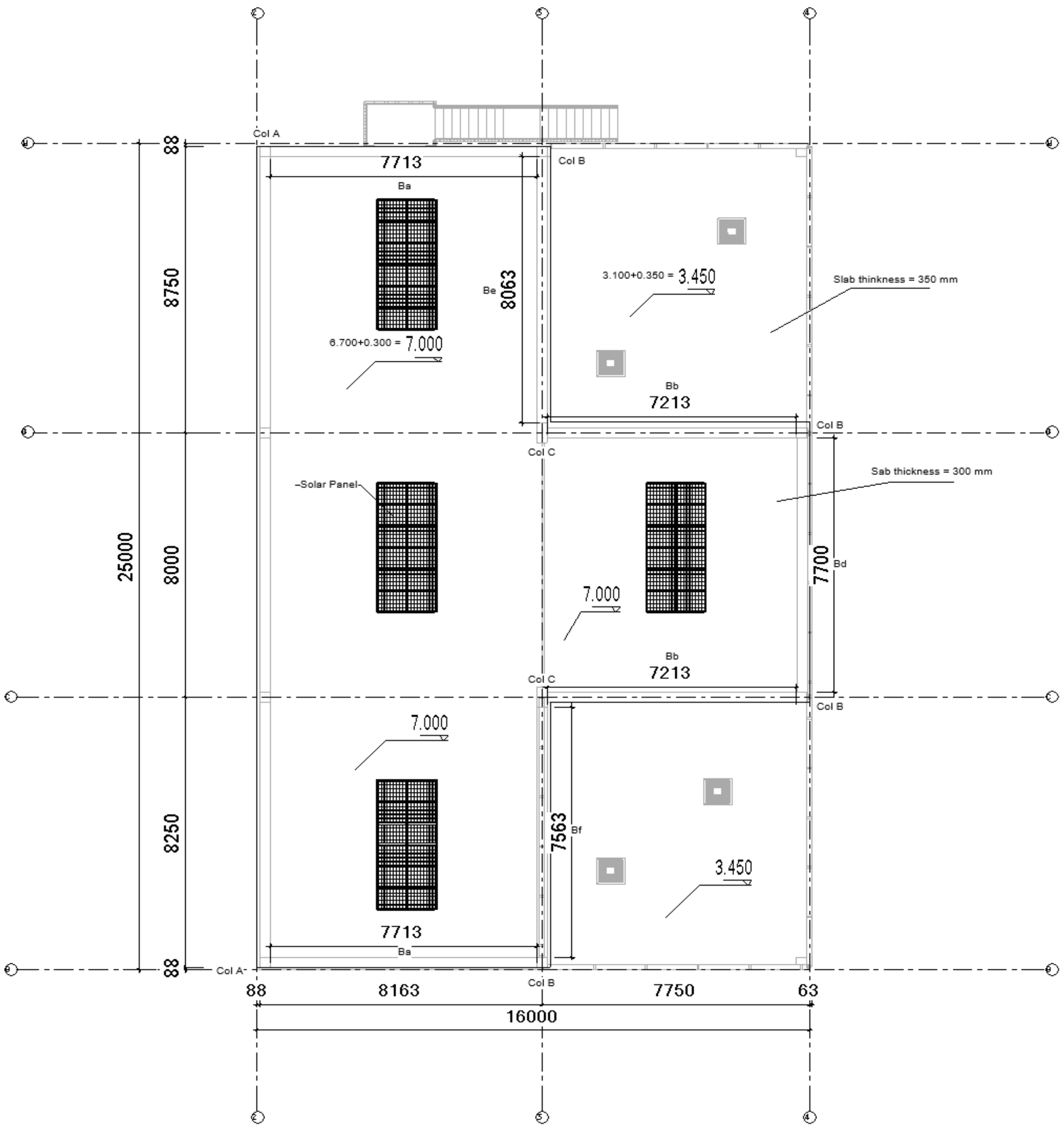
Clinet Name: UBC SEEDS

Project Name: Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building 3rd Floor
Date	04/06/19
Drawing No.	A-004



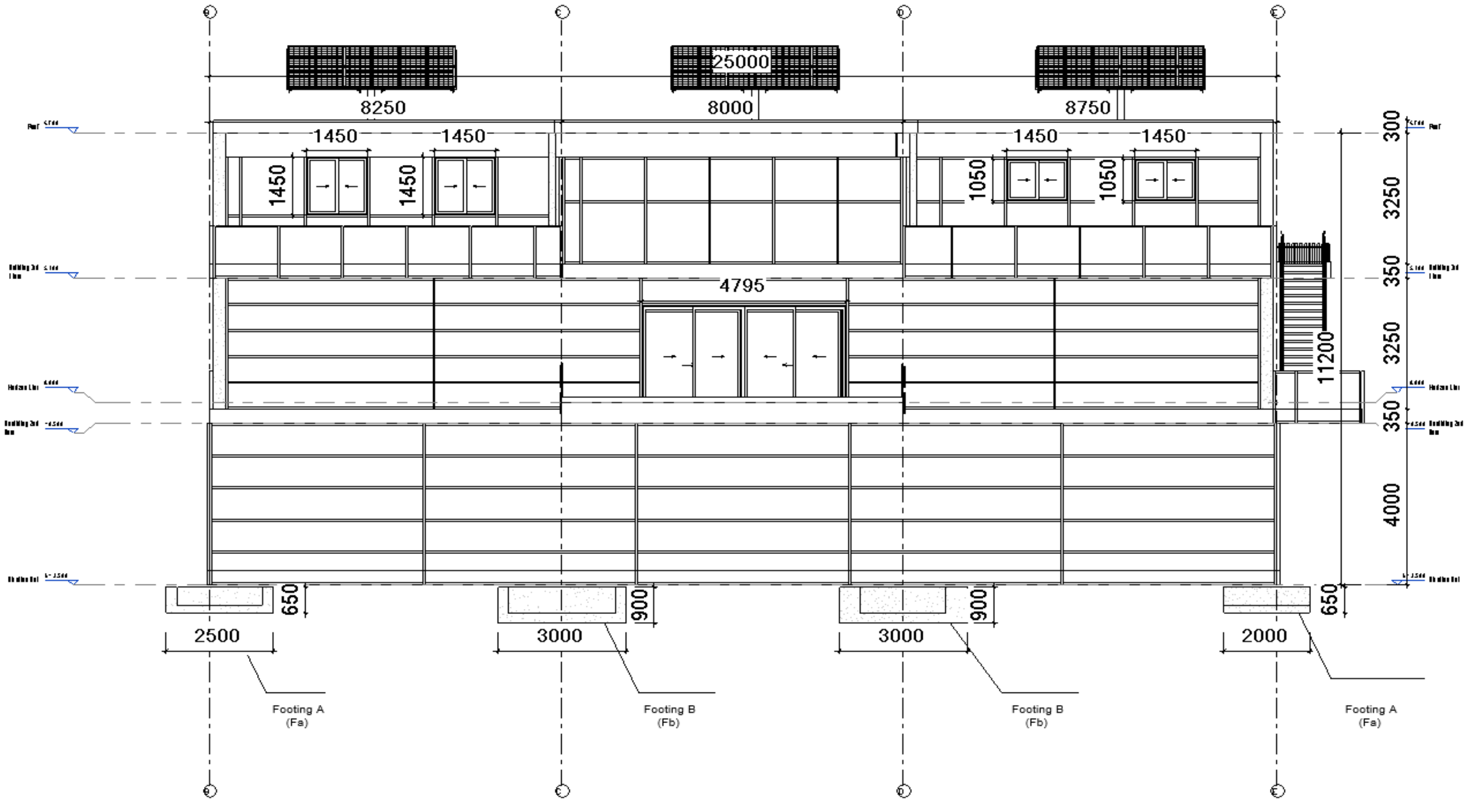
Roof Plan View

Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Roof Plan View
Date	04/06/19
Drawing No.	A-005

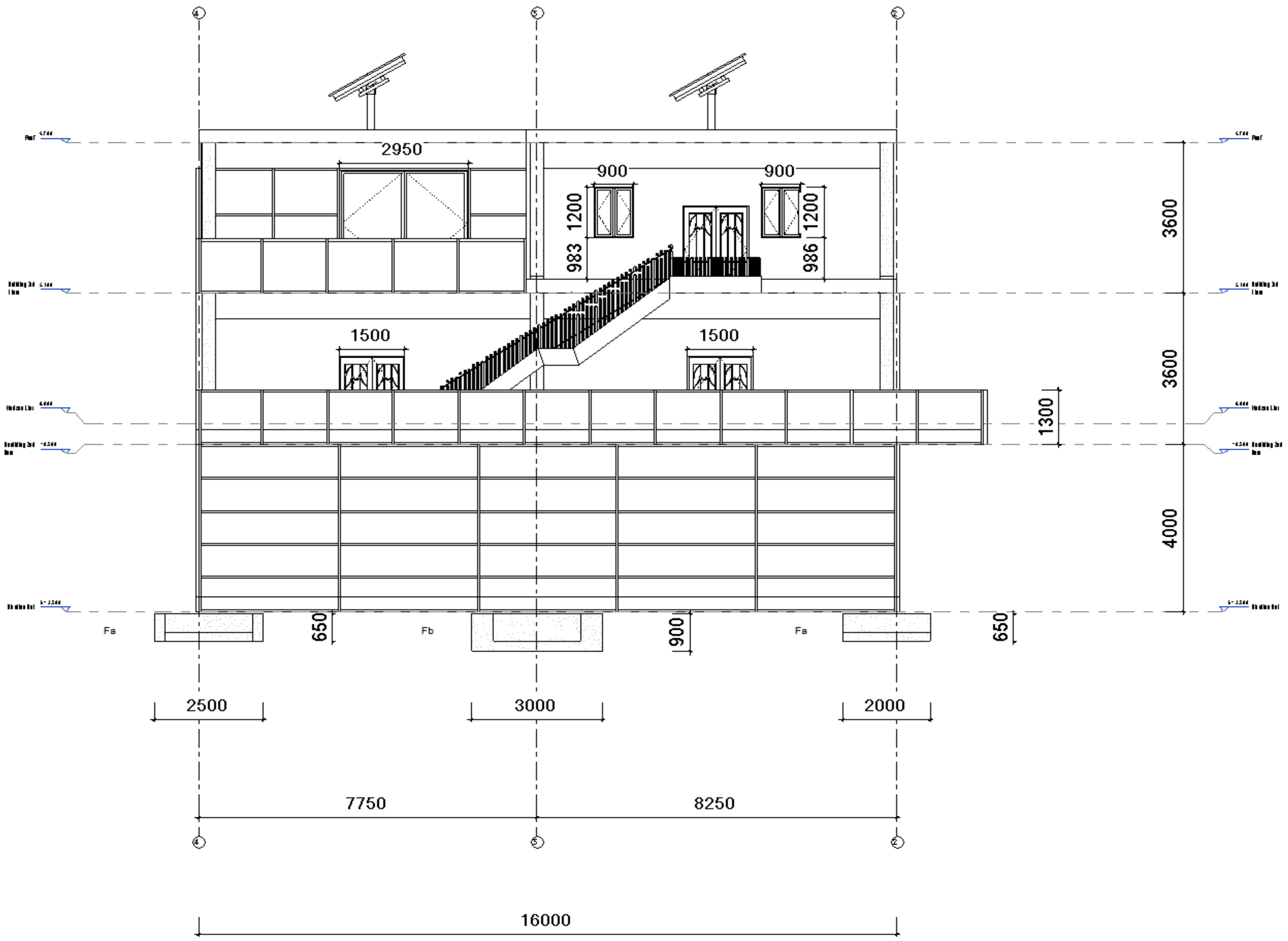


Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building Elevation View (East Side)
Date	04/06/19
Drawing No.	A-006

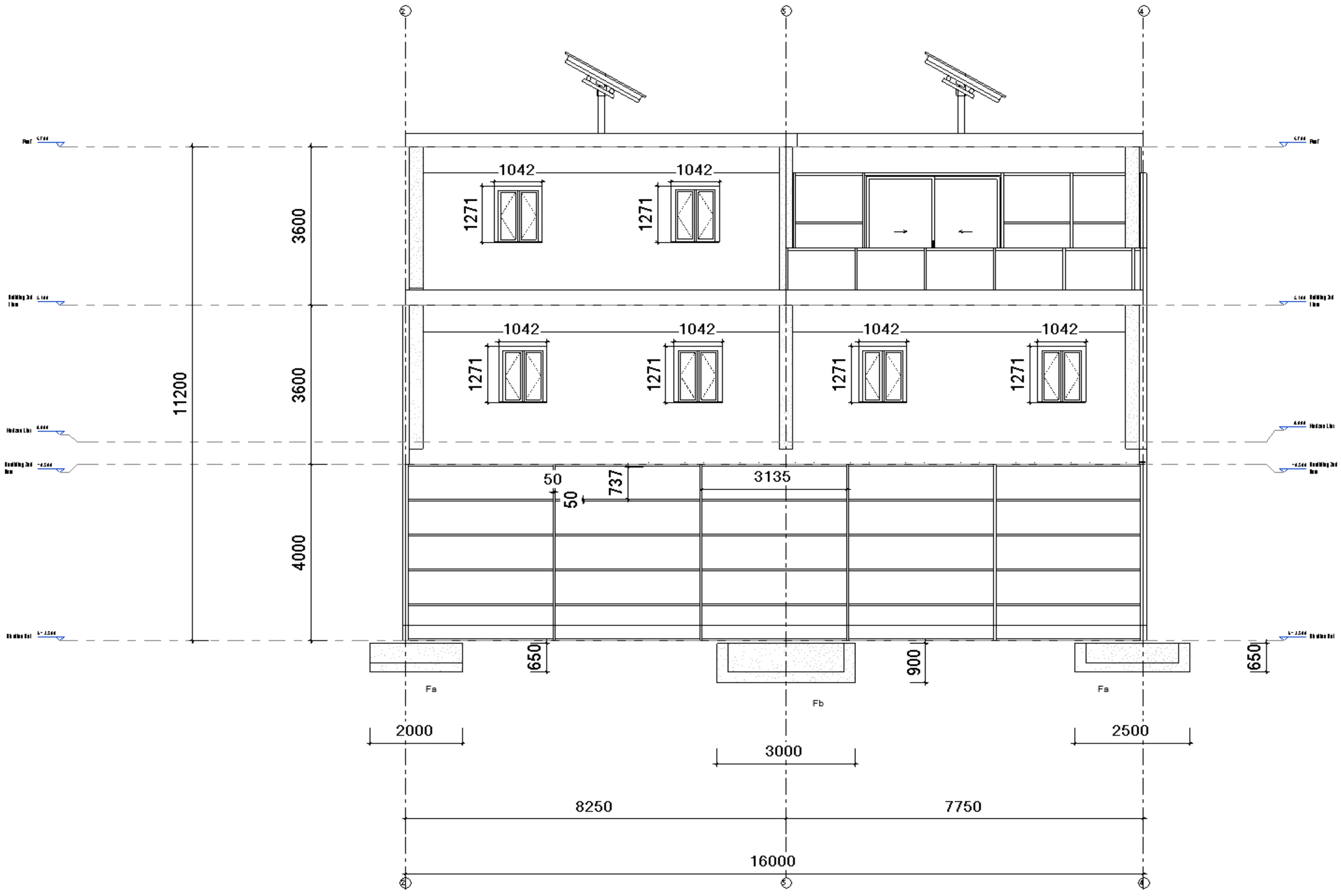


Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

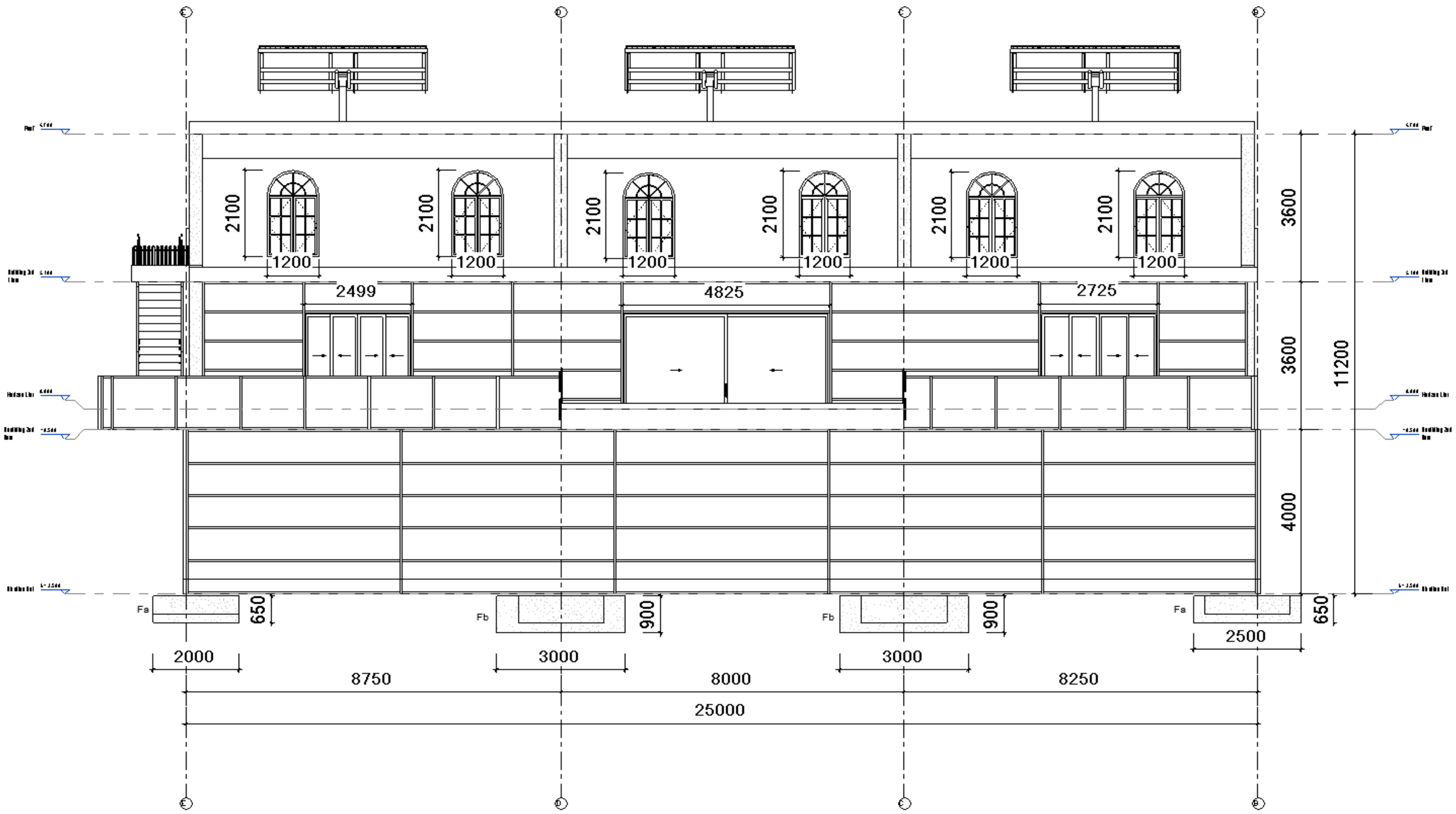
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building Elevation View (North Side)
Date	04/06/19
Drawing No.	A-007



Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building Elevation View (South Side)
Date	04/06/19
Drawing No.	A-008

Drawing Record

No.	Date	Poster



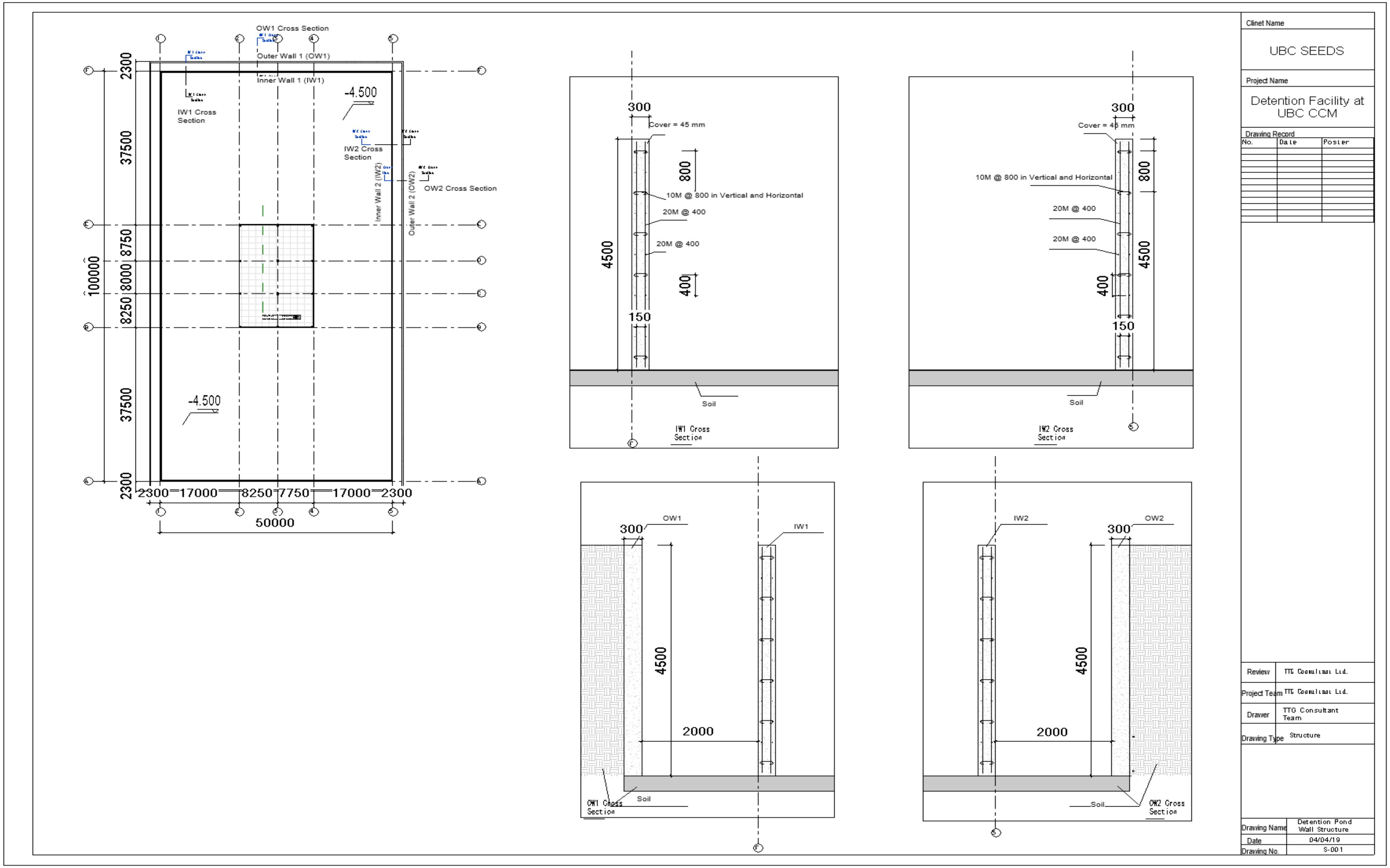
Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

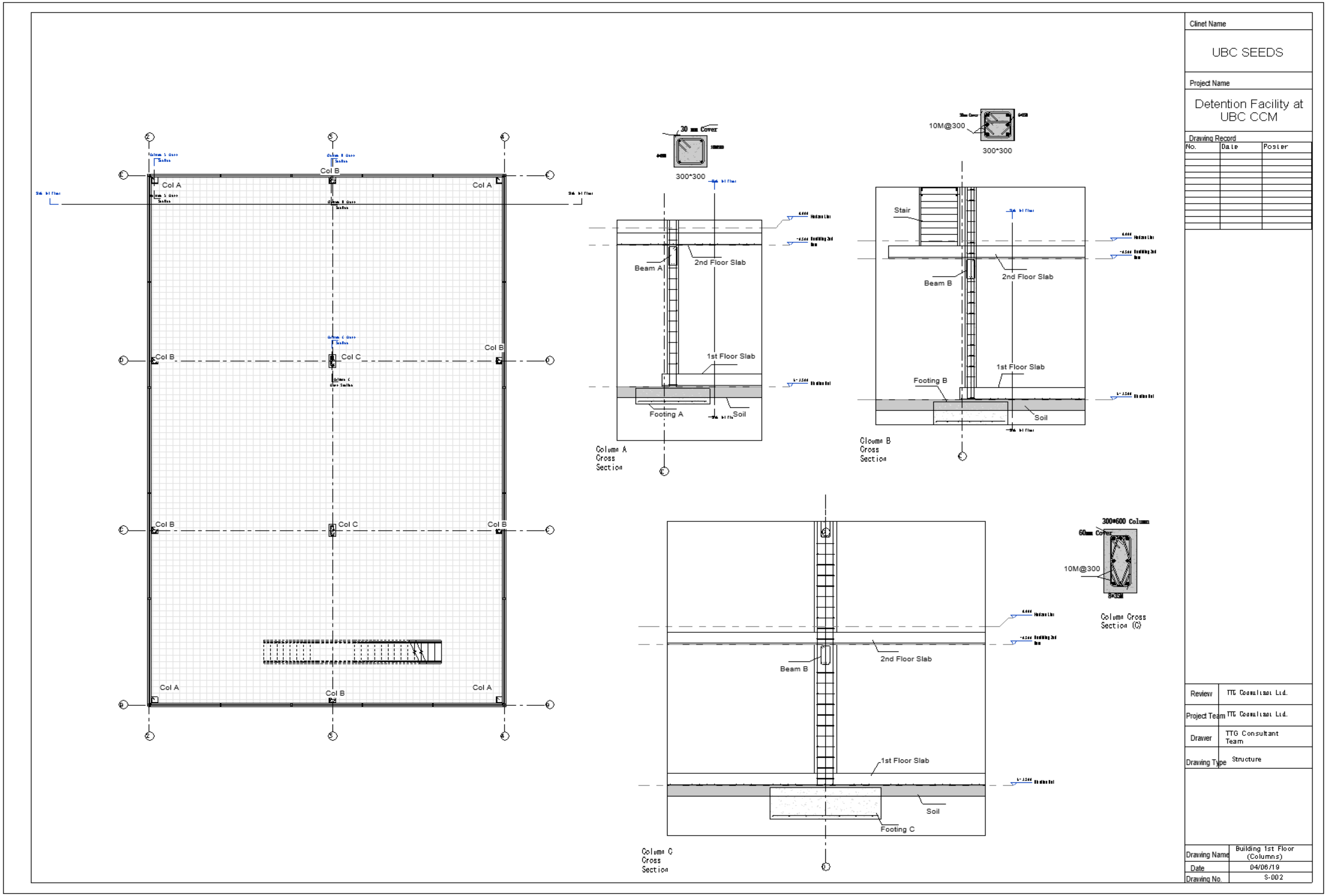
Drawing Record

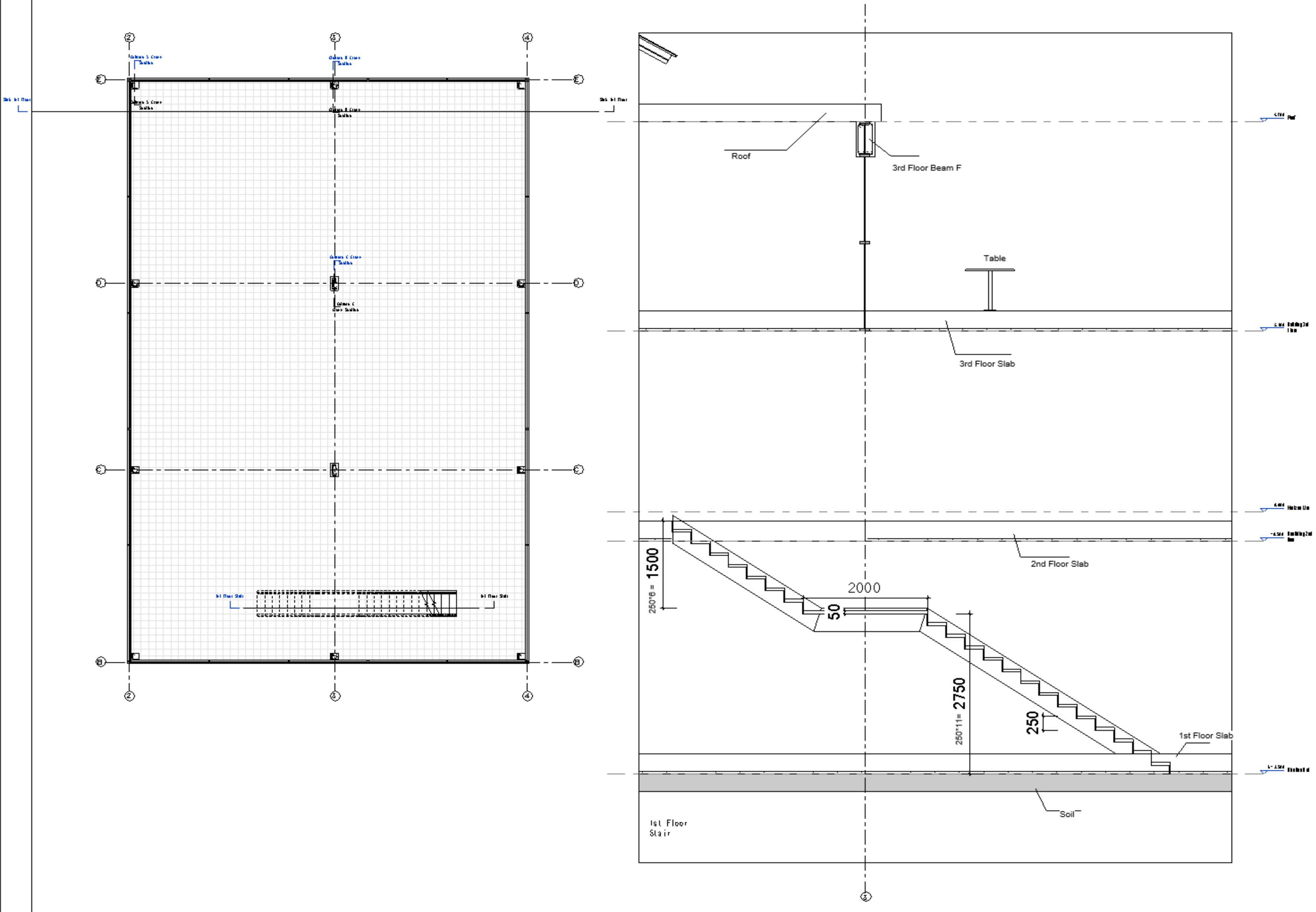
No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Architecture
Drawing Name	Building Elevation View (West Side)
Date	04/06/19
Drawing No.	A-009

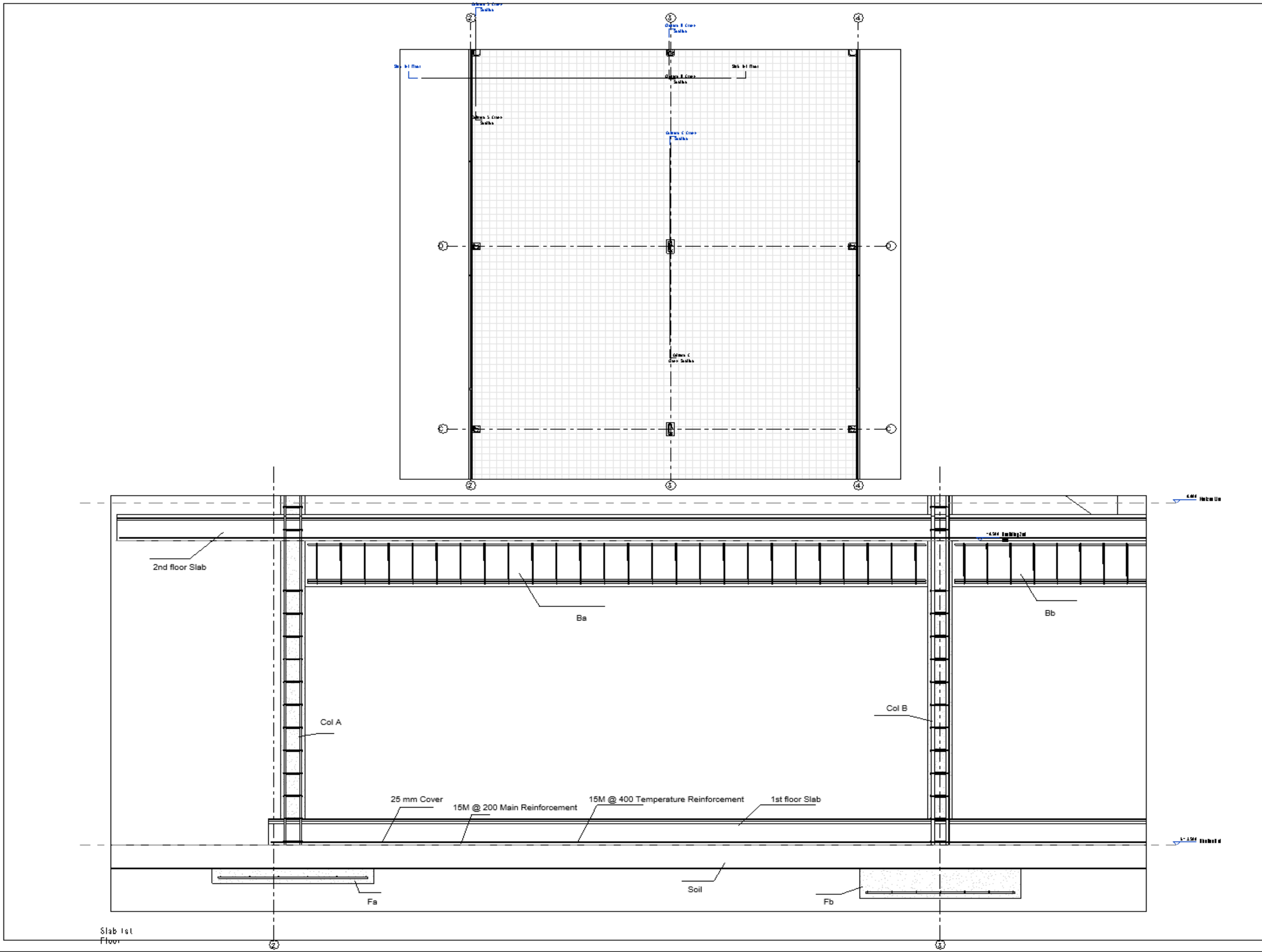
Appendix A-2 Structural Drawings




Col A
Col B
Col C
Beam A
Beam B
2nd Floor Slab
1st Floor Slab
Footing A
Footing B
Footing C
Soil
Stair
300*300
30 mm Cover
10M@300
300*600 Column
60mm Cover
Column A Cross Section
Cloumn B Cross Section
Column C Cross Section
Column Cross Section (C)
Clinet Name
UBC SEEDS
Project Name
Detention Facility at UBC CCM
Drawing Record
No.
Date
Poster
Review
TTG Consultant Ltd.
Project Team
TTG Consultant Ltd.
Drawer
TTG Consultant Team
Drawing Type
Structure
Drawing Name
Building 1st Floor (Columns)
Date
04/06/19
Drawing No.
S-002



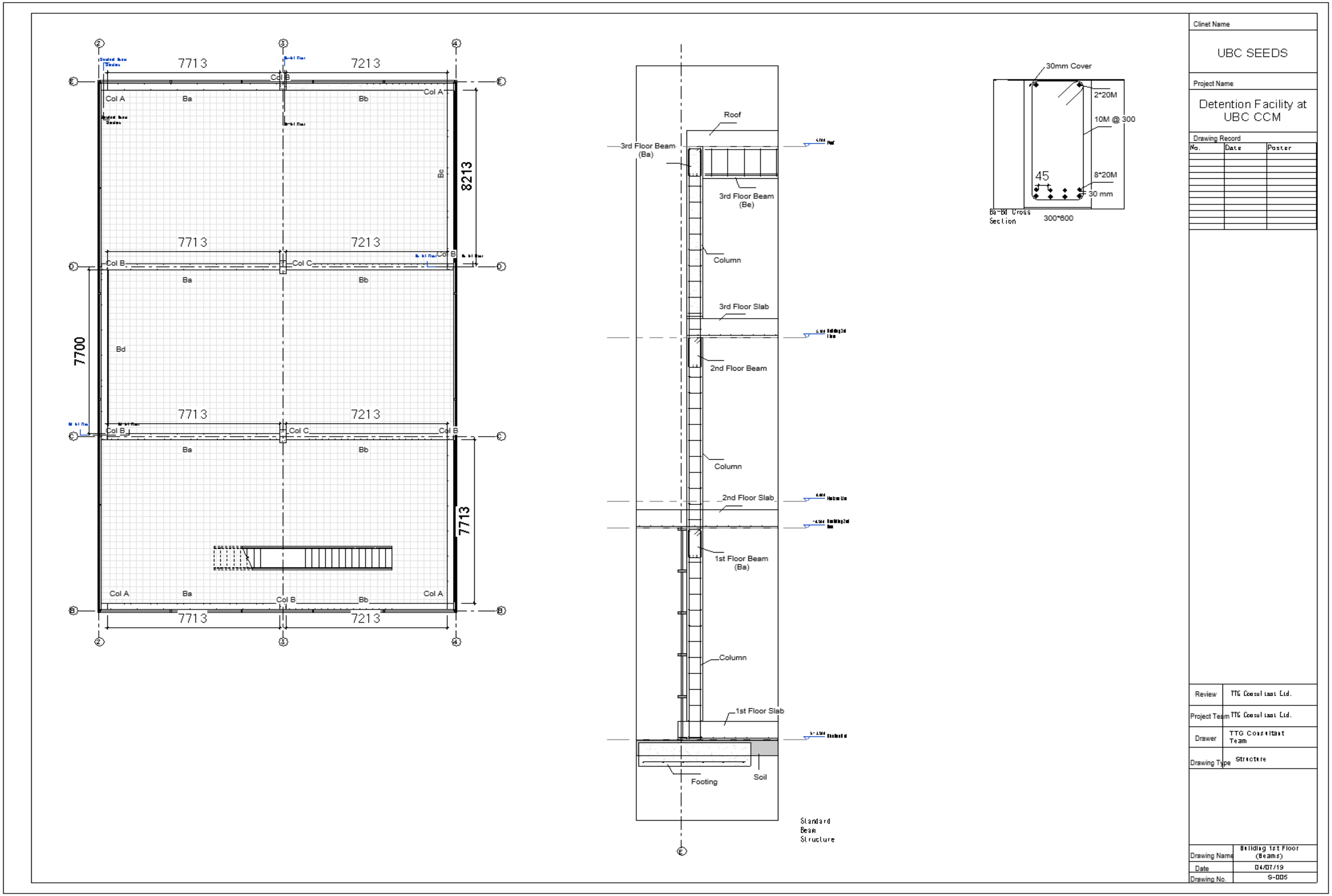
Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM
Drawing Record	No. / Date / Poster
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 1st Floor (Stairs)
Date	04/06/19
Drawing No.	S-003

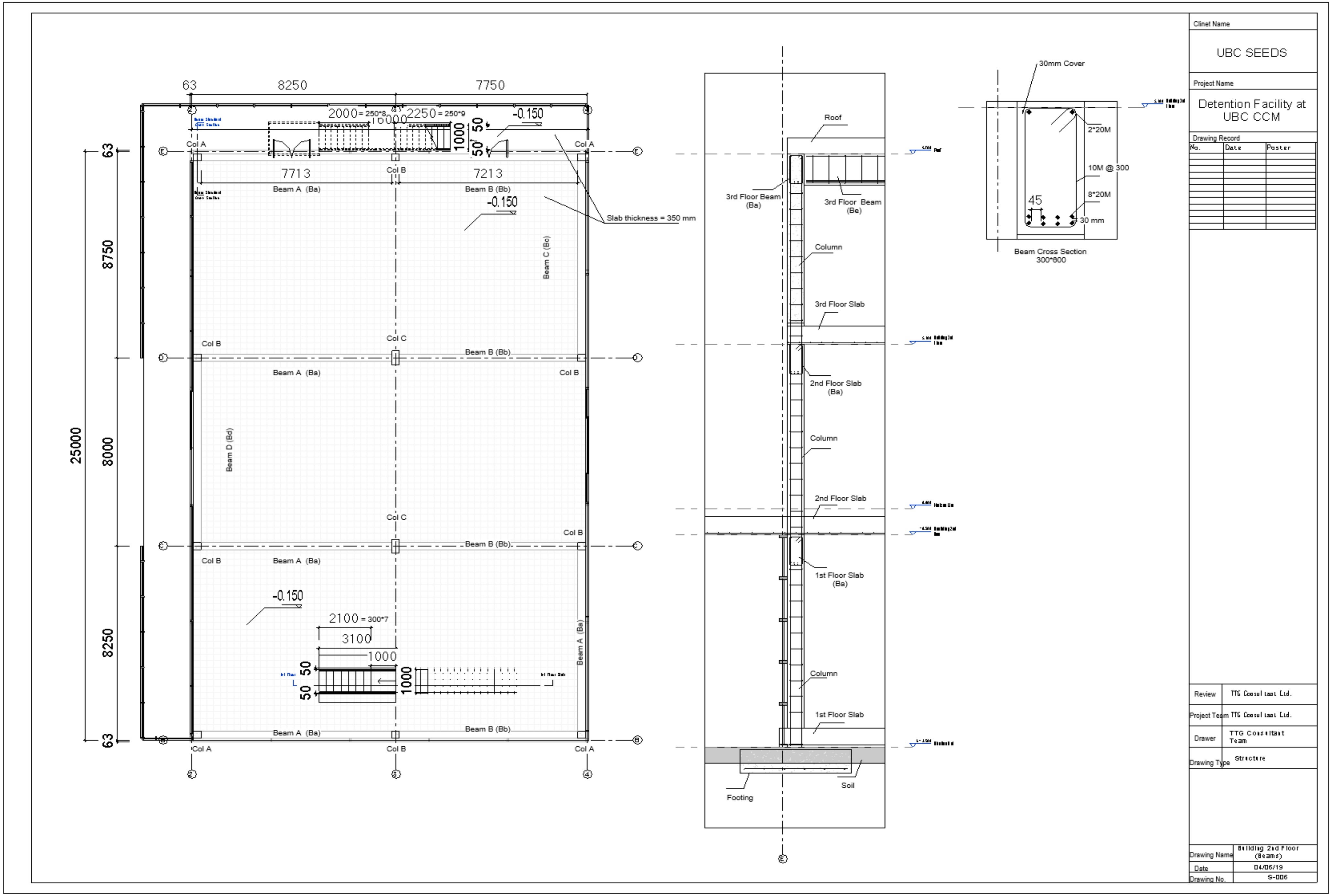


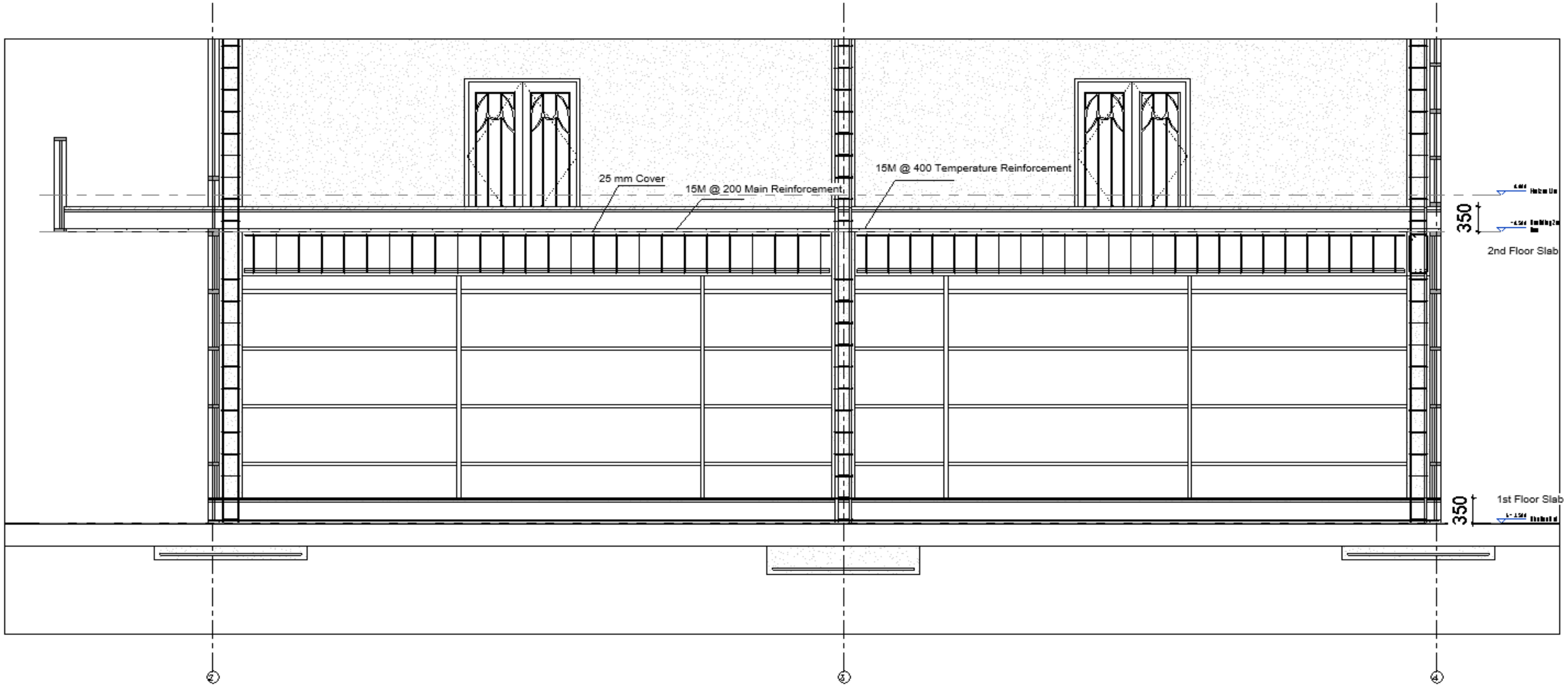
Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 1st Floor (Slab)
Date	04/06/19
Drawing No.	S-004

Drawing Record

No.	Date	Poster


7713
7213
Col A
Col B
Col C
Ba
Bb
Bc
Bd
8213
7700
7713
Roof
3rd Floor Beam (Ba)
3rd Floor Beam (Be)
Column
3rd Floor Slab
2nd Floor Beam
2nd Floor Slab
1st Floor Beam (Ba)
1st Floor Slab
Footing
Soil
Standard Beam Structure
30mm Cover
2*20M
10M @ 300
45
8*20M
30 mm
Ba-Bd Cross Section
300*600
Clinet Name
UBC SEEDS
Project Name
Detention Facility at UBC CCM
Drawing Record
No.
Date
Poster
Review
TTG Consultant Ltd.
Project Team
TTG Consultant Ltd.
Drawer
TTG Consultant Team
Drawing Type
Structure
Drawing Name
Building 1st Floor (Beams)
Date
04/07/19
Drawing No.
S-005


63
8250
7750
2000 = 250*8
2250 = 250*9
16000
-0.150
1000
50
Col A
Col B
Col C
7713
7213
Beam A (Ba)
Beam B (Bb)
Beam C (Bc)
Beam D (Bd)
Slab thickness = 350 mm
25000
8750
8000
8250
2100 = 300*7
3100
Roof
3rd Floor Beam (Ba)
3rd Floor Beam (Be)
Column
3rd Floor Slab
2nd Floor Slab (Ba)
2nd Floor Slab
1st Floor Slab (Ba)
1st Floor Slab
Footing
Soil
30mm Cover
2*20M
10M @ 300
8*20M
45
30 mm
Beam Cross Section 300*600
Clinet Name
UBC SEEDS
Project Name
Detention Facility at UBC CCM
Drawing Record
No.
Date
Poster
Review
TTG Consultant Ltd.
Project Team
TTG Consultant Ltd.
Drawer
TTG Consultant Team
Drawing Type
Structure
Drawing Name
Building 2nd Floor (Beams)
Date
04/06/19
Drawing No.
S-006

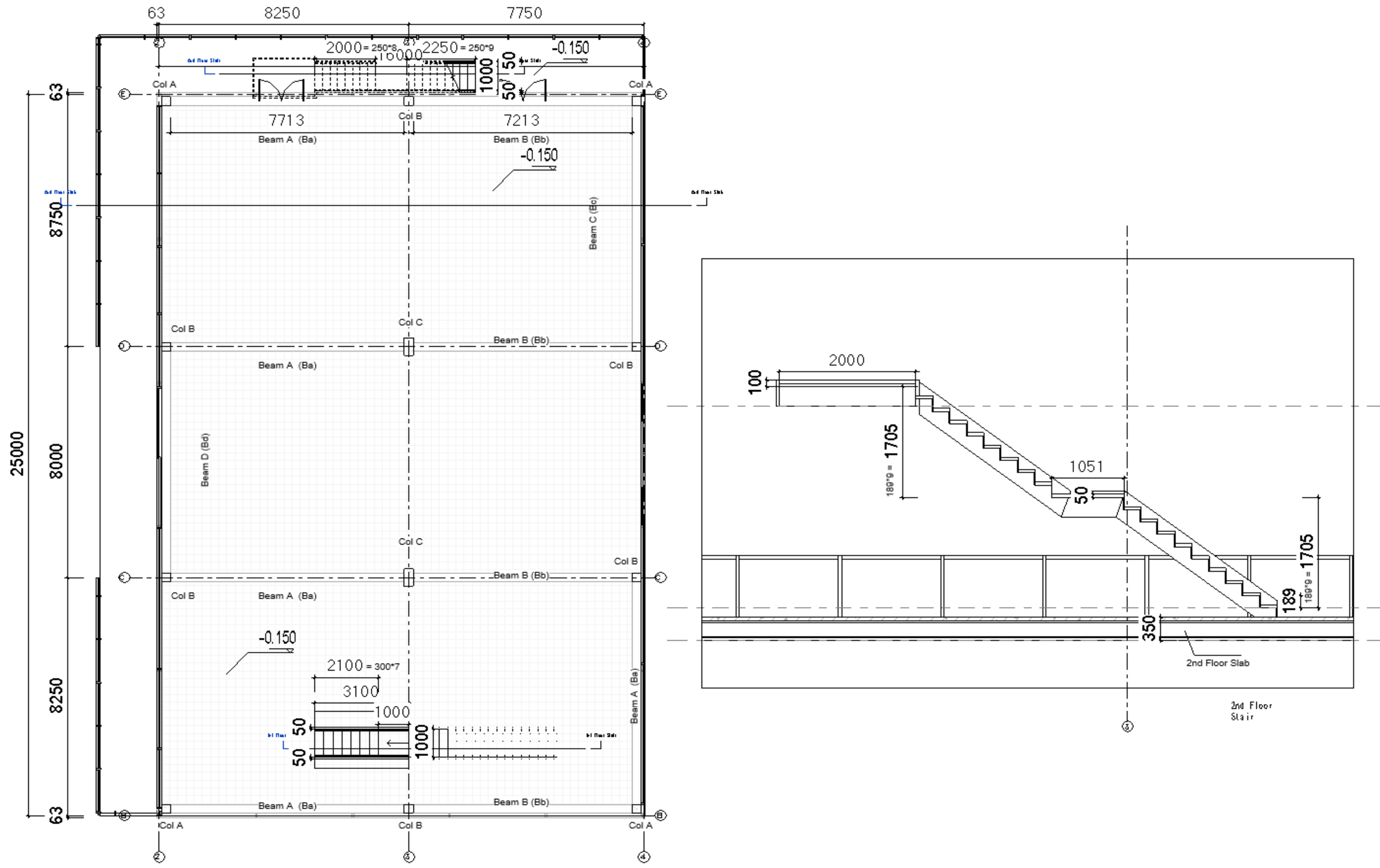


Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

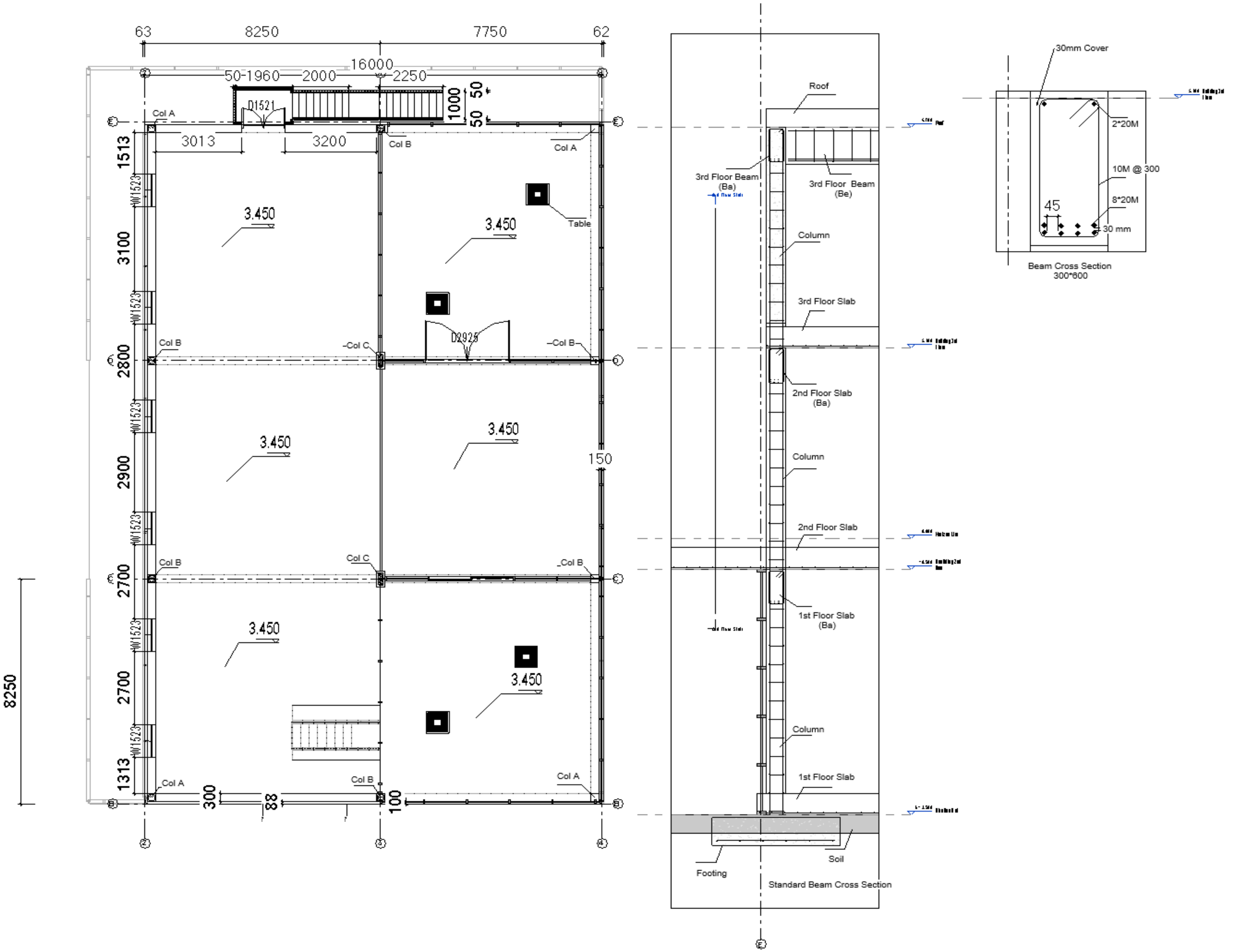
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 2nd Floor (Slab)
Date	04/06/19
Drawing No.	S-007



Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 2nd Floor (Stairs)
Date	04/06/19
Drawing No.	S-008

Drawing Record

No.	Date	Poster

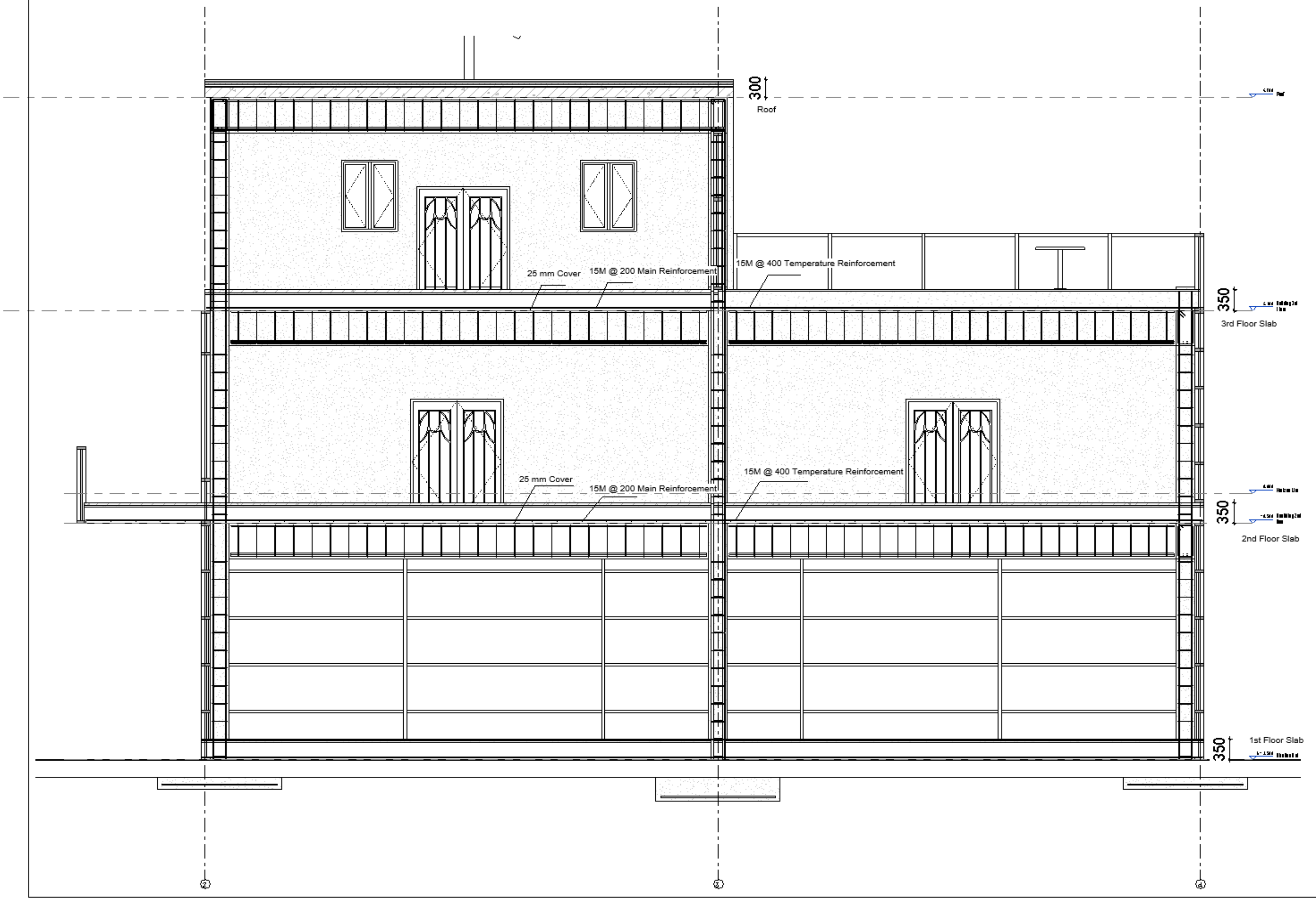


Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 3rd Floor (Beams)
Date	04/06/19
Drawing No.	S-009

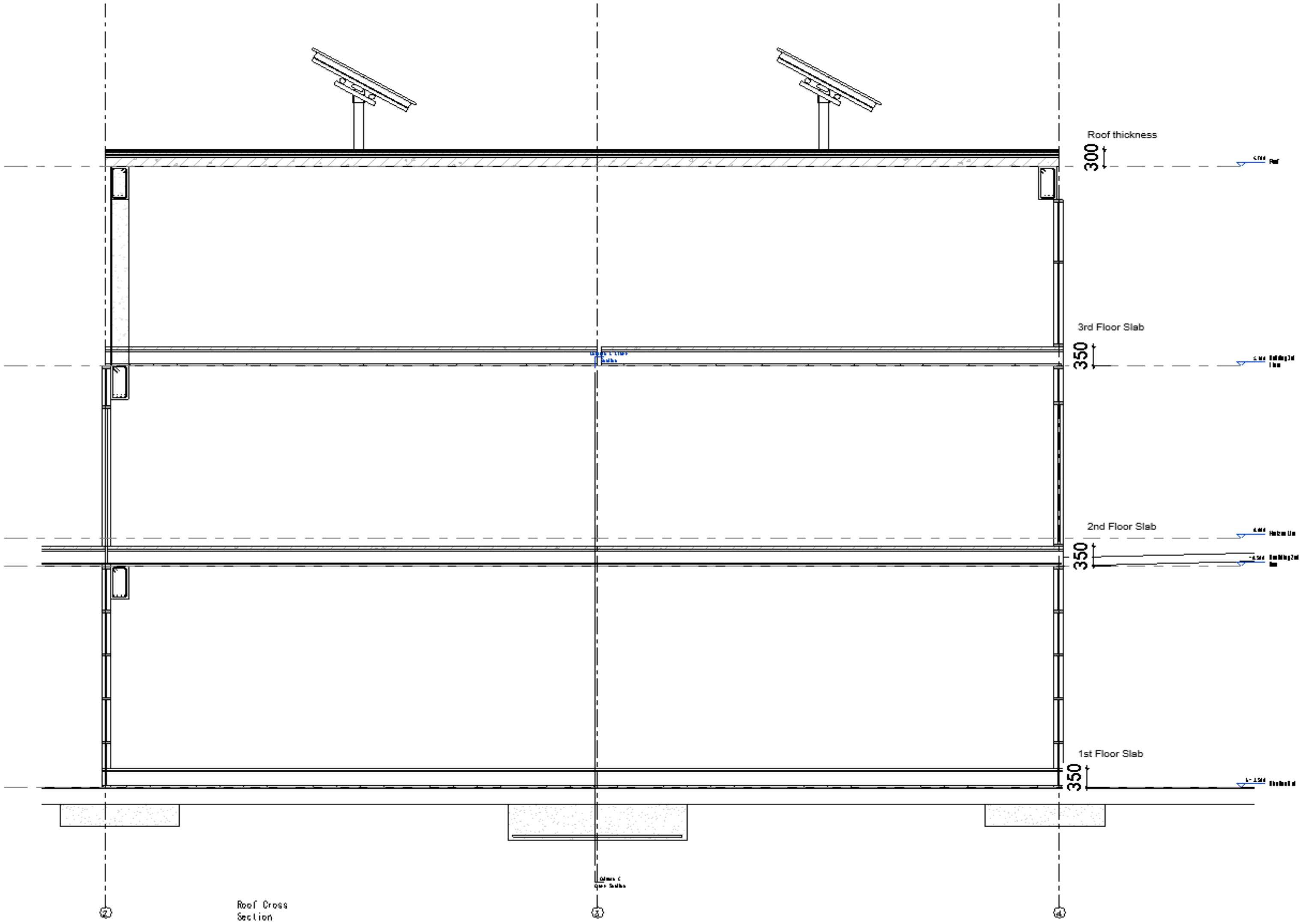


Clinet Name	UBC SEEDS
Project Name	Detention Facility at UBC CCM

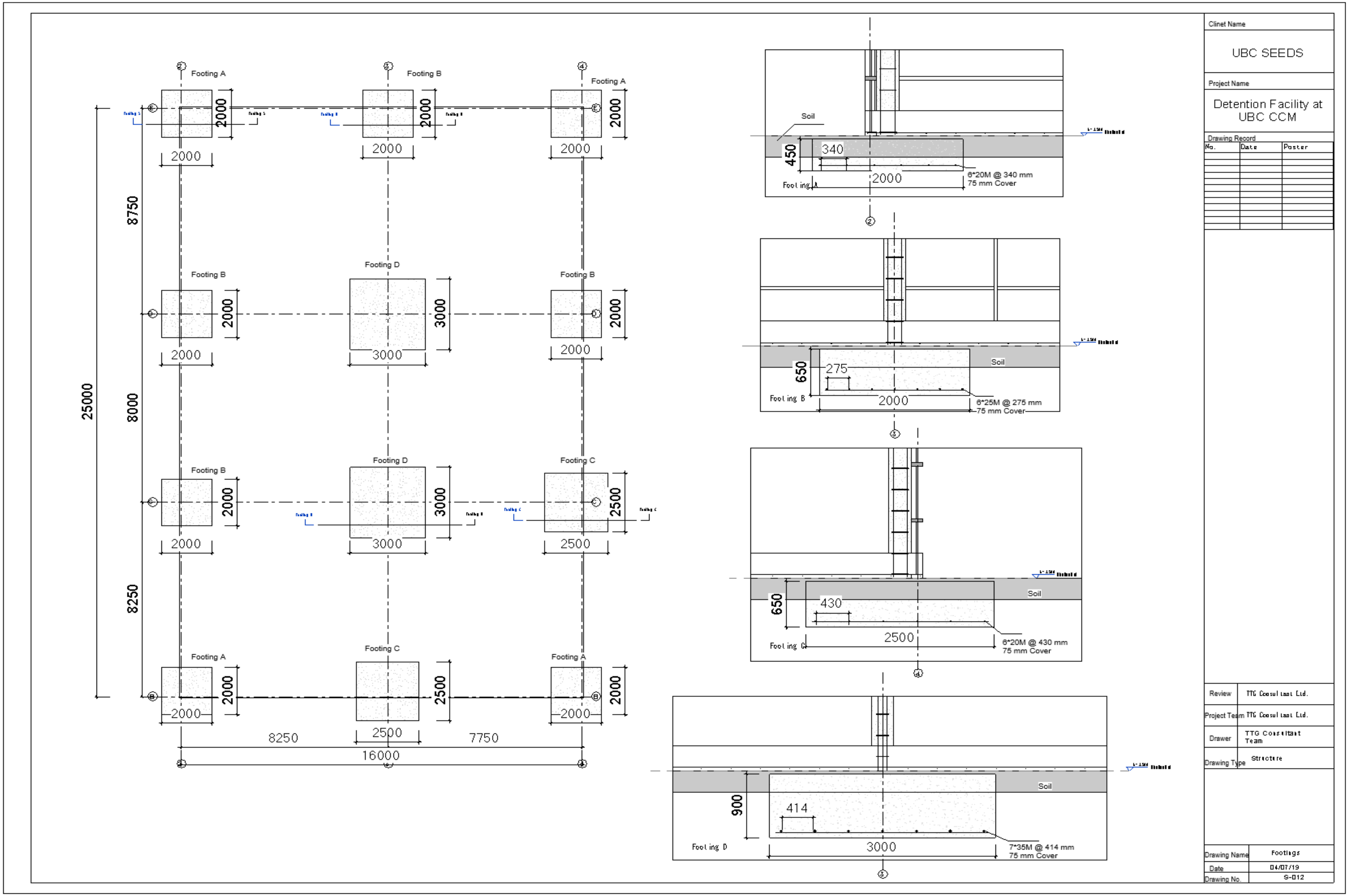
Drawing Record

No.	Date	Poster

Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Building 3rd Floor (Slab)
Date	04/06/19
Drawing No.	S-010



Clinet Name	
UBC SEEDS	
Project Name	
Detention Facility at UBC CCM	
Review	TTG Consultant Ltd.
Project Team	TTG Consultant Ltd.
Drawer	TTG Consultant Team
Drawing Type	Structure
Drawing Name	Roof
Date	04/07/19
Drawing No.	S-011


Footing A
Footing B
Footing C
Footing D
25000
8750
8000
8250
16000
Soil
6*20M @ 340 mm
75 mm Cover
6*25M @ 275 mm
75 mm Cover
6*20M @ 430 mm
75 mm Cover
7*35M @ 414 mm
75 mm Cover
Clinet Name
UBC SEEDS
Project Name
Detention Facility at UBC CCM
Drawing Record
No.
Date
Poster
Review
TTG Consultant Ltd.
Project Team
TTG Consultant Ltd.
Drawer
TTG Consultant Team
Drawing Type
Structure
Drawing Name
Footings
Date
04/07/19
Drawing No.
S-012

Appendix B Class B Cost Estimation

Detention Facility fo UBC CCM Class B Cost Estimation

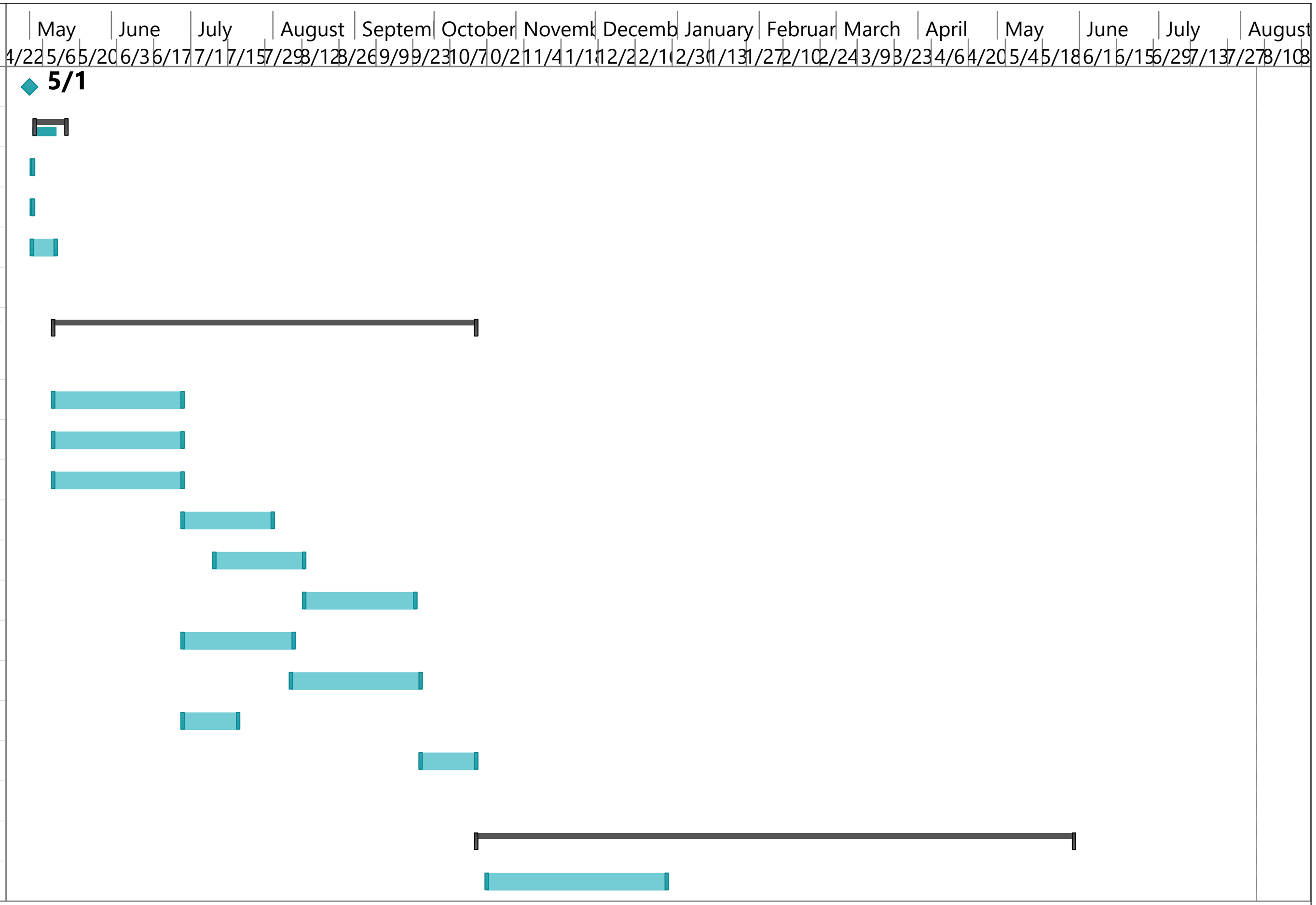
Description	Item	Labour		Material			Equipment			Subcontract		Total
		Man Hr	Rate($)	Qty	Unit	Rate($)	Qty	Unit	Rate($)	Qty	Rate($)	
Detention Pond												
01 General Requirement												
Surveying		12	145							1	$ 1,500	$ 3,240
Project Recod Documents										1	$ 2,000	$ 2,000
Material Testing	Soil Compaction&Concrete Testing	100	200							1	$ 3,000	$ 23,000
Project Manager		1142	60									$ 68,520
Project Coordinator		1142	35									$ 39,970
Safety Officer		1142	12									$ 13,704
Site Superintendent		1142	65									$ 74,230
Traffic Control										1	$ 8,000	$ 8,000
Temporary Power	Design Install and Consumption			15	month	$ 350				1	$ 8,000	$ 13,250
Temporary Facilities	Temporary Toliets, Offices, Drinking Water			15	month	$ 100	15	month	$ 1,550	1	$ 1,500	$ 26,250
Waste Management	Container Rental, Cleaning	21	40	15	month	$ 200						$ 3,840
First Aid				15	month	$ 1,000						$ 15,000
											Subtotal:	**$ 291,004**
02 Site Construction												
Sitework Demolition&Removal	Cut 200 trees	25	800	200	trees	$ 1,000	10	each	$ 1,500	1	$ 65,000	$ 300,000
Excavation, Trenching, and Backfilling	Machine excavation, common earth	2000	400				50	day	$ 690			$ 834,500
Floor Construction	Concrete puring and finishing											$ -
Roof Construction	Roof constructing and covering											$ -
Walls Construction	Exterior and interior walls											$ -
Glass Walls												$ -
Stair Construction	Stair flights and landings											$ -
Interior Doors	Transporing and installing											$ -
Exterior Doors	Transporing and installing											$ -
											Subtotal:	**$ 1,134,500**
03 Concrete												
Concrete Forming	Pouring Concrete	750	45	1782	m^3	$ 25						$ 78,300
Concrete Reinforcement	Placement of Rebar	18	24	2397	m	$ 1						$ 3,428
Cast-in-Place Concrete		21	21	643	m^3	$ 25						$ 16,516
Concrete Finishes	Exterior Protection	14	50	15	cans	$ 100						$ 2,200
Concrete Curing	for Foundations, walls and floors	120	25									$ 3,000
											Subtotal:	**$ 103,444**
33 Utilities												
Pipe Placement		12	25	6	each	$ 23				1	$ 1,200	$ 1,637
Pump		4	32	2	each	$ 360				1	$ 1,800	$ 2,648
Disinfection												$ -
Domestic Water Distribution												$ -
Standpipes												$ -
Plumbing Fixtures												$ -
											Subtotal:	**$ 4,285**
Maintenance												
Pump Maintenance								2	$ 2,000			$ 4,000
Pond Maintenance								1	$ 3,500			$ 3,500
											1-Year Maintenance Subtotal:	**$ 7,500**
											Lifecycle Maintenance Subtotal:	**$ 562,500**
											Detention Pond Lifecycle Cost:	**$ 2,095,733**

Detention Facility fo UBC CCM Class B Cost Estimation

Description	Item	Labour		Material			Equipment			Subcontract		Total
		Man Hr	Rate($)	Qty	Unit	Rate($)	Qty	Unit	Rate($)	Qty	Rate($)	
01 General Requirement												
Surveying		12	145									$ 1,740
Project Recod Documents												$ -
Material Testing	Soil Compaction&Concrete Testing	65	200									$ 13,000
Project Manager		1714	60									$ 102,840
Project Coordinator		1714	35									$ 59,990
Safety Officer		1714	12									$ 20,568
Site Superintendent		1714	65									$ 111,410
Traffic Control												$ -
Temporary Power	Design Install and Consumption			15	month	$ 350						$ 5,250
Temporary Facilities	Temporary Toliets, Offices, Drinking Water			15	month	$ 100	15	month	$ 1,550			$ 24,750
Waste Management	Container Rental, Cleaning	31	40	15	month	$ 200						$ 4,240
First Aid				15	month	$ 1,000						$ 15,000
											Subtotal:	**$ 358,788**
2. Site Construction												
Sitework Demolition&Removal	Cut 200 trees											
Excavation, Trenching, and Backfilling	Machine excavation, common earth											
Floor Construction	Concrete puring and finishing	1550	27.3	1162.25	m^2	$ 1						$ 42,896
Roof Construction	Roof constructing and covering	1050	27.3	265.25	m^2	$ 6						$ 30,257
Walls Construction	Exterior and interior walls	800	27.3	3891.92	m^2	$ 1						$ 23,786
Glass Walls		170	28.6	609.81	m^3	$ 20				55	$ 75	$ 21,183
Stair Construction	Stair flights and landings	520	27.3	2	each	$ 11,725						$ 37,646
Interior Doors	Transporing and installing	26	778.13	25	each	$ 1,001				1	$ 2,000	$ 47,256
Exterior Doors	Transporing and installing	6	1411.5	9	each	$ 3,825				1	$ 2,500	$ 45,394
											Subtotal:	**$ 248,418**
03 Concrete												
Concrete Forming	Pouring Concrete	350		900	m^3	$ 25						$ 22,500
Concrete Reinforcement	Placement of Rebar	10	24	1331	m	$ 1						$ 1,904
Cast-in-Place Concrete		11	21	357	m^3	$ 25						$ 9,156
Concrete Finishes	Exterior Protection	10	50	10	cans	$ 100						$ 1,500
Concrete Curing	for Foundations, walls and floors	400	25									$ 10,000
											Subtotal:	**$ 45,060**
33 Utilities												
Pipe Placement												
Pump												
Disinfection		43	22.8	20700	m^3	$ 5				2	$ 2,000	$ 115,104
Domestic Water Distribution		28	24.4	830	m^2	$ 8				2	$ 2,200	$ 11,873
Sprinkler		34	22.3	1472	m^2	$ 31				2	$ 2,800	$ 51,666
Standpipes		16	25	1054.3	m^2	$ 8				1	$ 3,500	$ 11,955
Lights and branch wiring		40	21	1054.3	m^3	$ 131				1	$ 2,300	$ 140,789
Plumbing Fixtures		46	22	34	each	$ 2,860				1	$ 2,300	$ 100,552
Fittings		5	22	46	m^3	$ 2,000				1	$ 3,100	$ 95,210
Other hvac system and equipment		38	23.4	12583	-	$ 2				1	$ 2,000	$ 26,042
											Subtotal:	**$ 553,192**
Maintenance												
Building maintenance								1	$ 4,500			$ 4,500
											Subtotal:	**$ 4,500**
											Lifecycle Maintenance Subtotal:	**$ 337,500**
											Building Lifecycle Cost:	**$ 1,542,957**
											Total Detention Facility Cost Over Lifecycle(Including Contingency & GST & PST):	**$ 4,413,000**

Appendix C Project Schedule

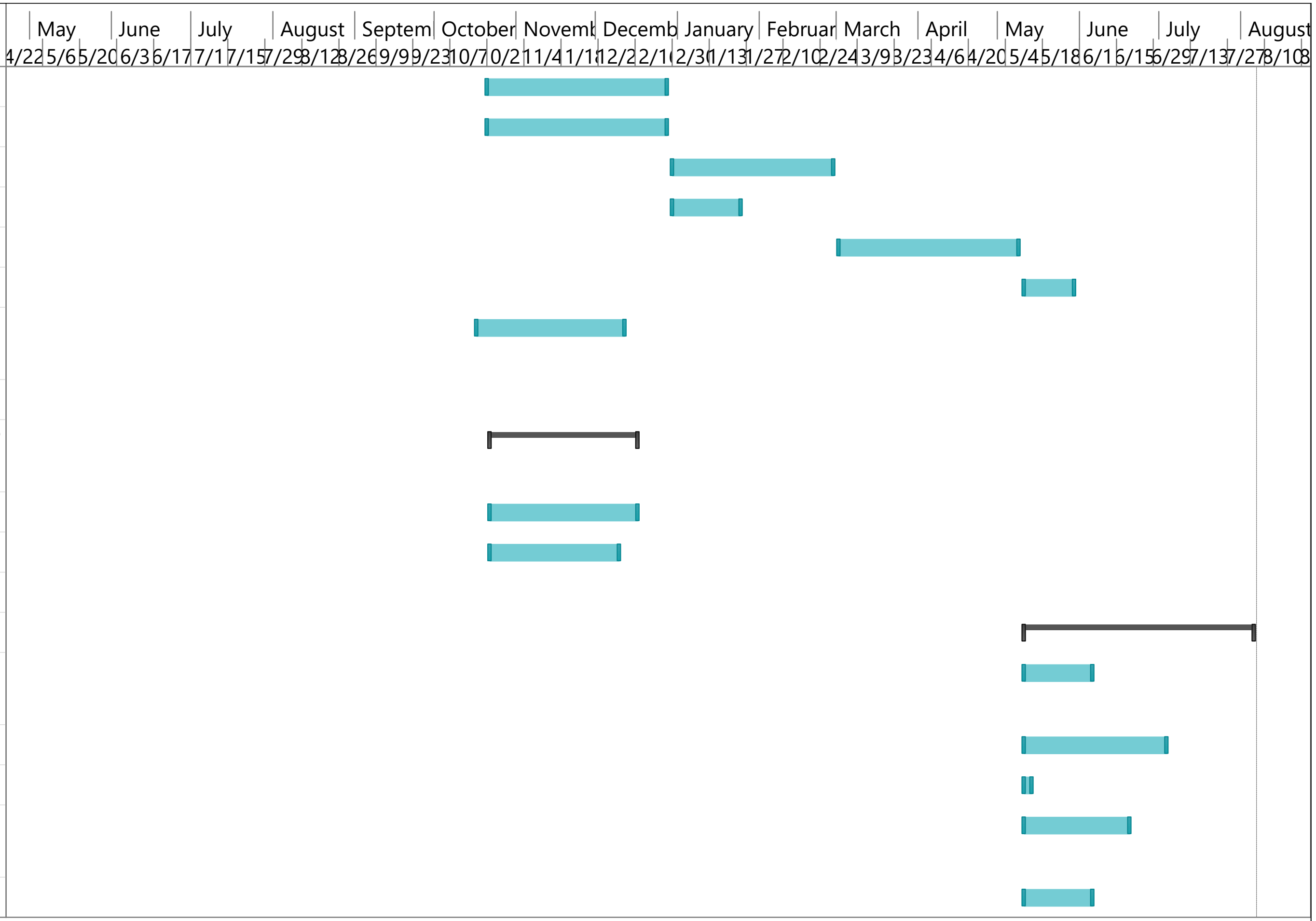
ID	Task Mode	Task Name	Duration	Start	Finish
1		START	0 days	Wed 19/5/1	Wed 19/5/1
2		**Site Preperation**	**8 days**	**Fri 19/5/3**	**Tue 19/5/14**
3		Site Survey	0.25 days	Thu 19/5/2	Thu 19/5/2
4		Fencing Layout	0.5 days	Thu 19/5/2	Thu 19/5/2
5		Demolition	7 days	Thu 19/5/2	Fri 19/5/10
6					
7		**Phase 1 Foundation Excavation**	**114 days**	**Fri 19/5/10**	**Wed 19/10/16**
8		Footings Excavation	35 days	Fri 19/5/10	Thu 19/6/27
9		etention Pond Excavatic	35 days	Fri 19/5/10	Thu 19/6/27
10		nstallation Soil Anchors	35 days	Fri 19/5/10	Thu 19/6/27
11		Footing Formwork	24 days	Fri 19/6/28	Wed 19/7/31
12		Footing Rebar	24 days	Wed 19/7/10	Mon 19/8/12
13		Footing Pour	30 days	Tue 19/8/13	Mon 19/9/23
14		etention Pond Formwo	30 days	Fri 19/6/28	Thu 19/8/8
15		Detetnion Pond Pour	35 days	Thu 19/8/8	Wed 19/9/25
16		Underground Piping	15 days	Fri 19/6/28	Thu 19/7/18
17		Backfill and Compact	15 days	Thu 19/9/26	Wed 19/10/16
18					
19		**hase 2 Building conctructio**	**162 days**	**Thu 19/10/17**	**Fri 20/5/29**
20		ab on grades constructi	50 days	Mon 19/10/21	Fri 19/12/27



Project: Project Schedule
Date: Mon 19/4/8

Task	Manual Task	Deadline
Split	Duration-only	Path Predecessor Milestone Task
Milestone	Manual Summary Rollup	Path Predecessor Summary Task
Summary	Manual Summary	Path Predecessor Normal Task
Project Summary	Start-only	Critical
Inactive Task	Finish-only	Critical Split
Inactive Milestone	External Tasks	Progress
Inactive Summary	External Milestone	Manual Progress

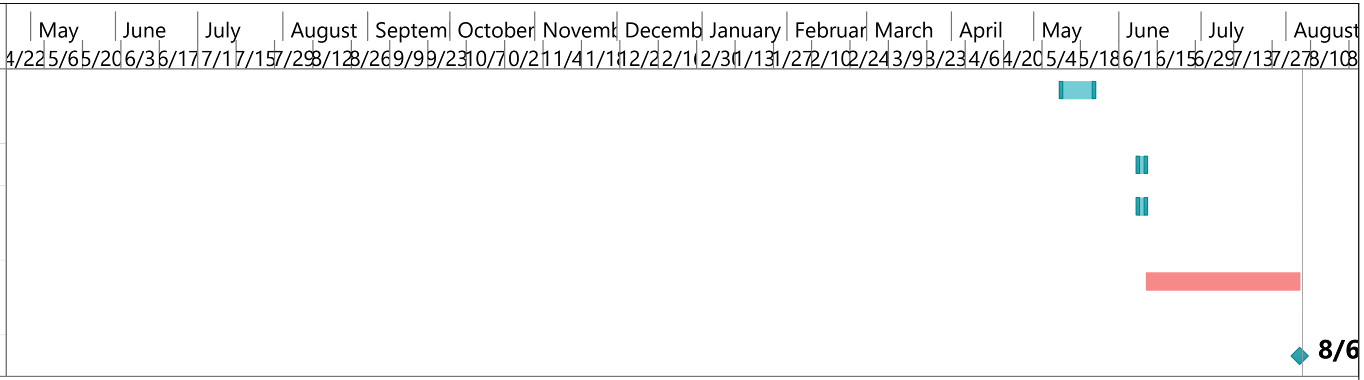
ID	Task Mode	Task Name	Duration	Start	Finish
21		Columns Construction	50 days	Mon 19/10/21	Fri 19/12/27
22		Beam Construction	50 days	Mon 19/10/21	Fri 19/12/27
23		ncrete Wall Constructi	45 days	Mon 19/12/30	Fri 20/2/28
24		Glass Wall Construction	20 days	Mon 19/12/30	Fri 20/1/24
25		Roof Construction	50 days	Mon 20/3/2	Fri 20/5/8
26		Stair Forming	15 days	Mon 20/5/11	Fri 20/5/29
27		Entrance Connection Construction	40 days	Thu 19/10/17	Wed 19/12/11
28					
29		**Phase 3 Detention Pond Construction**	**40 days**	**Tue 19/10/22**	**Mon 19/12/16**
30		Pump Installation	40 days	Tue 19/10/22	Mon 19/12/16
31		Filtration Installation	35 days	Tue 19/10/22	Mon 19/12/9
32					
33		**Phase 4 Finishing**	**63 days**	**Mon 20/5/11**	**Thu 20/8/6**
34		Dry wall construction + Mud and Taping	20 days	Mon 20/5/11	Fri 20/6/5
35		Painting	40 days	Mon 20/5/11	Fri 20/7/3
36		interior Decorations	3 days	Mon 20/5/11	Wed 20/5/13
37		Mechanical and electrical utilities	30 days	Mon 20/5/11	Fri 20/6/19
38		Plumbing	20 days	Mon 20/5/11	Fri 20/6/5



Project: Project Schedule
Date: Mon 19/4/8

Task	Manual Task	Deadline
Split	Duration-only	Path Predecessor Milestone Task
Milestone	Manual Summary Rollup	Path Predecessor Summary Task
Summary	Manual Summary	Path Predecessor Normal Task
Project Summary	Start-only	Critical
Inactive Task	Finish-only	Critical Split
Inactive Milestone	External Tasks	Progress
Inactive Summary	External Milestone	Manual Progress

ID	Task Mode	Task Name	Duration	Start	Finish
39		Door/Windows Installations	10 days	Mon 20/5/11	Fri 20/5/22
40		Fence Installation	3 days	Mon 20/6/8	Wed 20/6/10
41		Toilet, bar utility installation	3 days	Mon 20/6/8	Wed 20/6/10
42		Landscaping/ Sidewalks	40 days	Thu 20/6/11	Wed 20/8/5
43		END	0 days	Thu 20/8/6	Thu 20/8/6



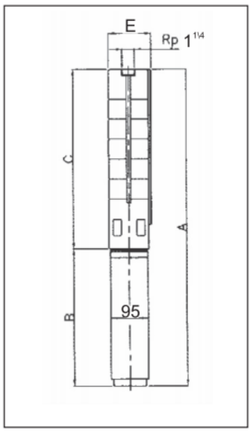
Project: Project Schedule
Date: Mon 19/4/8

Task	Manual Task	Deadline
Split	Duration-only	Path Predecessor Milestone Task
Milestone	Manual Summary Rollup	Path Predecessor Summary Task
Summary	Manual Summary	Path Predecessor Normal Task
Project Summary	Start-only	Critical
Inactive Task	Finish-only	Critical Split
Inactive Milestone	External Tasks	Progress
Inactive Summary	External Milestone	Manual Progress

Appendix D Sample Calculations

Appendix C-1 Pump Design Calculation

Dimensions and Weights



E = Max. Dia of Pump inclusive of cable guard & motor.

QF-2-75 and QF-2-90 are mounted in sleeve for R 1¹/₄ "connection and with max. diameter 108 mm

TECHNICAL DATA QF 2												
PUMP	MOTOR		DIMENSIONS (mm)							NET WEIGHT (Kg)		
				B		A				PUMP WEIGHT (Kg)	MOTOR	
TYPE	TYPE	POWER (KW)	C	1X230V	3X220V 3X400V	1X230V	3X220V 3X400V	D	E		1 X 230	3X220V 3X400V
QF2 - 6	RO 100	0.37	312	352	302	664	614	95	101	3	8	8
QF2 - 9	RO 100	0.37	375	352	302	727	677	95	101	4	8	8
QF2 - 13	RO 100	0.55	459	367	317	826	776	95	101	5	9	9
QF2 -18	RO 100	0.75	564	382	352	946	916	95	101	6	10	9
QF2 - 23	RO 100	1.1	669	422	382	1091	1051	95	101	7	12	10
QF2 - 28	RO 100	1.5	774	478	422	1252	1196	95	101	9	13	12
QF2 - 33	RO 100	1.5	879	478	422	1357	1301	95	101	10	13	12
QF2 - 28	RO 101	1.5	839	517	414	1356	1253	95	101	9	13	12
QF2 - 33	RO 101	1.5	944	585	414	1529	1358	95	101	10	13	12
QF2 - 40	RO 101	2.2	1091	585	480	1676	1571	95	101	11	18	16
QF2 - 48	RO 101	2.2	1259	585	480	1844	1739	95	101	13	18	16
QF2 - 55	RO 101	3.0	1406	-	547	-	1953	95	101	15	-	19
QF2 - 65	RO 101	3.0	1616	-	547	-	2163	95	101	17	-	19
QF2 - 75	RO 101	4.0	1826	-	623	-	2449	95	101	20	-	22
QF2 - 90	RO 101	4.0	2141	-	623	-	2764	95	101	23	-	22

h=dh+hl
dh = |Hinlet - Houtlet|=6m
hl = kQ^2 max Q = 1.53 m3/s = 25.5 L3/min but normally, Q = **0.51** m3/s = 8.5 L3/min
Liquid pipeline size: $V = 0.012\frac{Q_L}{d}$ Vmin = 0.034 m/s 0.034
Vmax = 0.102 m/s 0.102
dmin = 0.18 m
dmax = 0.54 m Assuming d = **0.41** m = 410 mm, to minimize minor loss
k = 8f(L+Leq)/(pi^2*g*D^5) f= 1.9 Area of x-section = 0.1320254 m2 **Submersible Pumps - QF Series**
Leq = ∑ kD/f = 0.44 Assume L = 15m Hmax = 660 m
k (s2/m5) = 209.28 Pressrue Gradient -48.673 km/s2 Flow = 440 m3/hr
Rating = 0.5 to 335 HP

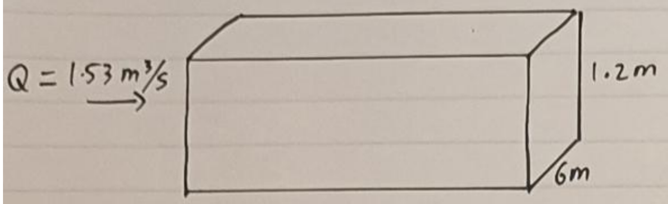
Q (m3/s)	hl (m)	h (m)	V (m/s)	ws	HP
0.000	0.000	-4.500	0.000	74.305	7.57
0.015	0.047	-4.453	0.114	74.311	7.58
0.030	0.188	-4.312	0.227	74.330	7.58
0.045	0.424	-4.076	0.341	74.363	7.58
0.060	0.753	-3.747	0.454	74.408	7.58
0.075	1.177	-3.323	0.568	74.466	7.59
0.090	1.695	-2.805	0.682	74.537	7.60
0.105	2.307	-2.193	0.795	74.621	7.61
0.120	3.014	-1.486	0.909	74.718	7.62
0.135	3.814	-0.686	1.023	74.827	7.63
0.150	4.709	0.209	1.136	74.950	7.64
0.165	5.698	1.198	1.250	75.085	7.65
0.180	6.781	2.281	1.363	75.234	7.67
0.195	7.958	3.458	1.477	75.395	7.69
0.210	9.229	4.729	1.591	75.570	7.70
0.225	10.595	6.095	1.704	75.757	7.72
0.240	12.055	7.555	1.818	75.957	7.74
0.255	13.609	9.109	1.931	76.170	7.76
0.270	15.257	10.757	2.045	76.396	7.79
0.285	16.999	12.499	2.159	76.634	7.81
0.300	18.835	14.335	2.272	76.886	7.84
0.315	20.766	16.266	2.386	77.151	7.86
0.330	22.791	18.291	2.500	77.428	7.89
0.345	24.910	20.410	2.613	77.719	7.92
0.360	27.123	22.623	2.727	78.022	7.95
0.375	29.430	24.930	2.840	78.338	7.99
0.390	31.832	27.332	2.954	78.668	8.02
0.405	34.327	29.827	3.068	79.010	8.05
0.420	36.917	32.417	3.181	79.365	8.09
0.435	39.601	35.101	3.295	79.732	8.13
0.450	42.379	37.879	3.408	80.113	8.17
0.465	45.252	40.752	3.522	80.507	8.21
0.480	48.218	43.718	3.636	80.914	8.25
0.495	51.279	46.779	3.749	81.333	8.29
0.510	54.434	49.934	3.863	81.765	8.33
				AVE	7.83

Appendix C-2 Sedimentation Pond Design

Stoke's Law

$$V_s = g \times (S - 1) \times d^2 / (18 \times ǂ)$$ …(Equation G.2)

Where:
V_s = Settling velocity (cm/sec)
g = Acceleration of gravity (981 cm/sec^2)
ǂ = Kinematic viscosity of a fluid (cm^2/sec^2)
S = Specific gravity of a particle
d = Diameter of a particle (cm-assumed a sphere)



$Q = 1.53\ m^3/s$
$h = 1.2\ m$
$t = \frac{328}{V_H}$, $V_H = \frac{1.53}{6 \times 1.2} = 0.2125\ m/s$
$t_f = 1543.5$ second

$L = (100+1+6)2 + (50+1+6)2 = 328\ m$

Settling Velocity: $V_s = \frac{g \times (S-1)\, d^2}{18\, \mu_f}$, From table, medium silt settles at 0.078 cm/s in 20°C water

$V_s = 0.078\ cm/s$, $h = 120$ cm

$t_s = \frac{120}{0.078} = 1538.5$ sec

$1538.5 = t_s < t_f = 1543.5$ okay ✓

Parameters: Q = discharge rate = 1.53 m³/s

h = water height in basin = 1.2 m

t_f = Time for inflow particle to reach exit = 1543.5 seconds

L = Length of sedimentation basin = 328 m

V_s = Settling velocity = 0.078 cm/s @ 20°C water

t_s = Settling time = 1538.5 secs

Appendix C-3 Foundation Design

1. Determine the footing plan dimensions

The allowable soil pressure is q(all)=12000psf= 575 kPa
saturated sand unit weight = 19 kN/m^3
foundation constructed level = 20 feet= 6.096 m
water table level = 13 feet= 3.9624 m
detention pond Height = 4 m
backfill weight =γ(sat)*(foundation level-pond length)*(Afooting-Acolum) = 155.71 kN
Column 1 load= 993 kN Column 1 size 300*300mm , A= 0.09 m^2
Total Load=soil weigh + total factoed load on each column = 1148.712 kN
A≥P/q(all)= 1.99776 m^2 = 2 m^2
The width of the square footing is b=A^(1/2) 1.4 m = 2 m

2. Determine the factored soil presure, q(f)

First, calculate the footing plan area as
A=b^2= 4 > 2 m^2
Then calculated the factored soil bearing pressure as
q(f)=P(f)/A= 287.178 kPa

3. Determine the required footing thickness(h) based on the one-way and two-way shear design requirments

a. First,check the two-way shear requiremnts(A23.3Cl.13.3 and 13.3.4), which ususally govern in the case of spead footing
i.Determine the factoed load to be considered for two-way shear design:
V(f)=P(f)= 1148.712 kN
Note that this is a conservative assumption because the actual tributary area beneath the footing would result in a smaller factored load
ii. Determine the concrete shear resistance for the two=way shear,V®. There are three different criteria for determine the v(c)
First, determne v(c) based on the third criterion as
λ= 1 φ(c)= 0.65 f(c)'= 25 Mpa
v(c)=0.38*λ*φ(c)*f(c)'^(1/2)= 1.24 MPa= 1240 kPa
iii. Determine the d value based on the two-way shear requirements.
Determien the two-way shear resistance of concrete V(c) as
V(c)=v(c)*b(o)*d
To ensure that shear reinforcemnt is not rquired, set V(c)=V(f)= 1148.712 kN
Therefore, b(o)*d=V(c)/v(c) = 0.926 m^2
Determine the shear perimeter b(o) for a square column with t= 300 mm= 0.3 m
Therefore, b(o)*d=4*(t+d)*d = 4*(0.3+d)*d= 0.926380516 m^ so d= 0.322 m= 322 mm
So,b(o)=4*(t+d)= 2.488 m
iv. At this point, check the remianing two v(c) criteria:
v(c)=(1+2/β(c))*0.19*λ*φ(c)*f(c)'^(1/2)= 1.85 Mpa
and v(c)=(α(s)*d)/b(o)+0.19)*λ*φ(c)*f(c)'= 2.3 MPa
Therefore, the assumption that the third criterion v(c)=1.24MPa governs was correct
v. Next, determine the overall footing depth, assume use 20M reabar bars
d(b)= 20 mm
cover= 75 mm
The overall footing thickness, h=d+d(b)/2+cover= 407 mm round up to 450 mm
Therefore, d=h-d(b)/2-cover= 365 mm≈ 360 mm = 0.36 m
b. Finally check the one-way shear requirements(A23.3 Cl11.3.4)
i. First, determine the factored shear force V(f) at the critical section at a distance d away from the face of the column
V(f)=q(f)*b*((b-t)/2-d)= 281.4344 kN
ii. Then, determine the concrete shear resistance V(c) at the critical section
Determine the effective shear depth d(v) as the greater of
• 0.9*d= 324 mm
• 0.72*h= 324 mm
So d(v)= 324 mm ≈ 350 mm
The β value can be determined based on A23.3 Cl.11.3.6.2 provided that there is no transverse reinforcement
and the maximum aggregate size is not less than 20mm as follows
β=230/(1000+d(v))= 0.17037
Finally, V(c) can be determined for a section with width b(w)=b= 2 m= 2000 mm
V(c)=φ(c)*λ*β*(f(c)'^(1/2))*b(w)*d(v)= 387.59 kN≈ 400 kN
iii. To avoid the use of shear reinforcement in the footing A23.3 Cl 11.2.8.1 V(f) ≤ V(c)
Since, V(f)= 281.4344 kN < V(c)= 400 kN Therefore, shear reinforcemnt is not requried

4. Determien the required flexural reinforcement based on the lexural design reuqiremnts

a. First, determine the factored bending moment resistance at the critical section
M(f)=q(f)*((b-t)/2)*((b-t)/4)*b= 207.48608 kNm
b. Determine the required area of reinforcemnt. The strenght design rquiremnt states that M(r)≥M(f)
Set M(r)=M(f)= 207.4861 kNm
Then calculate the rquired area of flexural reinforcement
A(s)=0.0015f(c)'*b(d-(d^2-3.85*M(r)/f(c)'*b)^0.5)= 1719 mm^2

5. Confirm that the minimum reinforcement requriement i

First, determine the gross cross-sectional area of the footing as
A(g)=h*b= 900000 mm^2
Then, A(smin)=0.002*A(g)= 1800 mm^2
Because A(s)= 1800 mm^2 < A(g) = 900000 mm^2
the minimum reinforcement reuirement governs in this case. Use 6 -20M bars and A(b)= 300 mm^2
A(s)=#of rebars*A(b)= 1800 mm^2

6. Confirm that the CSA A23.3 bar spacing requriements are satisfied

Determine the bar spacing assuming 100 mm end spacing:
s=(b-2*end spacing)/(#bars-1)= 360 mm
According to A23.3 Cl7.4.1.2 and Cl.13.10.4, the maximum permitted bar spacing S(max) is equal to the lesser of 3h and 500mm
3h= 1350 mm
S(max)= 500 mm
s= 360 mm < S(max)= 500 mm
Therefore, s= 360 mm

7. Confirm that the maximum reinforcement requriement is satisfied

In this case, the maximum reinforcement requirement is satisfied by default because the amount of reinforcement
is governed by the minimum reinforcement requriement

8. Check the development length for the flexural reinforcement

The required development length for 25M reinforcement is
k(1)=k(2)=k(3)=k(4)= 1 f(y)= 400 MPa f(c)'= 25 Mpa for 20M rebars d(b)= 20 mm
l(d) = 0.45*k(1)*k(2)*k(3)*k(4)*f(y)/f(c)'^0.5*d(b) = 720 mm
Consider a 150mm cover at the edge of the footing:
therefore the available length of the reinforcing bar from the edge of the footing to the face of the column is
l=(b-t)/2-end spacing = 750 mm > 720 mm
the flexural reinforcement has sufficient length for proper developemnt

Appendix C-4 Load Analysis

Sample Calculation : Load Analysis

1. Vertical Dead Load :

The concrete density is between 2400 kg/m³ ~ 3000 kg/m³

∴ Take the average : concrete density = 2700 kg/m³

(a) Slab self-weight estimation : → Assume 350mm depth slab:

• 1st floor: DL of slab = 2.7 × 0.35m × 9.8 = 9.261 KPa

∵ The area of 1st Floor is 400m²

∴ The Dead weight of slab in 1st floor = 9.261 KPa × 400m² = 3704.4 kN

• 2nd floor: DL of slab = 2.7 × 0.35m × 9.8 = 9.261 KPa

∵ The area of 2nd floor = 18m × 27m = 486m²

∴ The Dead weight of slab in 2nd floor = 9.261 KPa × 486m² = 4500.85 kN

• 3rd floor: DL of slab = 2.7 × 0.35 × 9.8 = 9.261 KPa

∵ The area of 3rd floor = 7.5m × 8.5 + 25 × 8.5 = 276.25m²

∴ The Dead weight of slab in 3rd floor = 9.261 KPa × 276.25m² = 2558.35 kN

∴ The Total Dead weight of slab = 3704.4 kN + 4500.85 kN + 2558.35 kN = 10763.6 kN

(b) Column self-weight estimation: Assume 500×500 mm cross-section columns

2.7 × 9.8 × (0.5 × 0.5 × 11.2m) = 74.09 kN

(c) Beam self-weight estimation: Assume 400×700mm cross-section beams

The DL for a beam = 2.7 × 9.8 × 0.7 = 18.52 kPa

The Total Dead weight for beams = (18.52 × 0.4 × 66m) + (18.52 × 0.4 × 68m)

= 488.93 kN + 503.74 kN

= 992.67 kN

– The Total Dead weight = 10763.6 kN + 992.67 kN + 74.09 kN = 11830.36 kN

2. Vertical Live Load:

According to NBCC, the Live load for Museums is 4.8 kPa

∴ The total Live weight for the Sub-Miqu:

$4.8\,kPa \times 400m^2 + 4.8 \times 486m^2 + 4.8 \times 276.25m^2 = 5578.8\,kN$

3. Snow Load Estimation:

$S = I_s[S_s(C_bC_wC_sC_a) + S_r]$ – NBCC 2010 4.1.6.2

· Importance factor: $I_s = 1.0$ – NBCC 2010 Table 4.1.6.2

Assuming normal importance

· Assume all "C" factors = 1.0

· $S_s = 1.1\,kPa$, $S_r = 0.2\,kPa$ – NBCC 2010 Table C-2

– check: $S_r < S_s(C_bC_wC_sC_a)$

$\Rightarrow 0.2 < 1.1[1.0]$

$\Rightarrow 0.2 < 1.1$ ✓ ok

$\therefore S = (1.0)[(1.1)(1.0) + 0.2] = 1.3\,kPa$

∴ Total snow load at roof = $1.3\,kPa \times (16 \times 25) = 520\,kN$

– Governed Load Combinition:

$1.25D + 1.5L + 0.5S = 1.25 \times 11830.36 + 1.5 \times 5578.8 + 0.5 \times 520$

$= 23416.15\,kN$

4. Wind Load Estimation:

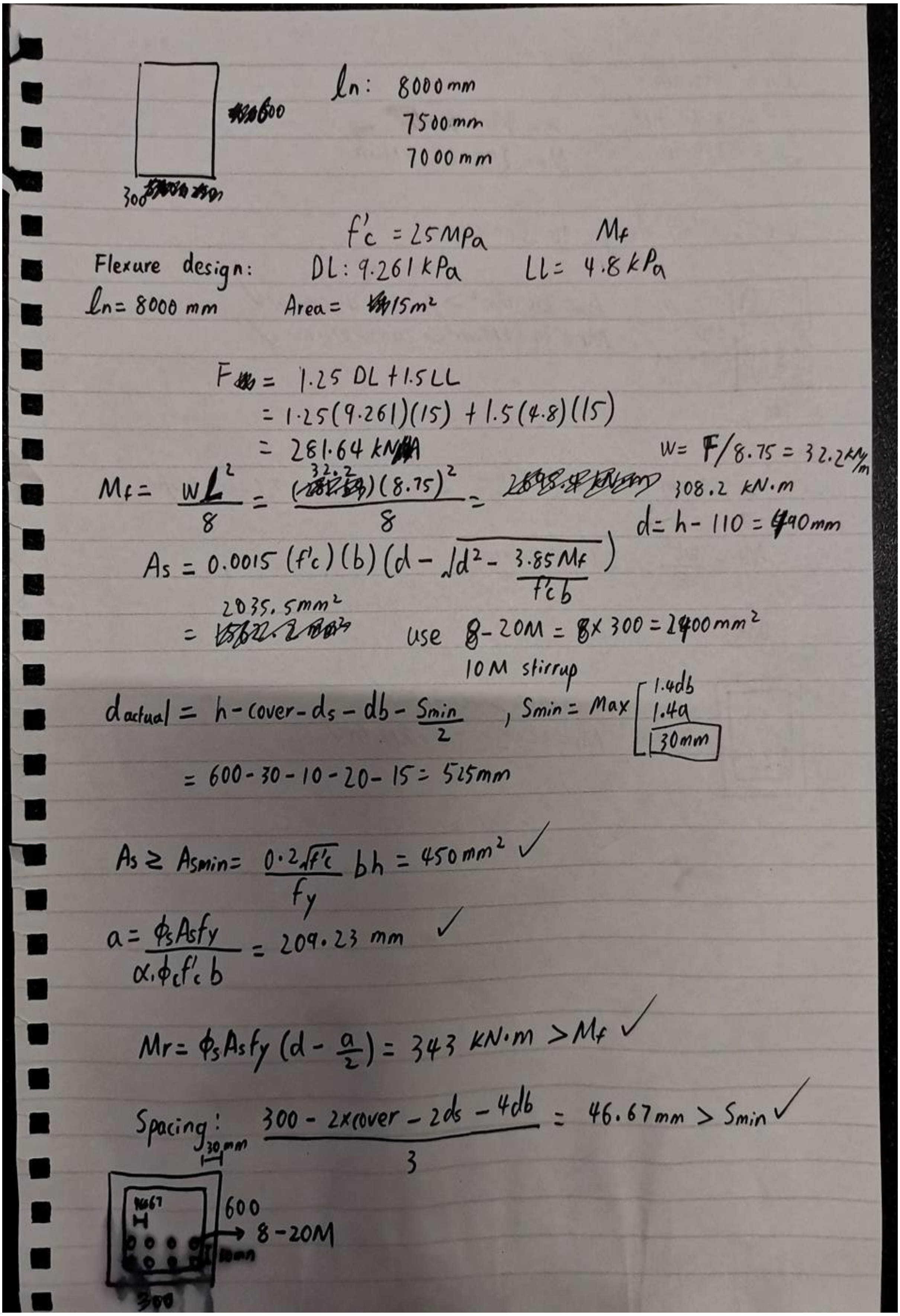
$P = I_w q C_e C_g C_p$ – NBCC 2010 4.1.7.1

Assume $P = 2.6q$

$q = 0.57$ for 1/50 year – NBCC 2010 Table C-2

$P = 2.6(0.57) = 1.482\,kPa$

Appendix C-5 Beam Design



600

300

l_n: 8000 mm

7500 mm

7000 mm

$f'_c = 25\ MPa$ M_f

Flexure design: DL: 9.261 kPa LL = 4.8 kPa

$l_n = 8000\ mm$ Area = 15 m²

$F = 1.25\ DL + 1.5\ LL$

$= 1.25(9.261)(15) + 1.5(4.8)(15)$

$= 281.64\ kN$

$w = F/8.75 = 32.2\ kN/m$

$M_f = \frac{wL^2}{8} = \frac{(32.2)(8.75)^2}{8} = 308.2\ kN \cdot m$

$d = h - 110 = 490\ mm$

$A_s = 0.0015\,(f'_c)(b)\left(d - \sqrt{d^2 - \frac{3.85 M_f}{f'_c b}}\right)$

$= 2035.5\ mm^2$ use 8-20M = 8 × 300 = 2400 mm²

10M stirrup

$d_{actual} = h - cover - d_s - d_b - \frac{S_{min}}{2}$, $S_{min} = Max \begin{bmatrix} 1.4 d_b \\ 1.4 a \\ 30\ mm \end{bmatrix}$

$= 600 - 30 - 10 - 20 - 15 = 525\ mm$

$A_s \geq A_{smin} = \frac{0.2\sqrt{f'_c}}{f_y} bh = 450\ mm^2$ ✓

$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f'_c b} = 209.23\ mm$ ✓

$M_r = \phi_s A_s f_y \left(d - \frac{a}{2}\right) = 343\ kN \cdot m > M_f$ ✓

Spacing: $\frac{300 - 2 \times cover - 2 d_s - 4 d_b}{3} = 46.67\ mm > S_{min}$ ✓

30 mm

46.67

600

8-20M

30 mm

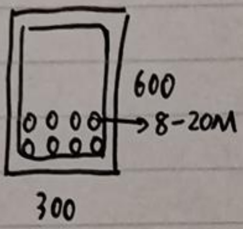
300

$l_n = 7500\,mm$

$F = 281.64\ kN$ $w = 34.14\ kN/m$

$L = 8250\,mm$ $M_f = 290.441\ kN \cdot m$

use similar design to $l_n = 8000\,mm$:



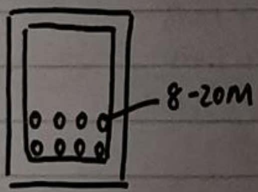
$A_s = 2400\,mm^2 > A_{smin} = 450\,mm^2$ ✓

$M_r = 343\ kN \cdot m > 290.4\ kN \cdot m$ ✓

$l_n = 7000\,mm$ $w = F/L = 281.64/7.75 = 36.34\ kN/m$

$$M_f = \frac{wL^2}{8} = 272.8\ kN \cdot m$$

use same design:



$A_s = 2400 > 450\,mm^2$ ✓

$M_r = 343 > 272.8\ kN.m$ ✓

Shear Design:

$V_f = \frac{wL_n}{2} = \frac{32.2 \times 8}{2} = 128.8\ kN$

$\ell_n = 8000mm$

$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v$, $d_v = Max \begin{bmatrix} 0.9d \\ 0.72h \end{bmatrix} = \begin{matrix} \boxed{472.5} \\ 432 \end{matrix}$

$\beta = 0.18$

$V_c = 82.9\ kN$ $\qquad V_s = V_f - V_c = 45.9 kN$

$V_s = \frac{\phi_s A_v f_y d_v \cot\theta}{S}$, $S = \frac{\phi_s A_v f_y d_v \cot\theta}{V_s} = 999.7\ mm$
900 mm

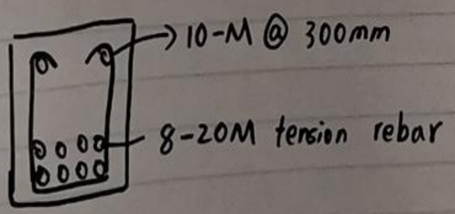
$S_{max} = Min \begin{bmatrix} 600 \\ 0.7 d_v = \boxed{330.75\ mm} \end{bmatrix}$ $\qquad S = \frac{A_v f_y}{0.06\sqrt{f'_c}\, b_w} = 889mm$

$S = 330.75mm$, use $300mm$

$V_s = 152.954\ kN$

$V_r = 235.9\ kN$, $V_{rmax} = 0.25\phi_c f'_c b_w d_v = 575.9kN$

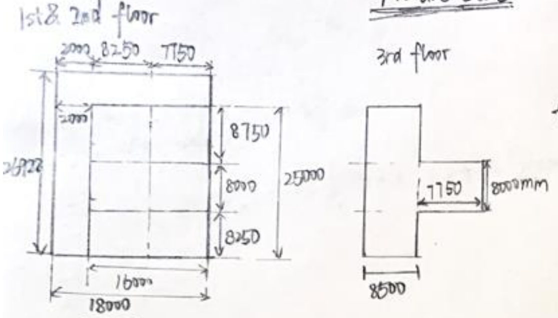
$V_r < V_{rmax}$ ✓ , use 2-legged 10-M rebar at 300 mm spacing.



Use similar design for 7500 mm and 7000 mm

Appendix C-6 Slab Design

Flexure slab



$\rho_{concrete}$ = 2400 kg/m³

thickness of slab = 240 mm (average)

slab. self-weight:

1st floor: DL = 2400 × 0.24m = 576 Pa = 0.576 kPa

The area of 1st floor is 16000 × 25000 = 4 × 10⁸ mm² = 400 m²

LL = 4.8 kPa ⇒ W_{f_1} = 1.25 × 0.576 + 1.5 × 4.8 = 7.92 kPa

2nd floor: DL = 0.576 kPa

The area of 2nd floor is 18000 × 26988 = 4.86 × 10⁸ mm² = 486 m²

LL = 4.8 kPa ⇒ W_{f_2} = 7.92 kPa

3rd floor: DL = 0.576 kPa

The area of 3rd floor is 7750 × 8000 + 25000 × 8500 = 2.75 × 10⁸ mm² = 275 m²

LL = 4.8 kPa ⇒ W_{f_3} = 7.92 kPa

∴ Total W_f: W_f = 1.25 DL + 1.5 LL = 1.25 × (0.576 × 3) + 1.5 × (4.8 × 3) = 23.76 kPa

L.L standard in Van:

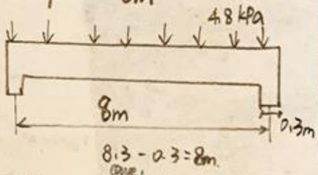
4.8 kPa (recreation area)

beam width: b = 1m = 1000 mm

Assume slab span = 6m

∴ W_{f_1} = 7.92 × 1 = 7.92 kN/m = W_{f_2} = W_{f_3}

$M_{f_1} = \frac{W_f \cdot l^2}{8} = \frac{7.92 \times 8^2 m}{8}$ = 63.36 kN·m/m = M_{f_2} = M_{f_3}



– Effective slab depth: $d = h - cover - \frac{d_b}{2}$ = 240 − 25mm − $\frac{15mm}{2}$ = 207.5mm ≈ 200 mm

Assume: 15M bars;

net cover = 25mm

– Take $M_r = M_f$ = 3272.4 kN·m/m

f_y = 400 MPa

f'_c = 25 MPa

$A_s = 0.0015 f'_c b \left(d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c b}}\right)$ = 0.0015 × 25 MPa × 1000mm × $\left(200 - \sqrt{200^2 - \frac{3.85 \times 63.36 \times 10^6 N \cdot mm}{25 MPa \times 1000 mm}}\right)$

= 978.6 mm²/m (required)

→ slab section: 200mm = d, 240mm = h, b = 1000mm

– 30M bar: A_b = 200 mm²; $S \le A_b \frac{1000}{A_s}$ = 200 mm² × $\frac{1000}{978.6}$ = 204.4 mm ≈ 200mm < S_{max} = 500 ✓

$S \le \{3h = 3 \times 240 = 720mm;\ 500mm\}$

$A_s = A_b \frac{1000}{s}$ = 200 × $\frac{1000}{110}$ = 1818.2 mm² > 978.6 mm² ✓

– $\rho = \frac{A_s}{bd} = \frac{1818.2 mm^2}{1000mm \times 200mm}$ = 0.009 < 0.022 = ρ_b ✓

- gross cross-sectional area for unit strip:

$A_g = b \times h = 1000\,mm \times 240\,mm = 240{,}000\,mm^2$

$A_{s\,min} = 0.002 A_g = 0.002 \times 240000 = 480\,mm^2/m < A_s$ ✓

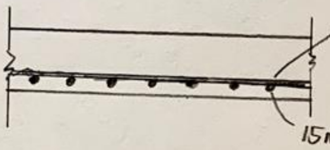
- $a = \dfrac{\phi_s f_y A_s}{\alpha_1 \phi_c f'_c b} = \dfrac{0.85 \times 400\,MPa \times 1818.2}{0.8 \times 0.65 \times 25\,MPa \times 1000\,mm} = 47.55\,mm$

$M_r = \phi_s f_y A_s (d - \frac{a}{2}) = 0.85 \times 400 \times 1818.2 \times (200 - \frac{47.55}{2}) = 1.09 \times 10^8\,N \cdot mm/m = 109\,kN \cdot m/m$

$M_r > M_f = 63.36\,kN/m$ ✓

- Temperature & shrinkage:

- $A_{s\,min} = 480\,mm^2/m$
- $S_{max} \le \begin{cases} 5h \\ (500) \end{cases} \Rightarrow S_{max} = 500\,mm$ $\quad S \le A_b \frac{1000}{A_s} = 200 \times \frac{1000}{480} = 416.7\,mm \cong 400\,mm$
- 15M bars: $A_b = 200\,mm^2$ $\quad A_s \le A_b \frac{1000}{s} = 200 \times \frac{1000}{400} = 500\,mm^2/m > A_{s\,min}$ ✓

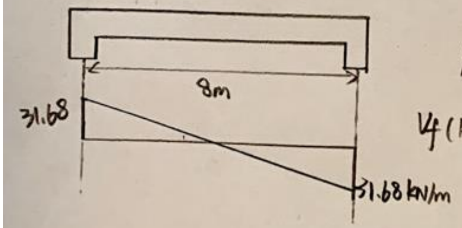


Shear slab

$l_n = 8m$

$w_{f_1} = w_{f_2} = w_{f_3} = 7.92\,kN/m$ → $V_f = \dfrac{w_f \times l_n}{2} = \dfrac{7.92 \times 8}{2} = 31.68\,kN/m$

$(b_w = 1m)$



15M flexural rebar: $d_b = 15\,mm$; net cover $= 25\,mm$

$h = 240\,mm; d \cong 200\,mm$

- effective shear depth $d_v = \begin{cases} 0.9d = 0.9 \times 200 = 180\,mm \text{ governs!} \\ 0.72h = 0.72 \times 240 = 172.8\,mm \end{cases}$

$d_v = 180\,mm$

- $h = 240\,mm < 350\,mm$ $\therefore \beta = 0.21$ (A23.3 Cl. 11.3.6.2)

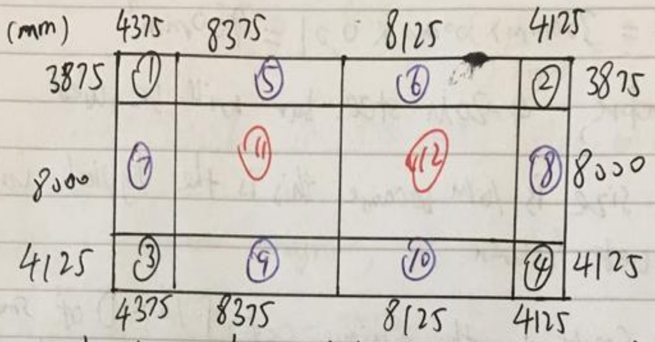
- $V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v = 0.65 \times 1 \times 0.21 \times \sqrt{25} \times 1000\,mm \times 180\,mm$
$= 1.23 \times 10^5\,N \simeq 123\,kN/m$

- $V_f < V_c$ ∴ shear reinforcement is not required.

Appendix C-7 Column Design

Column Design Calculation:

All the columns are short columns, so they are not susceptible to buckling failure



The graph shows the tributary area of each column.
The total factored load is 23416.15 kN, so the loads distributed to each column are:

① 993 kN ② 936 kN ③ 1057 kN ④ 996 kN
⑤ 1900 kN ⑥ 1843 kN ⑦ 2049 kN ⑧ 1932 kN
⑨ 2032 kN ⑩ 1962 kN ⑪ 3923 kN ⑫ 3805 kN

For columns ① ② ③ ④,

We take ③ to calculate the capacity.

300 x 300 column will be used with 4 bars

For Rectangular section: A_g should $> \frac{P_f}{0.5 f_c'}$

$f_c' = 25\,MPa$ $\quad f_y = 400\,MPa$ $\quad P_f = 1057\,kN$

$A_g = b \times h$, so $b > 293\,mm$.

We use $b = h = 300\,mm$, clear cover $= 30\,mm$, $e = 100\,mm$

$$\frac{P_r}{A_g} = \frac{1057 \times 10^3 N}{300mm \times 300mm} = 11.74 \qquad \frac{M_r}{A_g h} = \frac{P_r \times e}{A_g h} = 3.91$$

$\gamma = \frac{h - 2\times cover}{h} = \frac{300 - 2\times 30}{300} = 0.8$

According to Column interaction diagram, $\rho_t = 0.01$

$A_{st} = 300mm \times 300mm \times 0.01 = 900mm^2$

Therefore, 4-20M steel bar will be used

Tie size is 10M because this is the typical value in reinforced concrete column.

Tie spacing is the minimum of
- 16 × D of smallest bar = 320mm
- 48 × tie diameter = 480mm
- Least lateral dimension = 300mm

So, tie spacing = 300 mm

For columns ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

We take column ⑦ to calculate capacity

We will also use 300×300 column, but with 6 bars

$P_r = 2049kN$

$\frac{P}{A_g} = 22.8 \quad \frac{M}{A_g h} = 7.6 \quad \gamma = \frac{300 - 2\times 30}{300} = 0.8$

According to Interaction Diagram, $\rho = 0.06$

$A_{st} = 0.06 \times 300 \times 300 = 5400mm^2$

Therefore, 6-35M will be chosen with 10M tie and 300mm tie spacing

For columns (11) and (12)

We use (11) to calculate the capacity, and we will use 300x600 ~~bars~~ column with 8 bars.

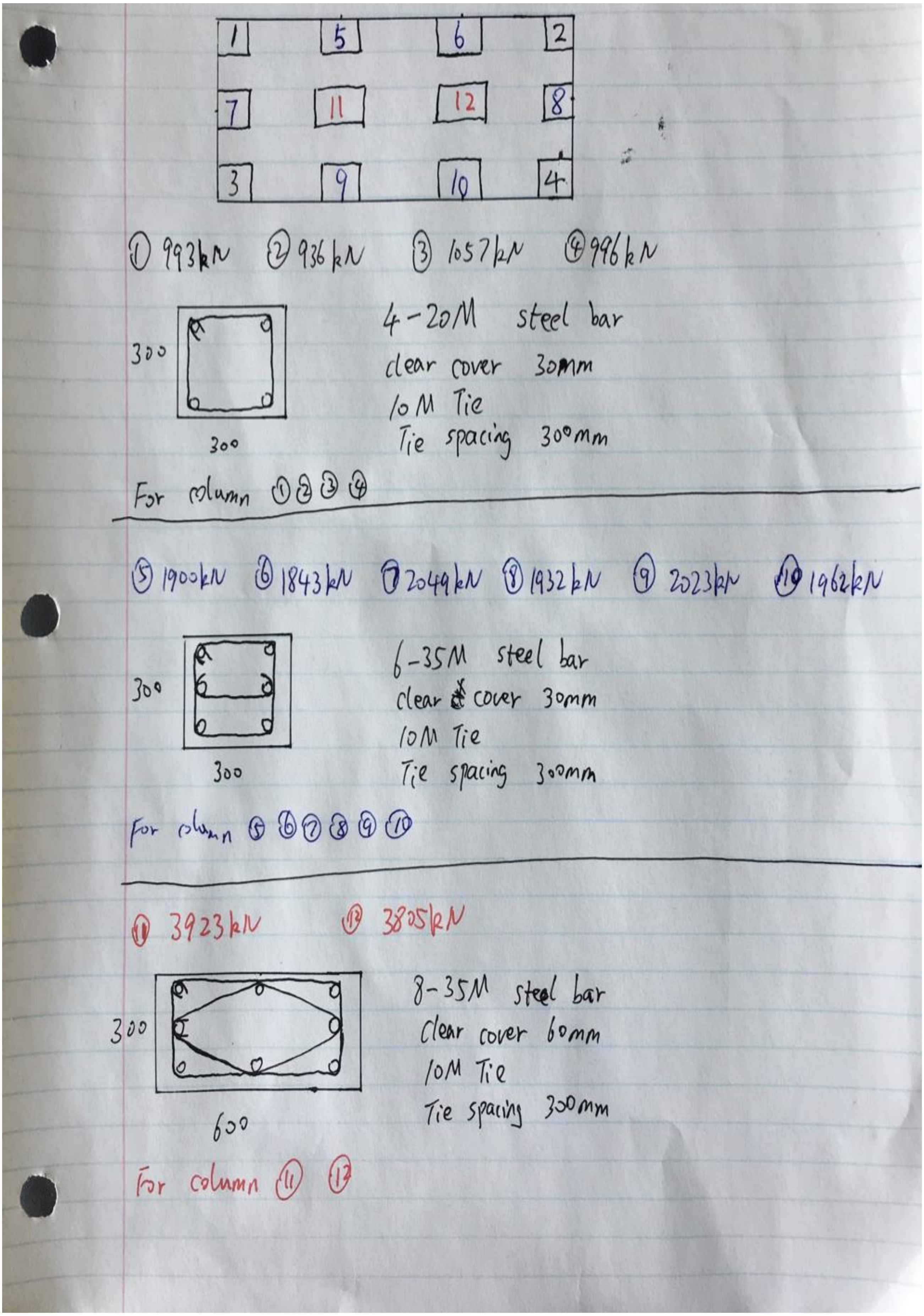
$P_r = 3923\,kN$ $\quad \frac{P_r}{A_g} = 21.8$ $\quad \frac{M_r}{A_g h} = 3.63$

$\gamma = \frac{600 - 2 \times 60}{600} = 0.8$, in this case, clear cover = 60mm

According Interaction Diagram, $\rho_t = 0.043$

$A_{st} = 0.043 \times 300 \times 600 = 7740\,mm^2$

Therefore, 8-35M will be used with 10M tie and 300mm tie spacing



① 993kN ② 936kN ③ 1057kN ④ 996kN

300
300

4-20M steel bar
clear cover 30mm
10M Tie
Tie spacing 300mm

For column ① ② ③ ④

⑤ 1900kN ⑥ 1843kN ⑦ 2049kN ⑧ 1932kN ⑨ 2023kN ⑩ 1962kN

300
300

6-35M steel bar
clear cover 30mm
10M Tie
Tie spacing 300mm

For column ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

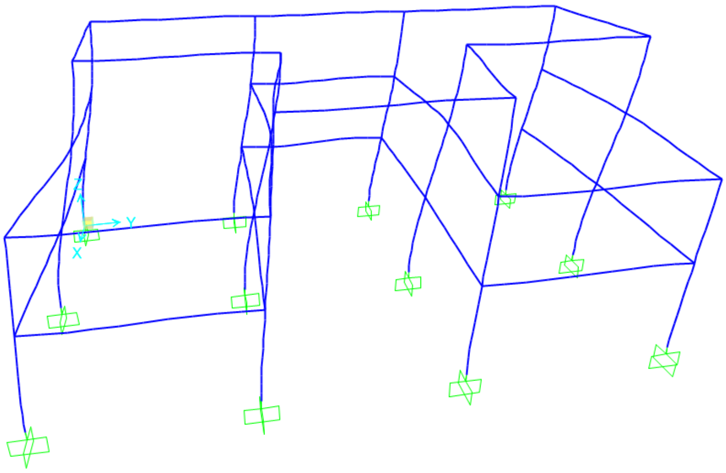
⑪ 3923kN ⑫ 3825kN

300
600

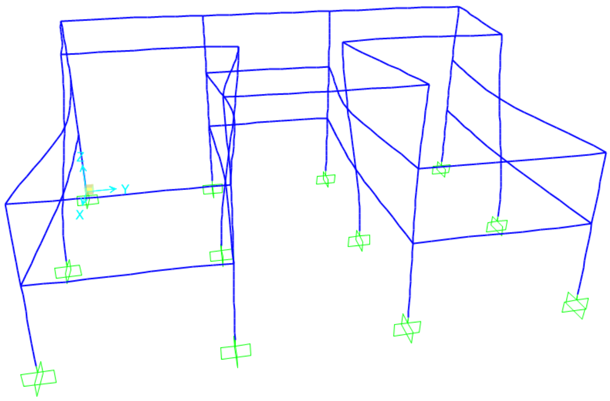
8-35M steel bar
Clear cover 60mm
10M Tie
Tie spacing 300mm

For column ⑪ ⑫

Appendix C-8 Dynamic Analysis



Mode 1 (T=0.42955; f=2.32746)



Mode 2 (T=0.33543; f=2.98103)