PATERSON GROUP

memorandum

re: **Geotechnical Review – Global Stability Analysis**
Proposed Retaining wall
Barrett Lands – Block 148 - Ottawa

to: Barrett Co-Tenancy - **Mrs. Melissa Cote** - melissa.cote@taggart.ca

to: HP Urdan - **Mr. Peter Hume** – peter.hume@hpurban.ca

date: January 16, 2023

file: PG6353-MEMO.01

Further to your request and authorization, Paterson Group (Paterson) prepared the following memorandum to provide a geotechnical review of the global stability analysis of the proposed retaining wall structure.

Background Information

As requested, Paterson Group Inc. (Paterson) completed a Redi-Rock retaining wall design to be located at the south and west end of the proposed development. The Redi-Rock retaining wall system has been designed for the subject site to consider site constraints and grading requirements. The walls have also been designed in accordance with the Canadian Highway and Bridge Design Code (CHBDC) 2019. Details of the retaining walls are presented below and are depicted in Drawing PG6353-1 Revision 2 attached.

The following grading plan prepared by IBI Group was reviewed as part of our retaining wall designs:

❑ Project no. 135925, sheet no. 200, grading plan revision 2 dated November 11, 2022.

Based on our review, the exposed portions of the subject Redi Rock retaining wall vary in height between 0.3 m to 3.0 m.

Retaining Wall Fencing

The proposed fencing and noise barrier posts are recommended to be extended through the top three blocks (min1.3 m) of the Redi Rock and designed by others. Open guide rail, chain link fences and others of a “flow-through” configuration, will not impart significant wind loads on the wall. Wind and snow/ice loads were considered as per CHBDC 2019 on privacy fencing and noise barriers. It should be noted that the fencing should be installed using galvanized steel to protect the railing/fencing system from long-term corrosion. Refer to City of Ottawa fencing standard - Figure 7.9.

Global and Internal Stability Analysis

The global stability analysis was modeled using Fine by Geo 5, a computer program which permits a two-dimensional slope stability analysis calculating several methods including the Bishop's method, which is a widely accepted slope analysis method. The software further allows for the internal review of the design as per various codes including the CHBDC 2019. The program calculates a factor of safety, which represents the ratio of the forces resisting failure to forces favoring failure. Theoretically, a factor of safety of 1.0 represents a condition where the slope is stable. However, due to intrinsic limitations of the calculation methods and the variability of the subsurface soil and groundwater conditions, a factor of safety greater than 1.0 is generally required for the failure risk to be considered acceptable.

A minimum factor of safety of 1.5 is generally recommended for conditions where the slope failure would comprise permanent structures. An analysis considering seismic loading was also completed. A horizontal acceleration of 0.15 g was considered for the sections for the seismic loading condition. A factor of safety of 1.1 is considered to be satisfactory for stability analyses including seismic loading.

The retaining wall section was reviewed using the design loading according to CHBDC 2015.

The highest retaining wall cross-section was studied as the worst-case scenario. The following parameters were used for the slope stability analysis under static and seismic conditions:

Table 1 - Effective Soil Parameters for Stability Analysis

Soil Layer	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Silty Clay	18	33	5
Granular B Type II	21	36	0

The total strength parameters for seismic analysis were chosen based on our general knowledge of the geology in the area. The strength parameters used for seismic analysis at the slope cross-section are presented in Table 2 below.

Table 2 - Total Strength Soil Parameters for Seismic Analysis

Soil Layer	Unit Weight (kN/m^3)	Friction Angle (degrees)	Cohesion (kPa)
Silty Clay	19	33	100
Granular B Type II	21	36	0

Analysis Results

The factor of safety for the retaining wall section was greater than 1.5 for static conditions. Similarly, the results under seismic loading yielded a factor of safety for this section greater than 1.1.

The internal and structural design reviewed the bearing capacity, overturning resistance, and sliding resistance of the retaining wall units as per various loading conditions described in the CHBDC 2019. All analysis were found to be acceptable, the worst case scenario are presented in attached calculation sheets.

Based on these results, the retaining wall design is considered suitable from a geotechnical perspective.

Geotechnical Recommendations

Backfill Material

The retaining wall should be backfilled with free-draining granular backfill materials and incorporate longitudinal drains and weep holes to provide positive drainage of the backfill. For the purpose of this report, it is recommended that the wall be backfilled with either OPSS Granular B Type II or Granular A materials. The backfill should be placed within a wedge-shaped zone defined by a line drawn up and back from the back edge of the base block of the wall at an inclination of 1H:1V or a minimum of 1 m behind the back of the blocks. All material should be compacted to a minimum of 98% of the material's SPMDD.

Drainage

A 100 mm diameter perforated drainage pipe wrapped in geotextile and surrounded on all sides by 150 mm of clear crushed stone, should be installed at the heel of the bottom block. The drainage should have positive drainage to a nearby outlet such as a catch basin or an existing ditch. It is recommended that the outlets be spaced evenly along the retaining wall with a minimum spacing of 30 m center to center passing through the wall or connected to a nearby catch basin.

Recommendations

It is recommended that the following be completed once the retaining wall design and course of action are determined

- Observation of all bearing surfaces prior to backfill.
- Observation of all subgrades prior to placing backfilling materials.
- Observation of the drainage system prior to backfilling.
- Field density tests to ensure the specified level of compaction was achieved.
- Periodic observation of the retaining wall installation, especially at the first course

A report confirming that these works have been conducted in general accordance with Paterson's recommendations could be issued upon request, following the completion of a satisfactory material testing and observation program by the geotechnical consultant.

We trust the current memorandum satisfies your immediate requirements.

Best Regards,

Paterson Group Inc.

LICENSED PROFESSIONAL ENGINEER
Jan 16, 2023
J. R. VILLENEUVE
100504344
PROVINCE OF ONTARIO

Balaji Nirmala, M.Eng.

Joey R. Villeneuve, M.A.Sc, P.Eng

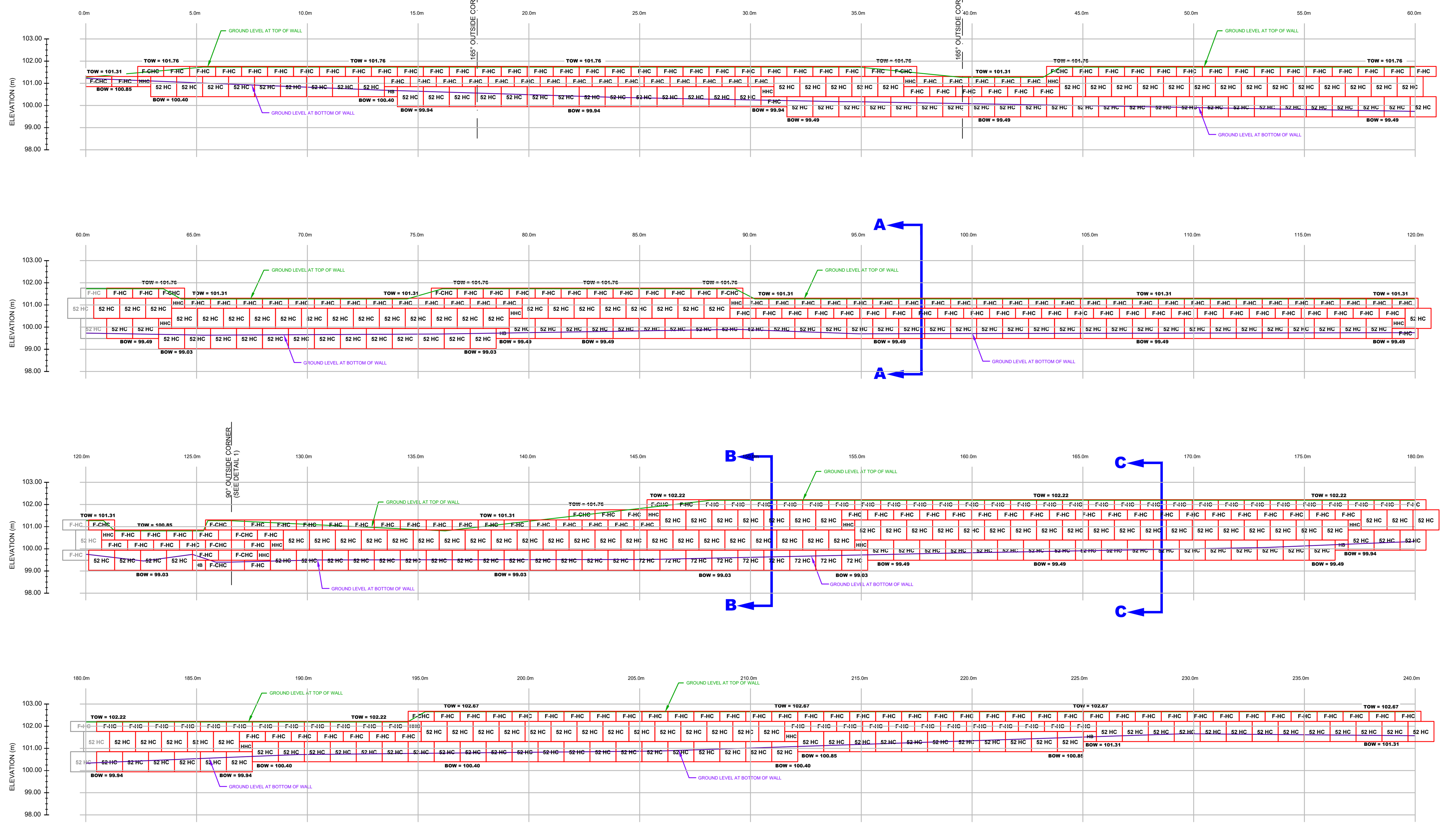
Attachments

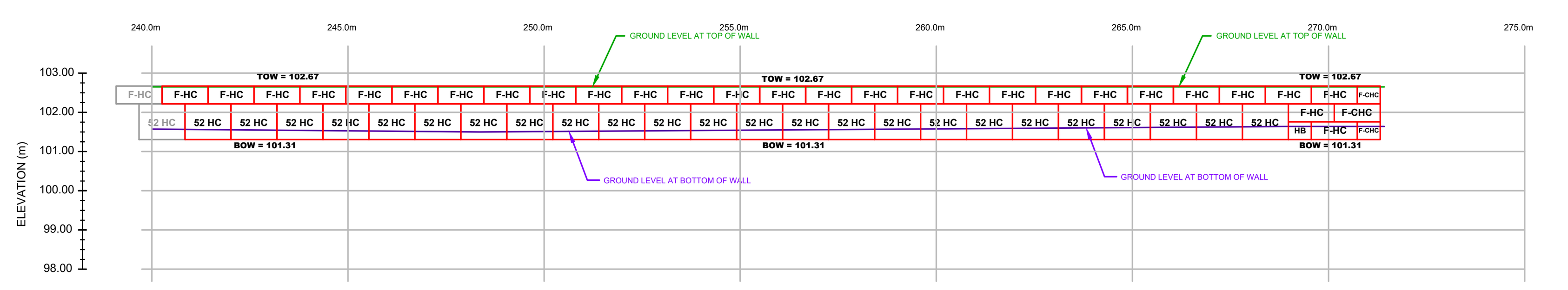
- ❑ PG6353-1 Revision 2 – Redi Rock Retaining wall Design
- ❑ Global Stability Section

PROFILE VIEW (RR1):

ISSUED FOR REVIEW

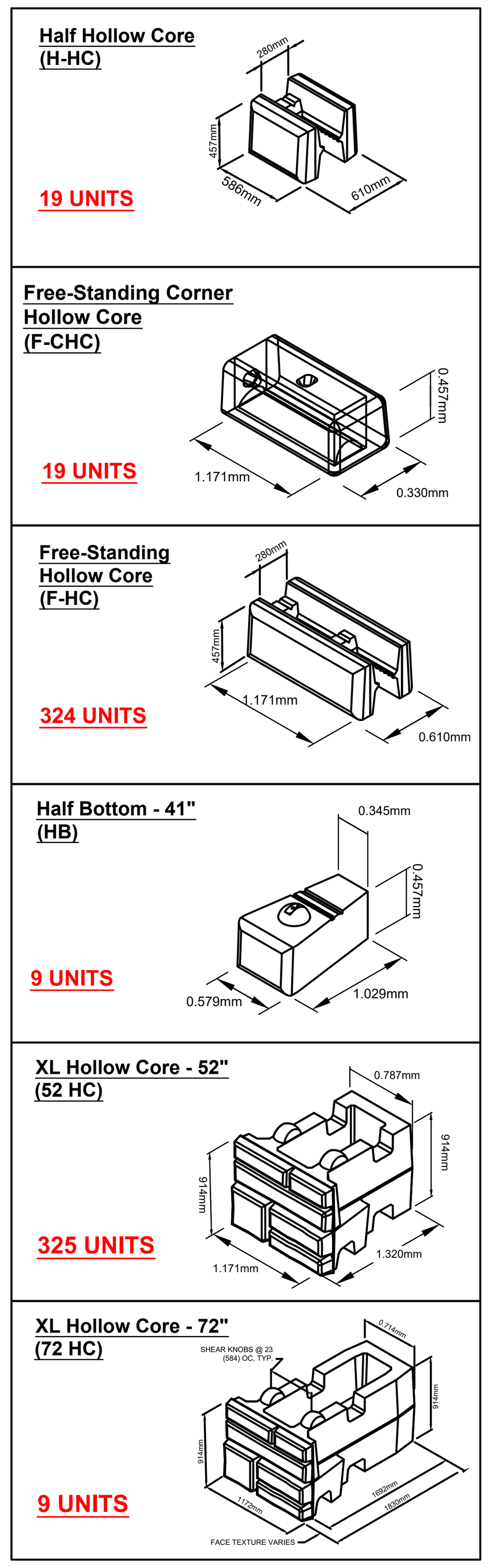
SCALE 1:150





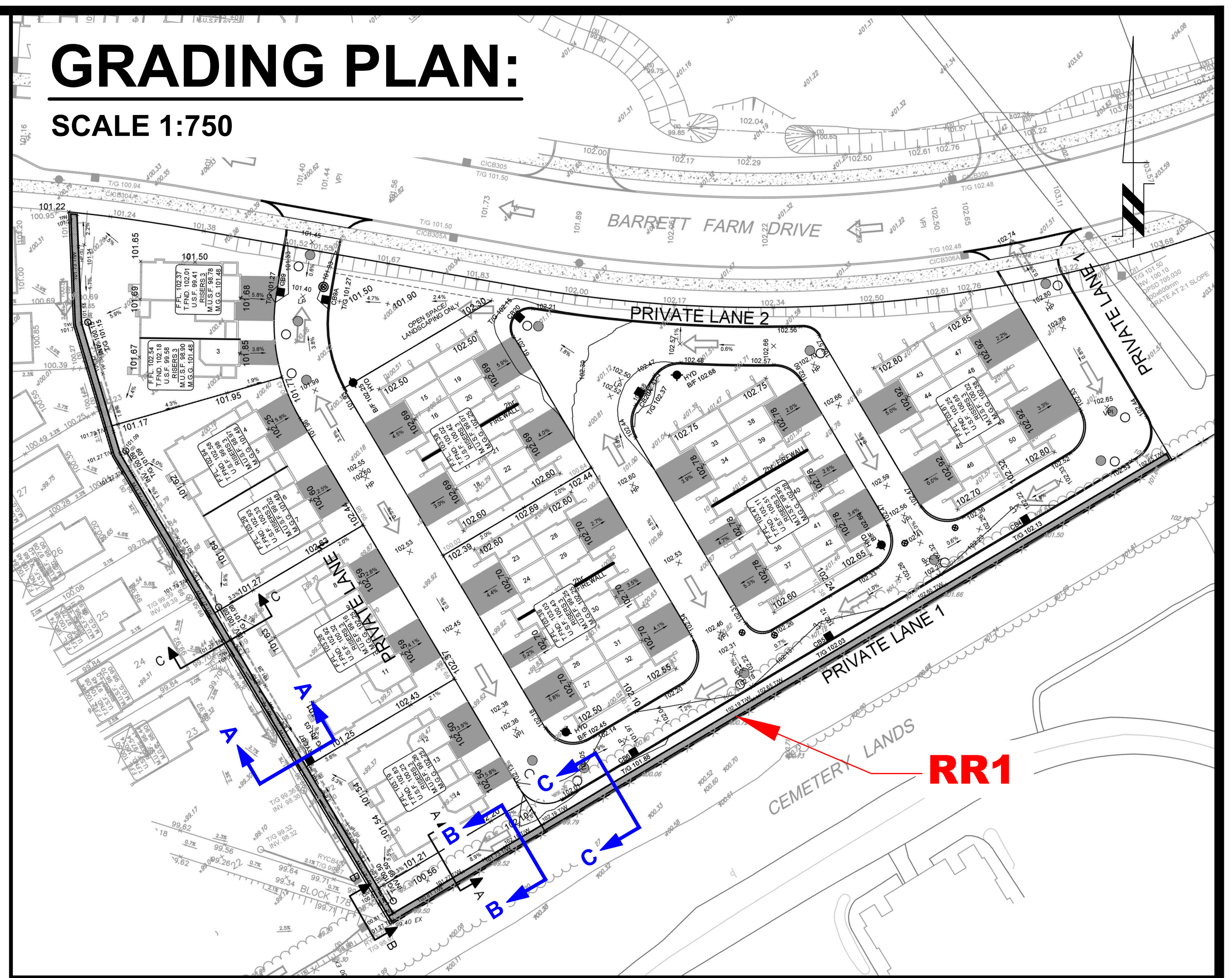
BLOCK COUNT:

N.T.S.



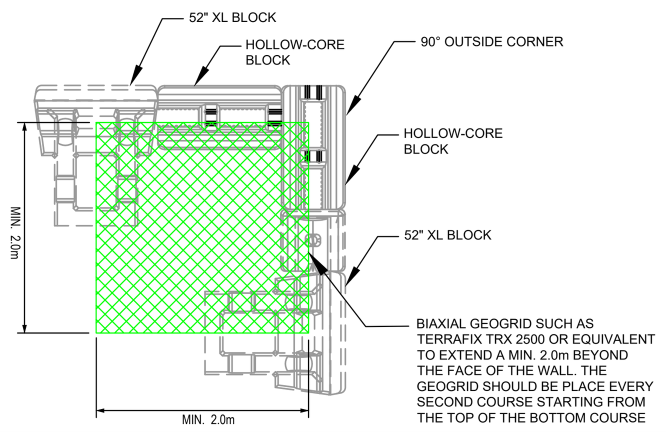
GRADING PLAN:

SCALE 1:750



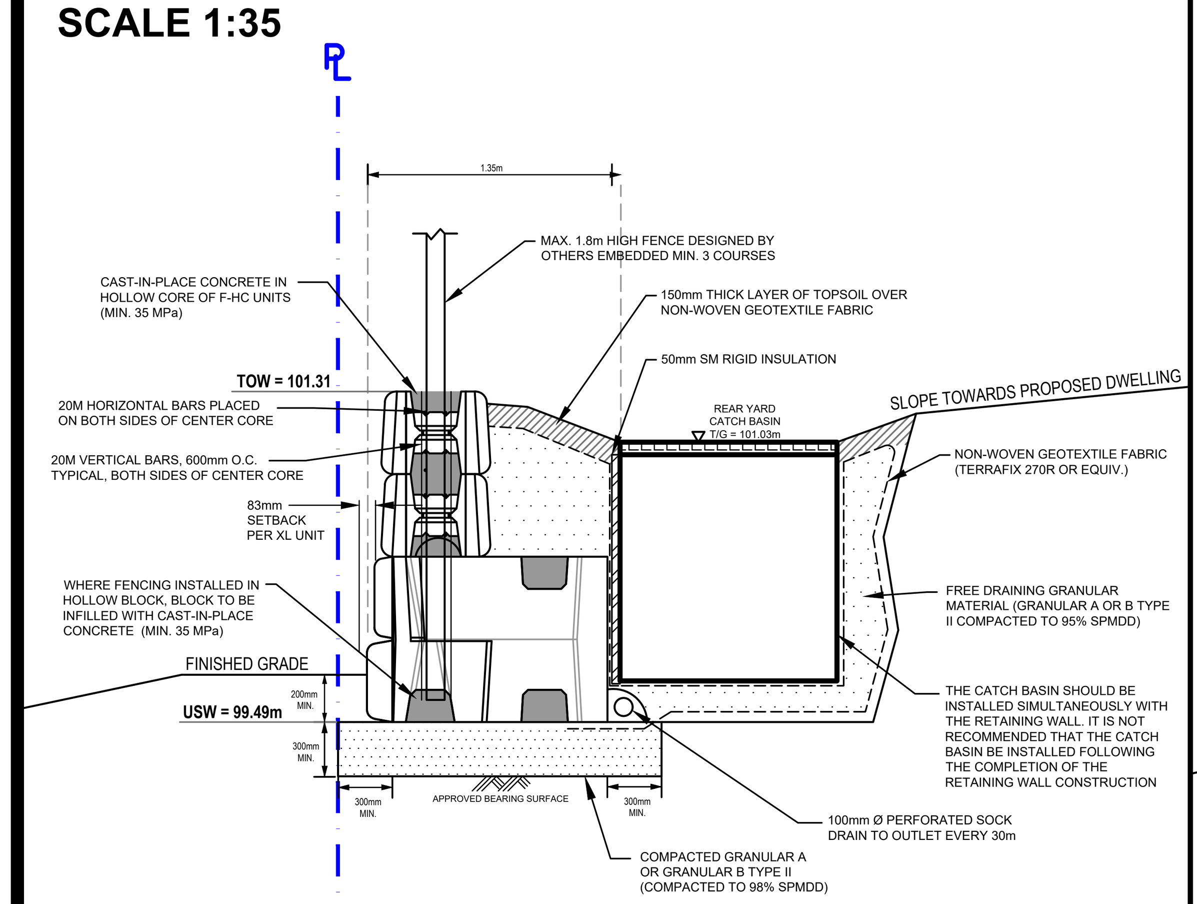
DETAIL 1:

N.T.S.



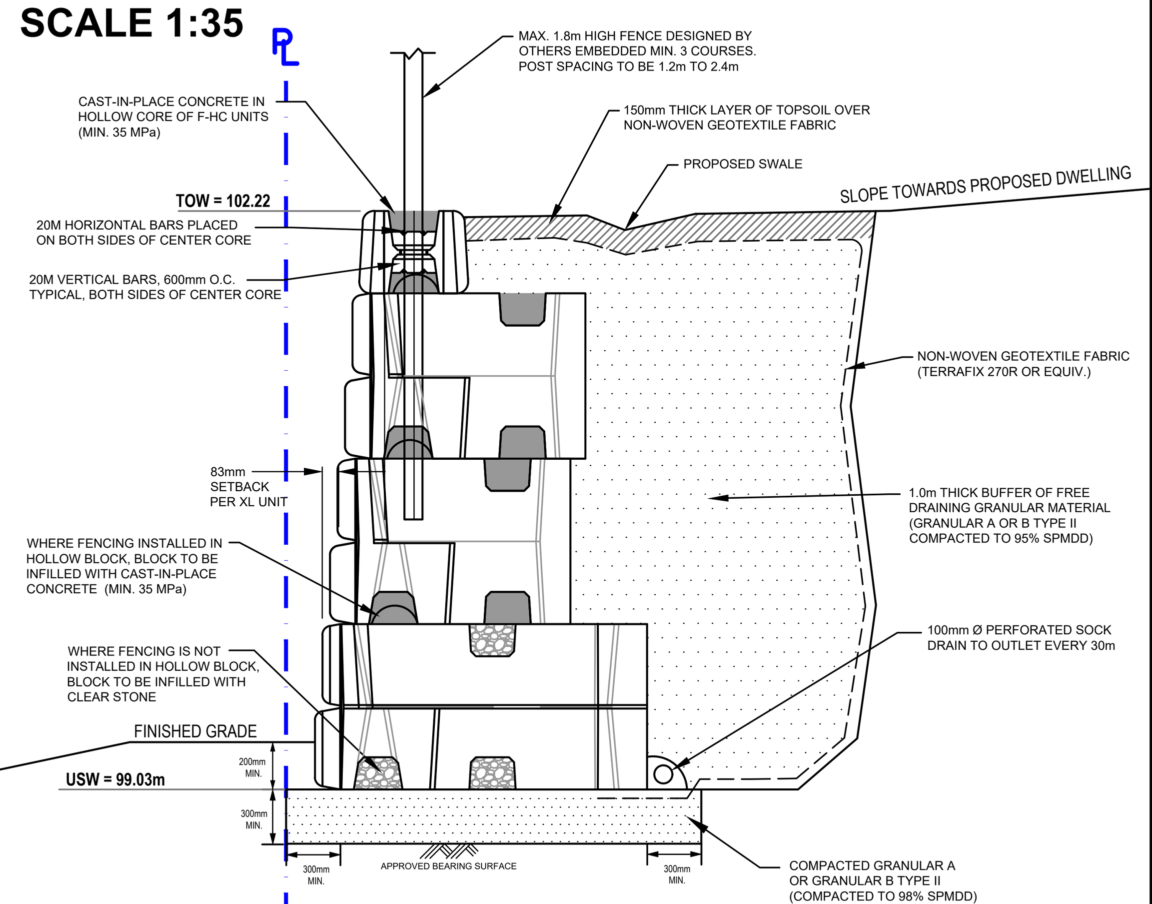
CROSS SECTION A-A:

SCALE 1:35



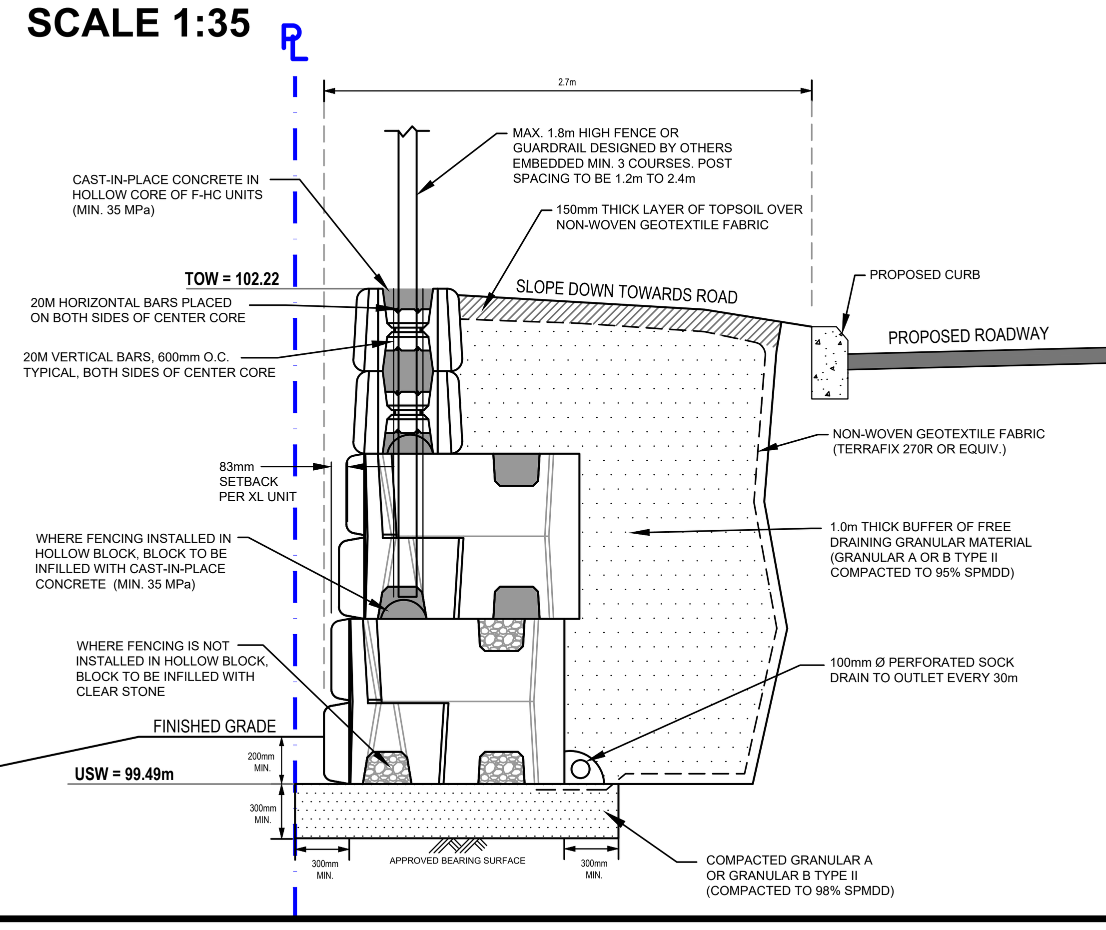
CROSS SECTION B-B:

SCALE 1:35



CROSS SECTION C-C:

SCALE 1:35



NOTES:

1. THE CONTRACTOR IS SOLELY RESPONSIBLE FOR UTILITY CLEARANCES AND CONSTRUCTION SITE SAFETY. PATERSON GROUP SHALL NOT BE RESPONSIBLE FOR MEANS OR METHODS OF CONSTRUCTION OR FOR SAFETY OF WORKERS OR OF THE PUBLIC.
2. THIS DESIGN IS BASED ON THE FOLLOWING SOIL PROPERTIES:

PROPERTY	RETAINED FILL	FOUNDATION MEDIUM (1)
FRICTION ANGLE - ϕ	36°	33°
UNIT WEIGHT - γ	21 kN/m3	18 kN/m3
COHESION - C	0	5 kPa
SOIL TYPE	OPSS GRANULAR B TYPE II	VERY STIFF SILTY CLAY

MATERIAL PROPERTIES ARE BASED ON SITE EVALUATION BY PATERSON GROUP AND DISCUSSIONS WITH CONTRACTOR. SEISMIC LOADING WAS EVALUATED ACCORDING TO THE CURRENT CHBDC WITH A PEAK GROUND ACCELERATION VALUE OF 0.303.

3. THE DESIGN ELEVATIONS USED WERE BASED ON GRADING PLAN PROVIDED BY IBI GROUP, PROJECT No. 135925, SHEET No. 200, GRADING PLAN REVISION 2 DATED NOVEMBER 11, 2022. THE WALL BASE DESIGN ASSUMES A BEARING RESISTANCE AT SLS OF 150 kPa ON VERY STIFF SILTY CLAY. PATERSON GROUP ENGINEER SHOULD OBSERVE THE BEARING CONDITIONS AND ADJUST THE THICKNESS OF THE GRANULAR BASE TO ACCOMMODATE THE SITE CONDITIONS, IF NECESSARY.
4. THE DESIGN HAS BEEN REVIEWED FOR THE STABILITY OF THE PRECAST MODULAR RETAINING WALL SYSTEM AND GLOBAL STABILITY WITH A FACTOR OF SAFETY OF 1.5 FOR STATIC CONDITIONS AND 1.1 UNDER SEISMIC CONDITIONS. WALL GEOMETRY AND GRADE ELEVATIONS ABOVE AND BELOW THE WALL SHOULD CONFORM WITH THE GRADING PLAN PROVIDED HERE IN. IF ACTUAL SITE GRADES VARY SIGNIFICANTLY FROM THOSE SHOWN OR IF THE BACK SLOPE DOES NOT CONFORM, INSTALLATION SHALL NOT PROCEED UNTIL THE DESIGN IS VERIFIED OR MODIFIED IN THE APPLICABLE AREA.
5. PRECAST UNITS SHALL BE REDI-ROCK RETAINING WALL UNITS MANUFACTURED UNDER LICENSE FROM REDI-ROCK.
6. THE WALL BASE FOR THE WALL SHALL CONSIST OF A MIN. 300mm THICK OPSS GRANULAR A COMPACTED TO MIN. 98% OF THE MATERIALS SPMDD AND TESTED BY PATERSONGROUP GEOTECHNICAL PERSONNEL AT THE TIME OF CONSTRUCTION. SURFACE OF GRANULAR BASE MAY BE DRESSED WITH FINER AGGREGATE TO AID LEVELING. ENSURE GRADATION OF DRESSING MATERIAL IS SUCH AS TO PRECLUDE LOSS OF FINES INTO BASE. THE THICKNESS OF DRESSING LAYER SHOULD NOT EXCEED 3 TIMES THE MAXIMUM PARTICLE SIZE USED.
7. WALL IS DESIGNED WITH A MIN. 200mm TOE EMBEDMENT WITH A MIN. HORIZONTAL LEDGE WITH A GRANULAR BEDDING LAYER EXTENDING A MIN. 300mm BEYOND THE FACE AND HEEL OF THE BASE BLOCK
8. INSTALL 100mm DIAMETER PERFORATED PIPE WRAPPED WITH A GEOSOCK DRAIN BEHIND HEEL OR UNDER THE WALL. PROVIDE CLEAR STONE SURROUND TO PROTECT PIPE FROM CLOGGING AND DAMAGE. PROVIDE OUTLETS THROUGH WALL, NO FURTHER APART THAN 10.0m ON CENTRES. THE DRAINAGE PIPE SHOULD BE CONNECTED TO A POSITIVE OUTLET ON BOTH ENDS OF THE RETAINING WALL SUCH AS AN EXISTING DITCH OR CATCH BASIN.
9. THE CONDITIONS WILL BE EVALUATED BY THE GEOTECHNICAL ENGINEER DURING PREPARATION FOR WALL CONSTRUCTION IN EACH AREA. WHERE GRANULAR BEDDING WILL NOT BE SUFFICIENT THE USE OF CONCRETE BEDDING MAY BE REQUIRED.
10. ALIGNMENT OF THE BOTTOM WALL UNIT COURSE SHOULD BE PLANNED TO CONSIDER THAT A NOMINAL 41mm AUTOMATIC SETBACK WILL OCCUR WITH EACH 0.46m INCREMENT OF HEIGHT.
11. BACKFILL MATERIAL SHALL BE APPROVED BY THE SITE GEOTECHNICAL ENGINEER PRIOR TO USE AND SHOULD CONSIST OF OPSS GRANULAR A OR B TYPE II FOLLOWED BY SUITABLE BACKFILL MATERIAL. ALL FILL WITHIN A 1H:1V ZONE UP AND BACK FROM THE HEEL SHOULD ALSO BE COMPACTED. BACKFILL SHALL BE PLACED IN MAXIMUM 300mm LOOSE LIFTS AND COMPACTED TO A MINIMUM OF 95% OF SPMDD. MOISTURE CONTENT SHOULD BE CONTROLLED AND MAINTAINED WITHIN -3 TO +4 PERCENT OF OPTIMUM.
12. MAINTAIN TEMPORARY GRADES TO DIVERT SURFACE WATER AWAY FROM THE RETAINING WALL EXCAVATION. SLOPE FINAL BACKFILL TO PROVIDE POSITIVE DRAINAGE AND TO ELIMINATE PONDING.
13. BACKSLOPE SHOULD BE CUT BACK TO A MINIMUM OF 2H:1V TO 3H:1V TO MAINTAIN A LONG TERM SAFE SLOPE BEHIND THE RETAINING WALL. IT SHOULD BE NOTED THAT WHERE TREES ARE PRESENT WITHIN THE TOP OF SLOPE. A MINIMUM 1.0m SET BACK IS REQUIRED FOR EXCAVATION FROM THE EDGE OF THE TREE LINE WHERE PRESENT.
14. EXCAVATION SIDE SLOPES SHOULD BE PROTECTED TEMPORARILY DURING CONSTRUCTION FROM PRECIPITATION EVENTS BY PLACEMENT OF TARPS.
15. ALL RETAINING WALL RELATED INSPECTIONS (BEARING SURFACE, COMPACTION, BLOCK INSTALLATION, ETC.) MUST BE COMPLETED BY PATERSON GROUP. ONCE THE WALL CONSTRUCTION IS COMPLETED AND REVIEWED BY PATERSON DURING CONSTRUCTION, A CERTIFICATE LETTER WILL BE ISSUED BY PATERSON GROUP.
16. ANY CUTTING OF BLOCKS TO SUIT SITE CONDITIONS OR WALL DESIGN WILL BE RESPONSIBILITY OF THE CONTRACTOR.
17. IF WINTER CONSTRUCTION IS CONSIDERED, HEAT MUST BE MAINTAINED WHEN THE BASE IS EXPOSED. THE WALL BASE MUST COVERED WITH HIGH GRADE INSULATION TARPS TO MAINTAIN HEAT AND PROTECT THE BASE FROM POTENTIAL FROST HEAVE. ONCE THE BASE IS BACKFILLED, THE TOP OF THE WALL MUST BE COVERED WITH INSULATION TARPS OVERNIGHT UNTIL THE WALL CONSTRUCTION IS COMPLETED. ADDITIONAL INSPECTIONS WILL BE REQUIRED DURING WINTER CONSTRUCTION TO ENSURE THE WALL CONSTRUCTION IS IN GENERAL CONFORMANCE WITH PATERSON'S RECOMMENDATIONS.
18. THE CONTRACTOR SHOULD REFER TO THE INSTALLATION MANUAL PROVIDED FOR THE RETAINING WALL BLOCK TYPE PROVIDED HEREIN FOR ADDITIONAL DETAILS ON ACCEPTABLE INSTALLATION PRACTICES.

PATERSON GROUP
9 AURIGA DRIVE
OTTAWA, ON
K2E 7S9
TEL: (613) 226-7381

NO.	REVISIONS	DATE	INITIAL
2	AS PER REVISED FENCING DETAIL	13/01/2023	JV
1	AS PER REVISED GRADING PLAN	14/11/2022	JV

BARRETT CO-TENANCY c/o IBI GROUP

PROPOSED RESIDENTIAL DEVELOPMENT
BARRETT LANDS - BLOCK 148

OTTAWA, ONTARIO

Title: **REDI-ROCK RETAINING WALL DESIGN (RR1)**

Stamp: LICENSED PROFESSIONAL ENGINEER 13/01/2023 J. R. VILLENEUVE 100504344 PROVINCE OF ONTARIO

Stamp: LICENSED PROFESSIONAL ENGINEER 13/01/2023 F. I. ABOU-SEIDO 100156744 PROVINCE OF ONTARIO

Scale:	AS SHOWN
Drawn by:	NFRV
Checked by:	JV
Approved by:	FA
Date:	07/2022
File No.:	PG6353
Drawing No.:	PG6353-1
Revision No.:	2

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Analysis of Redi Rock wall

Input data

Task : Global Stability
Description : Barrett Lands - Block 148
Customer : Barrett Co-Tenancy c o IBI Group
Author : Balaji Nirmala, M.Eng
Date : 1/11/2023
Project number : PG6353

Settings

Canadian Highway and Bridge Design Code

Wall analysis

Verification methodology : according to LRFD
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Mazindrani (Rankine)
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Internal stability : Standard - straight slip surface
Reduction coeff. of contact first block - base : 1.00

Load factors					
Design situation - Service I					
		Minimum		Maximum	
Dead load of structural components :	DC =	1.00	[–]	1.00	[–]
Dead load of wearing surfaces :	DW =	1.00	[–]	1.00	[–]
Earth pressure - active :	EH_A =	1.00	[–]	1.00	[–]
Earth pressure - at rest :	EH_R =	1.00	[–]	1.00	[–]
Earth surcharge load (permanent) :	ES =	1.00	[–]	1.00	[–]
Vertical pressure of earth fill :	EV =	1.00	[–]	1.00	[–]
Live load surcharge :	LL =	0.00	[–]	1.00	[–]
Water load :	WA =	1.00	[–]	1.00	[–]

Resistance factors			
Design situation - Service I			
Resistance factor on overturning :	φ_o =	1.00	[–]
Resistance factor on sliding :	φ_t =	1.00	[–]
Resistance factor on bearing capacity :	φ_b =	1.00	[–]
Resistance factor on passive pressure :	φ_{VE} =	1.00	[–]

Blocks

No.	Description	Height h [mm]	Width w [mm]	Unit weight γ [kN/m³]
1	Block 28	457.2	711.2	18.85
2	Block 41	457.2	1028.7	18.85
3	Block 60	457.2	1524.0	20.42

No.	Description	Height h [mm]	Width w [mm]	Unit weight γ [kN/m³]
4	Top block 24 straight	457.2	609.6	16.97
5	Planter 41	457.2	1028.7	18.85
6	Planter 60	457.2	1524.0	17.59
7	Top block 28	457.2	711.2	18.85
8	Top block 41	457.2	1028.7	18.85
9	Top block 24 straight garden	457.2	609.6	12.57
10	Block R-5236 HC	914.4	1320.8	17.28
11	Block R-7236 HC	914.4	1828.8	17.28
12	Block R-9636 HC	914.4	2438.4	17.28
13	Block R-41 HC	457.2	1028.7	17.28

No.	Description	Min. shear strength F_{min} [kN/m]	Max. shear strength F_{max} [kN/m]	Friction f [°]
1	Block 28	88.45	164.56	44.00
2	Block 41	88.45	164.56	44.00
3	Block 60	88.45	164.56	44.00
4	Top block 24 straight	88.45	164.56	44.00
5	Planter 41	88.45	164.56	44.00
6	Planter 60	88.45	164.56	44.00
7	Top block 28	88.45	164.56	44.00
8	Top block 41	88.45	164.56	44.00
9	Top block 24 straight garden	88.45	164.56	44.00
10	Block R-5236 HC	66.40	175.13	44.00
11	Block R-7236 HC	66.40	175.13	44.00
12	Block R-9636 HC	66.40	175.13	44.00
13	Block R-41 HC	78.19	188.35	37.00

Setbacks

No.	Setback s [mm]
1	0.254
2	9.525
3	41.275
4	238.125
5	422.275

Geometry

No. group	Description	Count	Setback s [mm]
1	Block R-7236 HC	1	82.6
2	Block R-5236 HC	2	82.6
3	Top block 24 straight	1	-

Base

Geometry

Upper setback a_1 = 0.30 m
Lower setback a_2 = 0.30 m
Height h = 0.30 m
Width b = 2.40 m

Material

Soil creating foundation - Granular

Basic soil parameters

No.	Name	Pattern	ϕ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
1	Granular		36.00	0.00	22.00	12.00	28.00
2	Silty Clay		33.00	5.00	18.00	8.00	27.00

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Granular

Unit weight : γ = 22.00 kN/m³
Stress-state : effective
Angle of internal friction : ϕ_{ef} = 36.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Angle of friction struc.-soil : δ = 28.00 °
Saturated unit weight : γ_{sat} = 22.00 kN/m³

Silty Clay

Unit weight : γ = 18.00 kN/m³
Stress-state : effective
Angle of internal friction : ϕ_{ef} = 33.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Angle of friction struc.-soil : δ = 27.00 °
Saturated unit weight : γ_{sat} = 18.00 kN/m³

Backfill

Assigned soil : Granular
Slope = 45.00 °

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	0.50	0.00 .. 0.50	Granular	
2	-	0.50 .. ∞	Silty Clay	

Terrain profile

Terrain behind the structure is flat.

Water influence

Ground water table is located below the structure.

Input surface surcharges

No.	Surcharge		Action	Mag.1	Mag.2	Ord.x	Length	Depth
	new	change		[kN/m²]	[kN/m²]	x [m]	l [m]	z [m]
1	Yes		variable	12.00				on terrain

Resistance on front face of the structure

Resistance on front face of the structure: at rest
Soil on front face of the structure - Silty Clay
Soil thickness in front of structure h = 0.50 m

Terrain in front of structure is flat.

Applied forces acting on the structure

No.	Force		Name	Action	F_x	F_z	M	x	z
	new	edit			[kN/m]	[kN/m]	[kNm/m]	[m]	[m]
1	Yes		Fence Load	permanent	0.00	3.00	0.00	-0.30	0.00

Settings of the stage of construction

Design situation : Service I
Reduction of soil/soil friction angle : do not reduce

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.00	-1.39	90.17	1.14	1.000	1.000	1.000
FF resistance	-1.02	-0.17	0.00	-0.15	1.000	1.000	1.000
Weight - earth wedge	0.00	-0.48	1.59	2.22	1.000	1.000	1.000
Weight - earth wedge	0.00	-1.47	3.59	1.86	1.000	1.000	1.000
Weight - earth wedge	0.00	-3.26	5.28	1.40	1.000	1.000	1.000
Active pressure	30.69	-1.17	41.52	2.10	1.000	1.000	1.000
Surch.1 - surface	9.78	-1.72	12.87	1.97	1.000	1.000	1.000
Surch.1 - surface	0.00	-3.50	4.75	1.36	0.000	0.000	1.000
Fence Load	0.00	-3.50	3.00	0.86	1.000	1.000	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 235.10 kNm/m
Overturning moment M_{ovr} = 52.59 kNm/m

Capacity demand ratio CDR = 4.47

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 114.17 kN/m

Active horizontal force H_{act} = 39.44 kN/m

Capacity demand ratio CDR = 2.89

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.00	-1.35	74.33	0.82	1.000	1.000	1.000
Weight - earth wedge	0.00	-1.17	3.59	1.56	1.000	1.000	1.000
Weight - earth wedge	0.00	-2.96	5.28	1.10	1.000	1.000	1.000
Active pressure	24.95	-1.08	25.79	1.66	1.000	1.000	1.000
Surch.1 - surface	8.60	-1.62	9.89	1.56	1.000	1.000	1.000
Surch.1 - surface	0.00	-3.20	4.75	1.06	0.000	0.000	1.000
Fence Load	0.00	-3.20	3.00	0.56	1.000	1.000	1.000

Verification of most stressed block No. 1

Check for overturning stability

Resisting moment M_{res} = 132.62 kNm/m
Overturning moment M_{ovr} = 40.81 kNm/m

Capacity demand ratio CDR = 3.25

Joint for overturning stability is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 88.55 kN/m
Active horizontal force H_{act} = 33.55 kN/m

Capacity demand ratio CDR = 2.64

Joint for verification is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	6.38	162.77	39.44	0.016	70.11
2	7.12	158.02	39.44	0.019	68.41

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	6.38	162.77	39.44
2	7.12	158.02	39.44

Verification of foundation soil

Stress in the footing bottom : rectangle

Eccentricity verification

Max. eccentricity of normal force e = 0.019
Maximum allowable eccentricity e_{alw} = 0.333

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom σ = 70.11 kPa
Bearing capacity of foundation soil R_d = 150.00 kPa
Capacity demand ratio CDR = 2.14

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Slope stability analysis (Static Loading)

Input data (Construction stage 1)

Project

Settings

Canadian Highway and Bridge Design Code

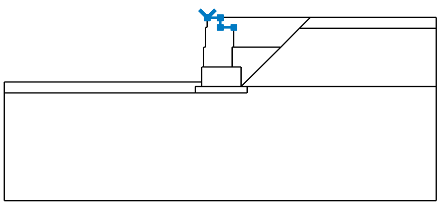
Stability analysis

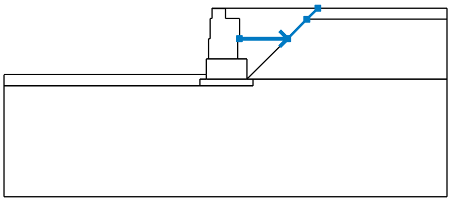
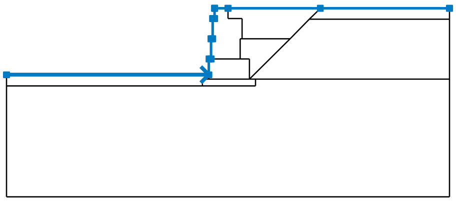
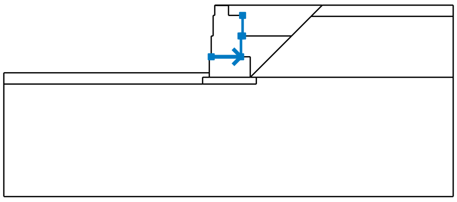
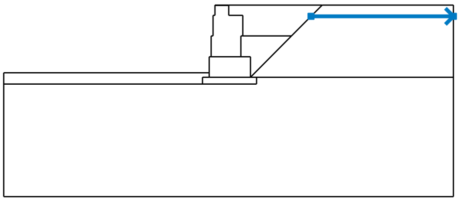
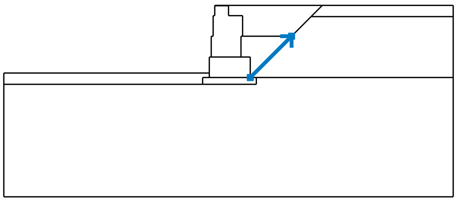
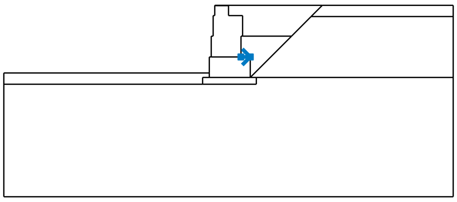
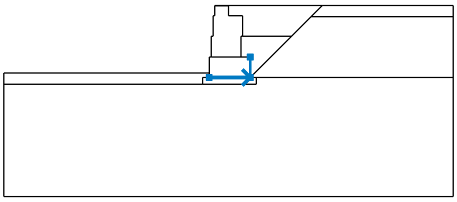
Verification methodology : according to LRFD
Earthquake analysis : Standard

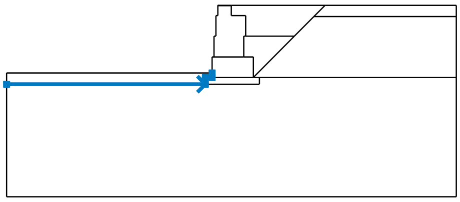
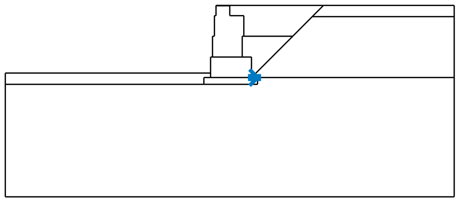
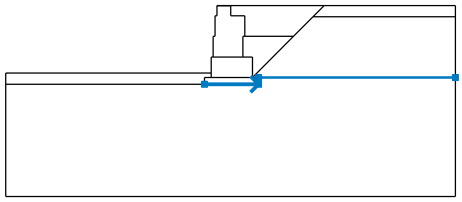
Load factors					
Design situation - Service I					
		Minimum		Maximum	
Earth surcharge load (permanent) :	ES =	1.00	[–]	1.00	[–]
Live load surcharge :	LL =	0.00	[–]	1.00	[–]

Resistance factors			
Design situation - Service I			
Resistance factor on stability :	φ_{SS} =	0.65	[–]

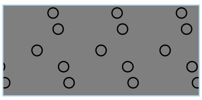
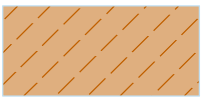
Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-0.60	0.00	-0.60	-0.01	0.00	-0.01
		0.00	-0.46	0.63	-0.46		

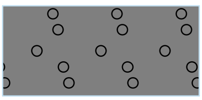
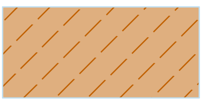
No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
2		0.63	-1.37	2.80	-1.37	3.67	-0.50
		4.17	0.00				
3		-10.00	-3.00	-0.86	-3.00	-0.86	-2.29
		-0.77	-2.29	-0.77	-1.37	-0.69	-1.37
		-0.69	-0.46	-0.61	-0.46	-0.61	0.00
		-0.60	0.00	0.00	0.00	4.17	0.00
		10.00	0.00				
4		-0.77	-2.29	0.55	-2.29	0.55	-1.37
		0.63	-1.37	0.63	-0.46		
5		3.67	-0.50	10.00	-0.50		
6		0.97	-3.20	2.80	-1.37		
7		0.55	-2.29	0.97	-2.29		
8		-0.86	-3.20	0.97	-3.20	0.97	-2.29

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
9		-10.00	-3.50	-1.16	-3.50	-1.16	-3.20
		-0.86	-3.20	-0.86	-3.00		
10		0.97	-3.20	1.24	-3.20		
11		-1.16	-3.50	1.24	-3.50	1.24	-3.20
		10.00	-3.20				

Soil parameters - effective stress state

No.	Name	Pattern	ϕ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Granular		36.00	0.00	22.00
2	Silty Clay		33.00	5.00	18.00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Granular		22.00		
2	Silty Clay		18.00		

Soil parameters

Granular

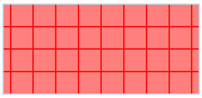
Unit weight : γ = 22.00 kN/m³

Stress-state : effective

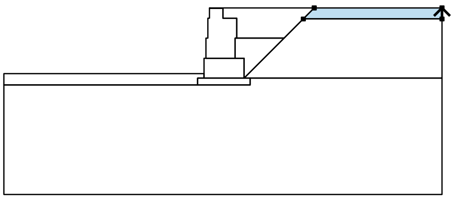
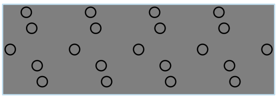
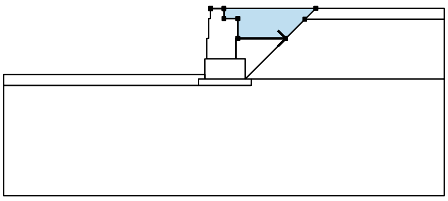
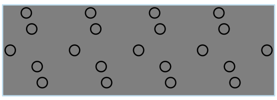
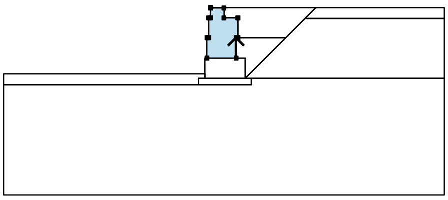
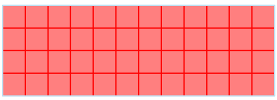
Shear strength : Mohr-Coulomb
Angle of internal friction : ϕ_{ef} = 36.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Saturated unit weight : γ_{sat} = 22.00 kN/m3

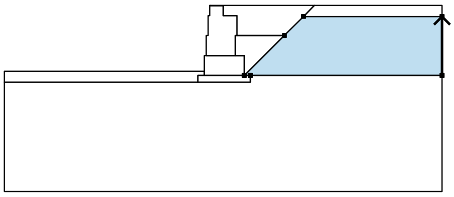
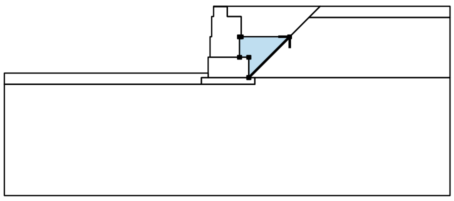
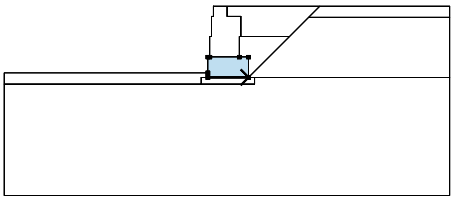
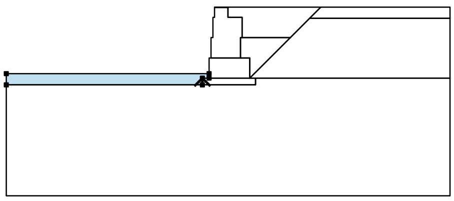
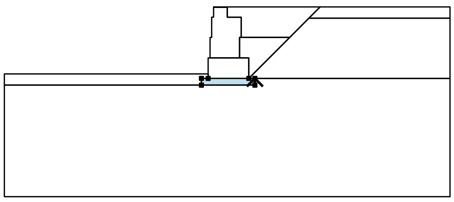
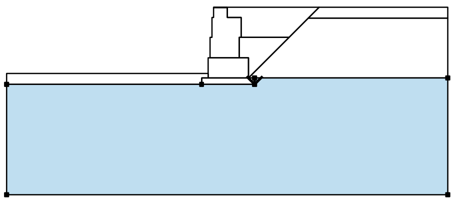
Silty Clay
Unit weight : γ = 18.00 kN/m3
Stress-state : effective
Shear strength : Mohr-Coulomb
Angle of internal friction : ϕ_{ef} = 33.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Saturated unit weight : γ_{sat} = 18.00 kN/m3

Rigid Bodies

No.	Name	Sample	γ [kN/m3]
1	Material of structure		18.85

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		10.00	-0.50	10.00	0.00	Granular
		4.17	0.00	3.67	-0.50	
2		0.63	-1.37	2.80	-1.37	Granular
		3.67	-0.50	4.17	0.00	
		0.00	0.00	-0.60	0.00	
		-0.60	-0.01	0.00	-0.01	
		0.00	-0.46	0.63	-0.46	
3		0.55	-2.29	0.55	-1.37	Material of structure
		0.63	-1.37	0.63	-0.46	
		0.00	-0.46	0.00	-0.01	
		-0.60	-0.01	-0.60	0.00	
		-0.61	0.00	-0.61	-0.46	
		-0.69	-0.46	-0.69	-1.37	
		-0.77	-1.37	-0.77	-2.29	

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
4		10.00	-3.20	10.00	-0.50	Silty Clay
		3.67	-0.50	2.80	-1.37	
		0.97	-3.20	1.24	-3.20	
5		0.97	-3.20	2.80	-1.37	Granular
		0.63	-1.37	0.55	-1.37	
		0.55	-2.29	0.97	-2.29	
6		-0.86	-3.20	0.97	-3.20	Material of structure
		0.97	-2.29	0.55	-2.29	
		-0.77	-2.29	-0.86	-2.29	
		-0.86	-3.00			
7		-1.16	-3.50	-1.16	-3.20	Silty Clay
		-0.86	-3.20	-0.86	-3.00	
		-10.00	-3.00	-10.00	-3.50	
8		1.24	-3.50	1.24	-3.20	Granular
		0.97	-3.20	-0.86	-3.20	
		-1.16	-3.20	-1.16	-3.50	
9		1.24	-3.20	1.24	-3.50	Silty Clay
		-1.16	-3.50	-10.00	-3.50	
		-10.00	-8.50	10.00	-8.50	
		10.00	-3.20			

Surcharge

No.	Type	Type of action	Location	Origin	Length	Width	Slope	Magnitude		
			z [m]	x [m]	l [m]	b [m]	α [°]	q, q_1, f, F, x	q_2, z	unit
1	strip	variable	on terrain	x = 0.00	l = 10.00		0.00	12.00		kN/m^2

Water

Water type : No water

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : Service I

Results (Construction stage 1)

Analysis 1

Circular slip surface

Slip surface parameters								
Center :	x =	-1.31	[m]	Angles :	α_1 =	-35.94	[°]
	z =	0.53	[m]		α_2 =	83.02	[°]
Radius :	R =	4.36	[m]				
The slip surface after optimization.							

Total weight of soil above the slip surface: 248.72 kN/m

Slope stability verification (Bishop)

Sum of active forces : F_a = 123.50 kN/m

Sum of passive forces : F_p = 226.77 kN/m

Sliding moment : M_a = 538.48 kNm/m

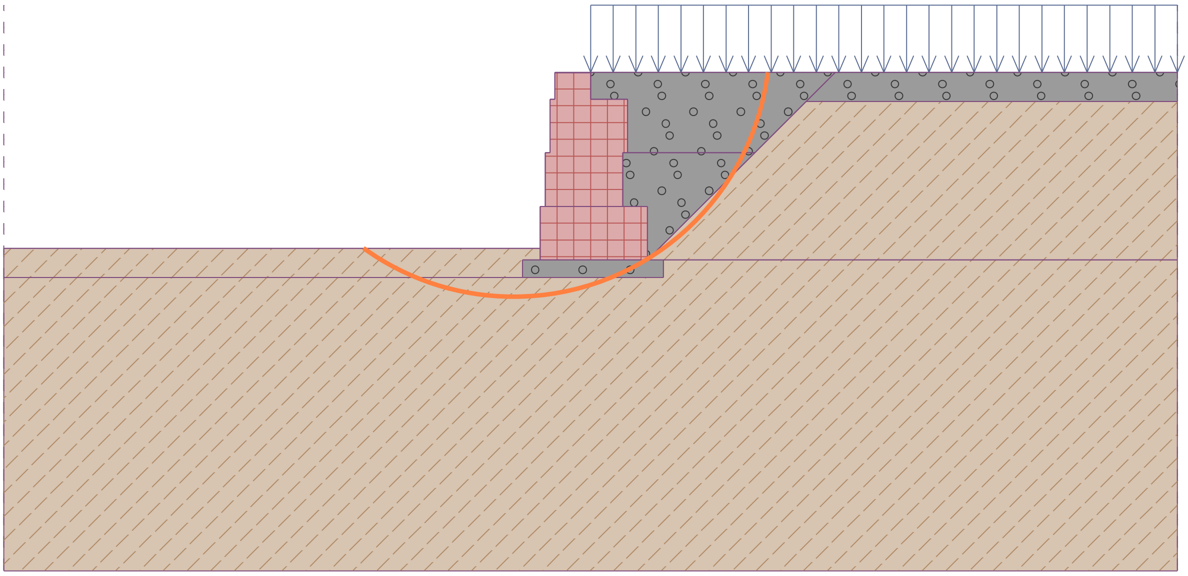
Resisting moment : M_p = 642.66 kNm/m

Utilization : 83.8 %

Capacity demand ratio CDR: 1.193

Slope stability ACCEPTABLE

Name : Analysis	Stage - analysis : 1 - 1



Slope stability analysis (Seismic Loading)

Input data (Construction stage 1)

Project

Settings

Canadian Highway and Bridge Design Code

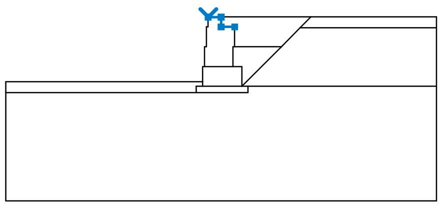
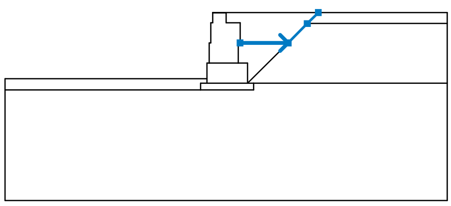
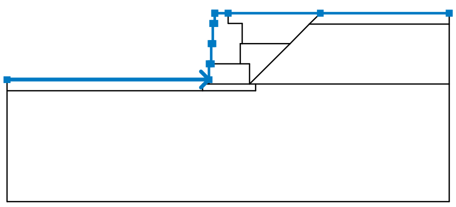
Stability analysis

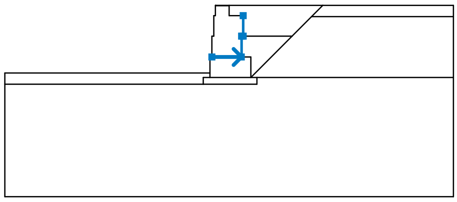
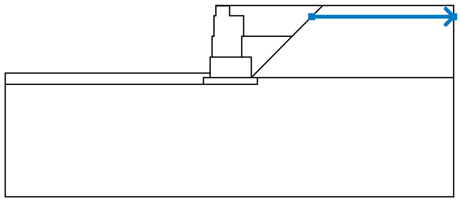
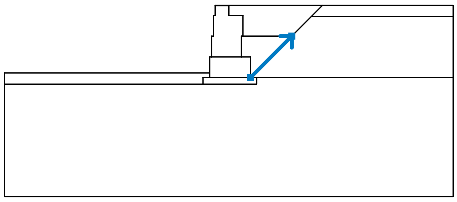
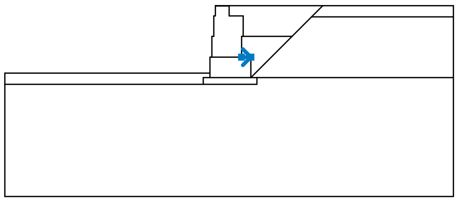
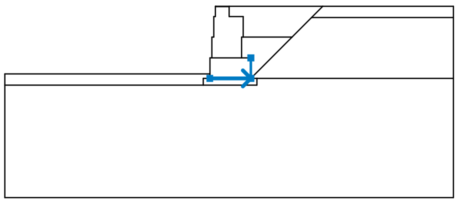
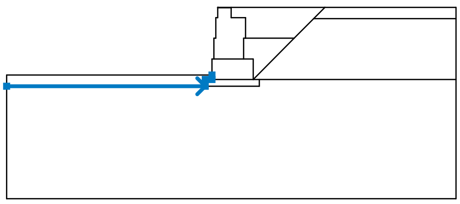
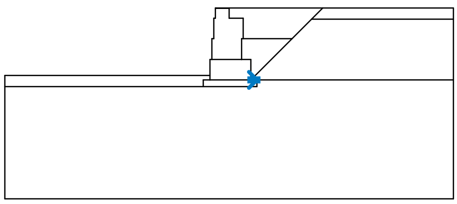
Verification methodology : according to LRFD
Earthquake analysis : Standard

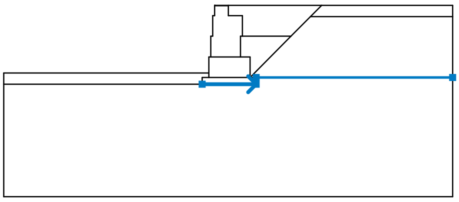
Load factors			
Design situation - Service I			
		Minimum	Maximum
Earth surcharge load (permanent) :	ES =	1.00 [–]	1.00 [–]
Live load surcharge :	LL =	0.00 [–]	1.00 [–]

Resistance factors		
Design situation - Service I		
Resistance factor on stability :	φ_{SS} =	0.65 [–]

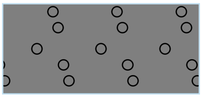
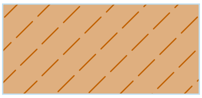
Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-0.60	0.00	-0.60	-0.01	0.00	-0.01
		0.00	-0.46	0.63	-0.46		
2		0.63	-1.37	2.80	-1.37	3.67	-0.50
		4.17	0.00				
3		-10.00	-3.00	-0.86	-3.00	-0.86	-2.29
		-0.77	-2.29	-0.77	-1.37	-0.69	-1.37
		-0.69	-0.46	-0.61	-0.46	-0.61	0.00
		-0.60	0.00	0.00	0.00	4.17	0.00
		10.00	0.00				

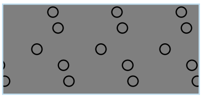
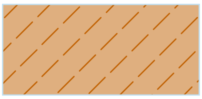
No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
4		-0.77	-2.29	0.55	-2.29	0.55	-1.37
		0.63	-1.37	0.63	-0.46		
5		3.67	-0.50	10.00	-0.50		
6		0.97	-3.20	2.80	-1.37		
7		0.55	-2.29	0.97	-2.29		
8		-0.86	-3.20	0.97	-3.20	0.97	-2.29
9		-10.00	-3.50	-1.16	-3.50	-1.16	-3.20
		-0.86	-3.20	-0.86	-3.00		
10		0.97	-3.20	1.24	-3.20		

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
11		-1.16	-3.50	1.24	-3.50	1.24	-3.20
		10.00	-3.20				

Soil parameters - effective stress state

No.	Name	Pattern	ϕ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Granular		36.00	0.00	22.00
2	Silty Clay		33.00	100.00	18.00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Granular		22.00		
2	Silty Clay		18.00		

Soil parameters

Granular

Unit weight : γ = 22.00 kN/m³
Stress-state : effective
Shear strength : Mohr-Coulomb
Angle of internal friction : ϕ_{ef} = 36.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Saturated unit weight : γ_{sat} = 22.00 kN/m³

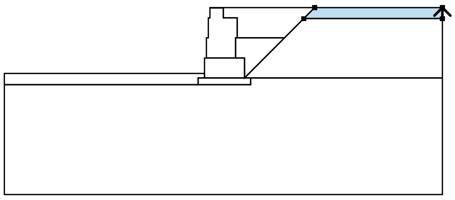
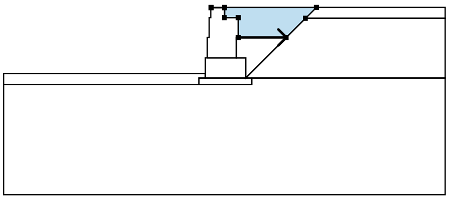
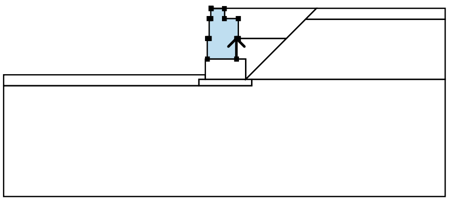
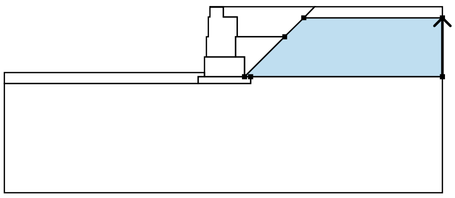
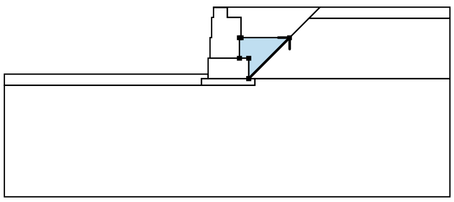
Silty Clay

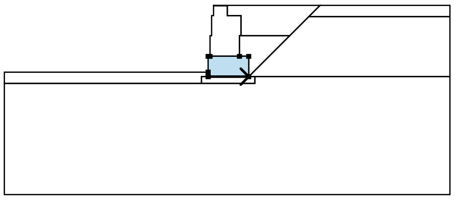
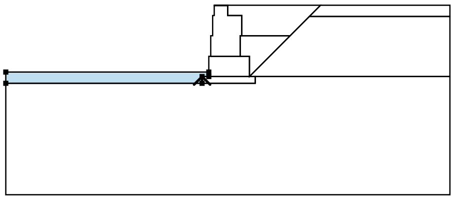
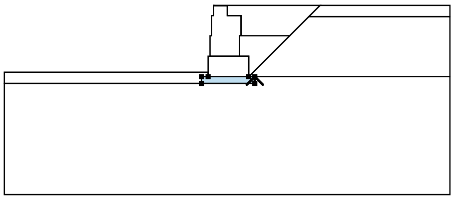
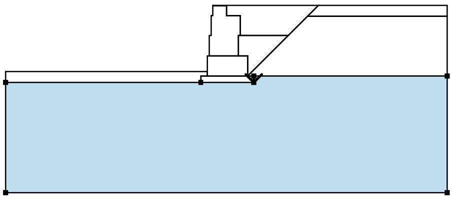
Unit weight : γ = 18.00 kN/m³
Stress-state : effective
Shear strength : Mohr-Coulomb
Angle of internal friction : ϕ_{ef} = 33.00 °
Cohesion of soil : c_{ef} = 100.00 kPa
Saturated unit weight : γ_{sat} = 18.00 kN/m³

Rigid Bodies

No.	Name	Sample	γ [kN/m³]
1	Material of structure		18.85

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		10.00	-0.50	10.00	0.00	Granular
		4.17	0.00	3.67	-0.50	
2		0.63	-1.37	2.80	-1.37	Granular
		3.67	-0.50	4.17	0.00	
		0.00	0.00	-0.60	0.00	
		-0.60	-0.01	0.00	-0.01	
		0.00	-0.46	0.63	-0.46	
3		0.55	-2.29	0.55	-1.37	Material of structure
		0.63	-1.37	0.63	-0.46	
		0.00	-0.46	0.00	-0.01	
		-0.60	-0.01	-0.60	0.00	
		-0.61	0.00	-0.61	-0.46	
		-0.69	-0.46	-0.69	-1.37	
		-0.77	-1.37	-0.77	-2.29	
4		10.00	-3.20	10.00	-0.50	Silty Clay
		3.67	-0.50	2.80	-1.37	
		0.97	-3.20	1.24	-3.20	
5		0.97	-3.20	2.80	-1.37	Granular
		0.63	-1.37	0.55	-1.37	
		0.55	-2.29	0.97	-2.29	

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
6		-0.86	-3.20	0.97	-3.20	Material of structure
		0.97	-2.29	0.55	-2.29	
		-0.77	-2.29	-0.86	-2.29	
		-0.86	-3.00			
7		-1.16	-3.50	-1.16	-3.20	Silty Clay
		-0.86	-3.20	-0.86	-3.00	
		-10.00	-3.00	-10.00	-3.50	
8		1.24	-3.50	1.24	-3.20	Granular
		0.97	-3.20	-0.86	-3.20	
		-1.16	-3.20	-1.16	-3.50	
9		1.24	-3.20	1.24	-3.50	Silty Clay
		-1.16	-3.50	-10.00	-3.50	
		-10.00	-8.50	10.00	-8.50	
		10.00	-3.20			

Surcharge

No.	Type	Type of action	Location z [m]	Origin x [m]	Length l [m]	Width b [m]	Slope α [°]	Magnitude q, q_1, f, F, x	Magnitude q_2, z	unit
1	strip	variable	on terrain	x = 0.00	l = 10.00		0.00	12.00		kN/m^2

Water

Water type : No water

Tensile crack

Tensile crack not input.

Earthquake

Horizontal seismic coefficient : K_h = 0.1515
Vertical seismic coefficient : K_v = 0.0000

Settings of the stage of construction

Design situation : Service I

Results (Construction stage 1)

Analysis 1

Circular slip surface

Slip surface parameters								
Center :	x =	-1.30	[m]	Angles :	α_1 =	-36.03	[°]
	z =	0.51	[m]		α_2 =	83.25	[°]
Radius :	R =	4.34	[m]				
The slip surface after optimization.							

Total weight of soil above the slip surface: 248.19 kN/m

Slope stability verification (Bishop)

Sum of active forces : F_a = 143.25 kN/m

Sum of passive forces : F_p = 850.54 kN/m

Sliding moment : M_a = 621.72 kNm/m

Resisting moment : M_p = 2399.38 kNm/m

Utilization : 25.9 %

Capacity demand ratio CDR: 3.859

Slope stability ACCEPTABLE

Name : Analysis	Stage - analysis : 1 - 1