Retaining Wall Guideline

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for the City of Nanaimo

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1.0 INTRODUCTION

The objective of this Guideline is to provide information on retaining wall design in accordance with the City of Nanaimo (the City) and the British Columbia Building Code (BCBC) requirements. The focus of the Guideline is the geotechnical aspects of retaining wall design; however, some regulatory and structural issues are discussed. This Guideline is not intended to be prescriptive nor is it intended to serve as a substitute for engineering judgement and experience. The City recognizes that engineers and contractors may pursue innovative retaining wall design and construction. In such instances, the design engineer must demonstrate that the proposed wall will meet or exceed safety and performance expectations as outlined in this Guideline.

Notwithstanding the purpose and scope of this Guideline, a qualified Professional Engineer may choose to deviate from the procedures detailed herein, so long as due diligence is met.

1.1 What Types of Retaining Structures are Covered in this Guideline?

This Guideline covers the following types of retaining wall:

- **Cast-in-Place (CIP) or Pre-cast Concrete Cantilever Walls**: Predominately reinforced concrete walls, but could also include reinforced masonry cantilever walls.

- **Gravity Walls and Semi-Gravity Walls**: e.g., Mass concrete gravity walls, bin walls, gabion walls.

- **Segmental Block Gravity Walls**: e.g., Lock-Block walls, Allen Block walls.

- **Mechanically Stabilized Earth (MSE) Walls**: Sometimes referred to as Structural Earth Walls (SEW) and Retained Soil Systems (RSS). Also includes green walls in which the wall facing supports vegetation growth. These walls typically use a range of proprietary facing elements and require soil reinforcement for stability.

- **Rock Stack Walls**: Also referred to as rockeries, stacked rock, dry-stacked, or dry-stone walls.

- **Reinforced Slopes**: Reinforced slopes are also covered by this Guideline if they are steeper than 45° to the horizontal (1H:1V). (Note that reinforced slopes flatter than 1H:1V must meet the requirements of the City’s Steep Slope Guideline.)

1.2 What Types of Retaining Structures are NOT Covered by this Guideline?

This Guideline does not cover the following retaining wall types:

- Walls less than 1.5 m high, unless failure would impact a structure

- Terraced retaining walls less than 1.5 m high, with:
  - Average slope angles less than 45° to the horizontal (1H:1V).
  - Step-back distances greater than the wall height.
  - An acceptable global factor of safety (FS) for the entire terraced slope.
• Slope protection/facing to slopes where the global factor of safety (FS) of the slope without the slope protection/facing is greater than 1.5 for static conditions.

• Reinforced slopes flatter than 45° to the horizontal (1H:1V).

• Walls for which specialized design is typically required (e.g., soil nail walls, shotcrete and anchor walls, sheet pile walls, shoring systems).

• Walls greater than 9 m height because specialized design is required.

• Foundation walls which are covered by Part 9 of the British Columbia Building Code (BCBC).

1.3 What is Design Life?

The design life of an engineered structure is the period of time (post-construction) over which the structure is expected to meet specific limiting criteria, generally in terms of allowable stresses and strains. Often, the design life indicates when major renovations (costing 50% or more of the value of the structure) may be required. The design, construction, environmental conditions, and maintenance of that specific structure greatly influence its useful design life.

If the performance of a retaining wall could affect the integrity of an adjacent structure, the design life of the retaining structure should be the same as that of a typical residential/commercial structure (typically 50 to 75 years).

For specific wall components requiring time-dependent calculations (e.g., long-term creep and corrosion of reinforcement), a design life of 75 years should be used in analyses.

The design life of a retaining structure includes both stability and serviceability aspects. For stability considerations, the design life will depend on the consequence of a failure (refer to Table 2). For serviceability considerations, a minimum design life of the facing materials of 20 years should be used for all classes of wall (refer to Table 2). This implies that some reconstruction/replacement of the facing may be acceptable after 20 years, and access to do the work will be available.

1.4 What is Failure?

For this Guideline, failure implies that a wall has not met its intended function within its design life. This intended function is specific to each retaining wall and must be identified at the time of design.

Types of failure include:

• **Collapse**: Retaining walls must be designed for “no collapse” under both static loading and the design earthquake loading. For this Guideline, collapse is defined as a failure that could endanger human life or cause damage to an adjacent structure(s) (e.g., wall falling over as a result of slow creep, blocks dislodging, or the wall toppling).

• **Repairable Damage**: The owner may elect to have the retaining wall designed to experience repairable damage during the design earthquake, which means the wall can be repaired following an earthquake without complete reconstruction.
• **Extreme Damage:** This normally applies to a severe loading event in which the wall may suffer damage requiring complete reconstruction, but collapse does not occur.

### 2.0 DEFINITIONS

#### 2.1 General

- **Earth Slope:** An inclined surface, either natural or constructed.
- **Reinforced Slope:** A constructed earth slope containing reinforcing elements (e.g., geogrid) within the soil mass and a facing to provide erosion protection. A reinforced slope steeper than 45° (1H:1V) should be treated as a retaining wall for the purposes of this Guideline.
- **Retaining Wall:** Vertical or near-vertical structure erected to hold back geotechnical materials and any pore water they contain. Geotechnical materials include soil, rock, mineral ore, and lightweight fill such as pumice or bottom ash. Retaining walls typically stabilize soil and rock from downslope movement and provide lateral support for steep to vertical grade changes.
- **Slope Protection/Facing:** Material(s) placed on the face of a stable slope to prevent surficial erosion, sometimes called revetment. Slope protection typically refers to vegetation but can also include manufactured products such as Erosion Control Blankets. Slope facing typically refers to rock, concrete paving, or other hard surfacing. Slope protection/facing is not considered a retaining wall if limit equilibrium slope stability calculations show the slope is stable with and without the protection/facing. The stability of the facing must be assessed as failure may have an adverse impact on downslope areas.
- **Retaining Walls Critical to a Building Foundation:** A retaining wall is considered critical to the stability of a building foundation when any part of it lies within the zone of influence of the foundation, defined as being below a 1H:1V plane extending downwards from the outside of a building footing.

#### 2.2 Types of Retaining Walls

- **Mechanically Stabilized Earth (MSE) Wall:** A soil-retaining system, employing either strip or grid-type, metallic, or polymeric tensile reinforcements in the soil mass, and a facing element that is either vertical or nearly vertical.
- **Prefabricated Modular Wall:** A soil-retaining system employing interlocking soil-filled timber, reinforced concrete, or steel modules or bins to resist earth pressures by acting as gravity retaining walls.
- **Rigid Gravity and Semi-Gravity (Conventional) Retaining Wall:** A structure providing lateral support for a mass of soil and owing its stability primarily to its own weight and to the weight of the soil located directly above its base.
  - A **gravity wall** depends entirely on the weight of the stone or concrete masonry and of any soil resting on the masonry for its stability. Only a nominal amount of steel is placed near the exposed faces to prevent surface cracking due to temperature changes.
A semi-gravity wall is more slender than a gravity wall and requires reinforcement consisting of vertical bars and dowels continuing into the footing.

A Cast-in-Place (CIP) or precast cantilever wall consists of a concrete stem and a concrete foundation slab, both of which are relatively thin and reinforced to resist the applied moments and shear forces resulting from the lateral earth loading.

- Stacked Rock Wall: A soil-retaining system employing interlocking pieces of rock to resist lateral earth pressures by acting as a gravity retaining wall. These walls can be constructed with or without mortar.

### 2.3 Retaining Wall Elements

Figure 1 depicts the various components of a typical retaining wall, as discussed in this Guideline. More detailed explanations of these elements are as follows:

- **Backslope:** Average ground inclination measured from the top of the wall to the crest of the slope of retained soil.

- **Blanket Drain/Chimney Drain:** A vertical drain directly against the back of a wall, or an inclined drain on the surface of a cut slope where seepage is occurring to reduce water flow into the wall backfill zone. A blanket drain provides full coverage and a chimney drain provides intermittent coverage.

- **Broken Backslope:** Backslope that reduces to a flatter/horizontal grade.

- **Drainage System:** An engineered system consisting of a permeable medium hydraulically connected to subsurface pipes or weep holes through the wall which collects and discharges water; intended to reduce hydrostatic pressures and prevent erosion.

- **Embedment:** Depth from finished grade level in front of the wall to the base of the wall footing; the minimum embedment zone is typically a function of frost considerations.

- **External Stability:** Stability of the wall relating to overturning, sliding, and bearing capacity failure modes.

- **Global Stability:** Stability against deep-seated failure that encompasses the entire wall.

- **Internal Stability:** Stability against failure of materials comprising the wall (e.g., reinforced concrete in the case of CIP cantilever walls, soil reinforcing in the case of MSE walls)

- **Reinforced Soil Zone:** The composite soil and reinforcement zone forming the MSE wall that is designed to perform as a unit.

- **Restrained (Non-Yielding) Walls:** Walls that are prevented from moving sufficiently for active pressures to develop behind the wall.

- **Retained Soil:** Fill (typically compacted mineral soil) immediately behind gravity or CIP walls, or the soil behind the reinforced soil zone in MSE walls.

- **Toe Slope:** Average ground inclination measured from the exposed bottom of the wall to the toe of the slope in front of the wall.
• **Unrestrained (Yielding) Walls**: Walls that are able to move sufficiently to allow active pressures to develop behind the wall in the limiting condition.

• **Wall Batter**: Slope of the front face of a wall.

• **Wall Height**: Distance from the bottom of the exposed wall to the top of the wall (see Figure 2). Where the backslope above the wall or a toe slope below the wall is steeper than 2H:1V, the height of the toe or back slope shall be included in the wall height. The wall height does not include the height of a guard where one is utilized.

• **Wall Movement**: Rotational and/or translational movements (as shown in Figure 3). Rotational movement results in an increase or decrease in the wall batter, whereas translational movement does not significantly impact the wall batter.

### 3.0 PART A: REGULATORY REQUIREMENTS

#### 3.1 City of Nanaimo Bylaws

Retaining structures are regulated by Bylaw 5693 which states in Section 19.1:

*A registered professional shall undertake the design and conduct field reviews of the construction of a retaining wall greater than 1.5 metres in height. Sealed copies of the design plan and field review by means of letter of assurance in the form of Schedule B and C-B referred to in Section 2.6 of Part 2 of the Building Code for all retaining structures greater than 1.5 metres in height shall be submitted to a building official prior to acceptance of the works.*

#### 3.1.1 Steep Slope Development Permit Guidelines

The Steep Slope Development Permit Guidelines (Development Permit Area 5 of the Official Community Plan) state that:

- Retaining wall height should generally be limited to 3.0 m for roads and site works, 1.2 m for front yards, and 2.4 m for rear and side yards. Higher walls may be appropriate where they are articulated, have a surface texture/pattern, or where sufficient landscaping is provided at its base (page 15).

- If the retaining wall is related to the structural integrity of the building, it will be necessary to address the retaining wall through the building permit process (page 16).

#### 3.1.2 Zoning Bylaw No.4500

Zoning Bylaw No. 4500 (2011) states the following:

- “Retaining Wall” – means a wall erected to hold back water or support a bank of earth, and which is considered a “fence” for the purpose of regulating height (Part 5 page 15).

- Section 6.10.2 – Table 6.10.2 specifies the maximum height of a “fence” for individual zones.
3.1.3  Retaining Wall Guide (Residential)

The Retaining Wall Guide (Residential) is attached in Appendix A and provides the following guidance:

- All retaining walls must conform to maximum fence height:
  - Front yard 1.2 m
  - Side and rear yard 2.4 m
  - Flanking side street yard 1.8 m

- All retaining walls require a Building Permit when they are greater than 1.5 m in height.

- All retaining walls require a Building Permit when they support ground that is critical to the stability of building foundations (BCBC 2006, A-9.3.2.9(4)).

- Concrete or brick retaining walls require a Building Permit as well as Structural and Geotechnical Engineers’ design and field review when they are greater than 1.5 m in height.

- Interlocking block retaining walls require a Building Permit and Geotechnical Engineer’s design and field review when they are greater than 1.5 m in height or when a wall is less than 1.5 m in height but it is required by manufacturer’s specifications.

- Wood retaining walls require a Building Permit and Geotechnical Engineer’s certification when they support ground critical to the stability of building foundations (regardless of height) or when they are greater than 1.5 m in height.

- For all other types of retaining walls, discuss with the Building Inspection Division.

In summary, if a retaining wall is critical to the stability of a foundation as defined in the BCBC or if the wall is greater than 1.5 m in height, a Building Permit is required and a design must be developed by a qualified Professional Engineer.

3.2  British Columbia Building Code (BCBC)

The following sections of the BCBC discuss retaining wall design and construction.

3.2.1  BCBC Division A, Part 1 (Section 1.1.1.1)

The Code applies to the following:

(a) The design and construction of a new building

(d) An alteration of any building

(h) The correction of an unsafe condition in or about any building

(m) Safety during construction of a building, including protection of the public.

Section 1.4.1.2 - building means any structure used or intended for supporting or sheltering any use or occupancy.
3.2.2 **BCBC Division B, Part 4**

- **Loads and Effects** (BCBC 4.1.2.1)
  
  “...the following categories of loads, specified loads and effects shall be taken into consideration...:
  
  - Dead load, earthquake load, and lateral earth pressure including groundwater, live load, and snow load
  
  - Effects of contraction, expansion, or deflection caused by temperature changes, shrinkage, moisture changes, creep, and ground settlement”

- **Field Review** (BCBC 4.2.2.3)
  
  2) a) ii The review shall be carried out on a continuous basis during the installation and removal of retaining structures and related backfilling operations.

- **Design** (BCBC 4.2.4.1 and 4.3.)
  
  - The design of foundations, excavations, and soil and rock retaining structures shall be based on a subsurface investigation carried out in conformance with the requirements of this section, and
  
  - application of generally accepted geotechnical and civil engineering principles by a professional engineer especially qualified in this field of work,
  
  - established local practice where such practice includes “successful” experience with both soils and rocks of similar type and condition.
  
  - Section 4.3 provides design requirements for structural materials including wood, concrete and steel.

The above sections imply that retaining walls for new or existing developments must meet the requirements of the BCBC, which include:

- Determining the applied loads and environmental impacts
- Completing field reviews
- Completing a site investigation
- Using generally accepted design practices.

3.2.3 **BCBC Division B, Part 9**

- **Wood Retaining Wall** (BCBC 9.3.2.9)
  
  - Refers to a structural wood retaining wall supporting ground that is critical to the stability of building foundations.
  
  - Defined in Appendix A as being within a 1H:1V line drawn down from the outer edge of the base of the footing.
– Retaining walls that are not critical to the support of building foundations but are greater than 1.2 m in height may pose a danger to persons adjacent to the wall.

- **Retaining Walls (BCBC 9.4.4.5)**
  – Walls shall be designed to resist the lateral pressure of the retained material.

### 3.3 Canadian Highway Bridge Design Code

The design of retaining walls for highway projects is regulated by CAN/CSA-S6-06 Canadian Highway Bridge Design Code (CHBDC) and for highway projects under the jurisdiction of the BC Ministry of Transportation and Infrastructure (BC MoT) by the BC Supplement to CAN/CSA-S6-06 BC Ministry of Transportation Bridge Standards and Procedures Manual.

### 3.4 Other Codes and Guidelines

Other Codes (for example, American Association of State Highway and Transportation Officials (AASHTO)) and Guidelines are available and may be used when insufficient guidance is available in the BCBC or CHBDC, for example:


### 3.5 City of Nanaimo Process

Flow charts have been developed to assist in explaining the retaining wall design and permitting process (refer to Figures 4 and 5).

#### 3.5.1 Planning Requirements

The Steep Slope Guidelines provide requirements for retaining walls in Section 3.1.3 Earthworks and Grading, Subsection 4 Retaining Walls. In general, the requirements are:

- Use retaining walls to reduce slope disturbance.
- Respect the natural character of the site.
- Limit heights to 3 m for roads and site works, 1.2 m for front yards, and 2.4 m for rear and side yards.
- Higher walls should be textured or have landscaping in front of them.
- Stepped walls are preferred to large uniform walls.
- If the retaining wall is related to the structural integrity of the building, it will be necessary to address the retaining wall through the building permit process.

Many of these requirements concern the aesthetics of the retaining wall/site development. A rendering should be submitted to the City showing the effect on the natural character of the site.
3.5.2 **Building Permit Requirements**

As discussed in Section 3.1.1 and Section 3.2, a Building Permit will be required for a retaining wall that is critical to foundation stability as defined by the BCBC or has a height of greater than 1.5 m.

The Building Permit Application must include the following information:

- Site plan/Legal survey, including the location of the proposed wall(s)
- Height of wall
- Soil stratigraphy
- Groundwater condition
- External loading
- Facing type
- Fill materials
- Soil reinforcement type and length if required
- Drainage provisions
- Global stability analysis
- Internal stability analysis
- Technical specifications
- “For Construction” drawings
- Anticipated Monitoring and Maintenance requirements (it is noted that these cannot be finalized until construction is complete); and
- BCBC Schedule B.

It should be noted that the City may initiate a third-party review of any design submitted for a wall height in excess of 3 m. The property owner will be responsible for the cost of the third party review.

As per Section 56 of the Community Charter, a covenant may be placed on the title of the subject property at the Application Stage which will include the geotechnical reports and the post construction monitoring and maintenance requirements.

During the construction, the Engineer of Record must have Field Reviews carried out. For geotechnical engineers, this requires field presence on a “continuous basis” during the installation. Refer to the Association of Professional Engineers of BC Bulletin K: BCBC September 2010 “Letters of Assurance in the BC Building Code and Due Diligence.

Prior to final approval of construction, the City will require an “As Constructed Survey” of the retaining wall, a completed BCBC Schedule C-B, and a letter outlining any required maintenance and monitoring of
the retaining wall. Should the design have changed during construction, the Schedule C-B should be accompanied by sealed “As Constructed” drawings.

4.0 PART B: RETAINING WALL CLASSIFICATION AND PERFORMANCE REQUIREMENTS

4.1 Performance Expectations

Retaining walls must be designed and constructed such that:

- They continue to meet design and performance criteria under static loading conditions over their design life.
- The total and differential settlement over their design life is compatible with the function, performance requirements, and wall materials.
- They do not collapse during the design seismic event.
- The drainage systems remain functional.
- They remain aesthetically pleasing.

4.2 Factors of Safety

The minimum factors of safety (FS) for the retaining wall design must be established based on the specific site requirements. Table 1 lists generally-accepted design criteria for retaining walls.

Table 1: Design Criteria

<table>
<thead>
<tr>
<th>Design Condition</th>
<th>Minimum Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Static Loading</td>
</tr>
<tr>
<td><strong>Global Stability</strong></td>
<td></td>
</tr>
<tr>
<td>Long-term</td>
<td>1.5</td>
</tr>
<tr>
<td>End of Construction/Transient Loading</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Internal Stability</strong></td>
<td></td>
</tr>
<tr>
<td>Sliding</td>
<td>1.5</td>
</tr>
<tr>
<td>Overturning</td>
<td>2.0</td>
</tr>
<tr>
<td>Bearing</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td></td>
</tr>
<tr>
<td>Long-term</td>
<td>Varies depending on end use</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Where FS is close to or less than 1.0, performance should be assessed based on the deformation criteria.
4.3  Classification of Retaining Walls

The City typically differentiates between retaining walls less than 1.5 m high (low walls), walls from 1.5 m up to 3 m high (moderately high walls), walls 3 m or more but less than 9 m high (high walls), and walls 9 m or greater in height. This leads to the following classification of walls:

- **Class 0 Walls**: Low walls that are not supporting structures.
- **Class I Walls**: Moderately High Walls that would not endanger adjacent facilities and structures if they experienced moderate displacement (typically 150 mm) during their design life.
- **Class II Walls**: High Walls that would not endanger adjacent facilities and structures if they experienced moderate displacement (typically 150 mm) during their design life.
- **Class III Walls**: Walls that could endanger adjacent facilities and structures if they displace even a small amount (typically 25 to 50 mm) during their design life.
- **Class IV Walls**: Walls greater than 9 m high and walls for which specialized design is required (see following page for Table 2)
### Table 2: Retaining Wall Classification and Design Requirement Chart

<table>
<thead>
<tr>
<th>Wall Class</th>
<th>Wall Height (m)</th>
<th>Potential to Impact Structural integrity of Adjacent Facilities/Structures</th>
<th>Typical Maximum Allowable Displacement (mm)</th>
<th>Minimum Design Life (Years)</th>
<th>Design Requirements</th>
</tr>
</thead>
</table>
|            |                 | Rotational | Translational | No restriction | No restriction | No restriction | No restrictions
| 0          | <1.5            | No impact  | No impact     | No restriction | No restriction | No restriction | No Building Permit required |
| I          | ≥1.5 to <3      | No impact  | Prevent Negative Batter | No restriction | 20             | Building Permit required |
| II         | ≥3 to <9        | No Impact  | Prevent Negative Batter | <150           | 30             | Building Permit required |
| III        | <9              | Will Impact| <25 †         | <50            | 50             | Building Permit required |
| IV         | ≥9 and Special Designs | All cases | Special Design | Special Design | 50             | Building Permit required |

† Horizontal movement measure at the top of the wall

Facilities and structures include public and private buildings, utilities, areas of public access and gathering, emergency access such as fire lanes, etc.
5.0 PART C: GENERAL APPROACH

5.1 Geotechnical Investigation and Reporting

The geotechnical engineer must tailor the geotechnical investigation to the specific application and class of wall. The general requirements include obtaining information and reporting on:

- Site history with respect to stability or other geotechnical behaviour, including previous earthworks and/or mining activities.
- Topography, property lines, easements, existing and/or proposed utilities, access issues if any, etc.
- Geotechnical conditions, including depth of groundwater and likely variations.
- Available backfill materials including unit weight, soil strength, and permeability parameters.
- Unit weight and soil strength parameters for native soils.
- Peak Ground Acceleration (PGA) and spectral responses acceleration Sa(T) corresponding to the wall location typically obtained from Earthquakes Canada (http://earthquakescanada.nrcan.gc.ca/) for the 1-in-475-year and 1-in-2475-year seismic events.
- Other site-specific conditions that may influence the design and construction (e.g., riparian areas, sensitive vegetation, protected species, flooding potential).

Regardless of Wall Class, the geotechnical engineer must justify the soil and groundwater parameters used. The level of testing required will depend on the Wall Class (e.g., Class I would likely use commonly accepted parameters without specific testing, whereas Class III and IV walls would likely require specific testing).

For Class III and IV walls, if soft or potentially liquefiable soil conditions are present, site-specific ground response analyses should be performed using a computer program such as SHAKE 2000. Such analyses require the shear wave velocity of the subsoils and can be measured during the site investigation or estimated from published relationships.

5.2 Design Approach

This section provides a suggested design approach (see also Figures 2 and 3).

5.2.1 Establish Design Requirements and Criteria

This requires a coordinated effort involving the design team and the owner. A necessary starting point is having available drawings showing proposed site grading and conceptual drainage layout based on a reliable topographic survey. Establishing design criteria includes considering the options required to achieve the proposed grade separation; accounting for actual site conditions; and determining the nature of the proposed development, availability of materials, geotechnical conditions, aesthetics, available access, surrounding developments, etc.

This discussion will identify the required Code to be used (e.g., BCBC) and the Wall Class. The design criteria will include the minimum factors of safety, deformation limits, monitoring and maintenance expectations, and other relevant criteria.
5.2.2 **Conduct Detailed Design**

Site-specific detailed design should be completed for each wall. This will include:

- Global stability for all loading conditions
- Internal and external stability of the wall
- Liquefaction potential and mitigation if required
- Settlement/deformation assessment.

The following steps are suggested:

- Confirm input parameters (wall location and height, soil parameters, groundwater conditions, traffic surcharge, etc.).
- Identify likely wall types and establish design approach.
- Determine the external loading conditions including the potential for scour or flooding.
- Determine lateral earth pressures; these will vary with the type of wall used, for example yielding or non-yielding.
- Determine seismic lateral earth pressures; these will vary for the type of wall used.
- Evaluate global stability.
- Evaluate internal stability and external stability (bearing capacity, sliding, and overturning).
- Estimate deformation (settlement and potential for lateral deformation).

5.2.3 **Construction Recommendations**

Recommendations must be developed to provide enough information and guidance that the wall construction meets the intent of the design. This will include:

- Material specifications
- Placement specifications
- Drainage works
- Construction sequence, if it affects geotechnical conditions and safety
- Temporary slopes
- Dewatering requirements
- Weather restrictions
- Quality control requirements.

As well, the effort to be expended during the Field Review by the Engineer of Record should be developed, as well as any monitoring requirements.
5.2.4 Monitoring and Maintenance

A monitoring program is necessary to confirm the ongoing performance of the wall is meeting expectations. Regular maintenance will help avoid conditions that could adversely affect the wall behaviour.

Although the City appreciates a complete monitoring and maintenance plan cannot reliably be finalized until construction of the wall is complete, the City needs to covenant and register monitoring and maintenance requirements on title before issuing the Building Permit. Therefore, the geotechnical report should provide Best Practice guidelines for monitoring and maintenance based on the proposed wall type and site conditions. The geotechnical report should acknowledge if there is a potential that the monitoring and maintenance plan may need to be revised after construction, and that once construction is complete, the final plan will be submitted to the party responsible for the monitoring and maintenance and a copy will be included with the completed BCBC Schedule C-B.

5.3 Reporting

A geotechnical report must be prepared for submission with the Building Permit Application. The components of Section 5.1 and Section 5.2 can be used when developing the table of contents for this report. As a minimum, the report must include the results of the geotechnical site investigation; unit weight; soil strength and the drainage design used in the design; Wall Type and Class; Design Criteria used; detailed geotechnical design recommendations including estimates of global site stability, lateral earth pressures, estimated displacements, and drainage requirements; construction recommendations; and recommendations for monitoring and maintenance.

5.4 Post-Construction Modification

The owner of the property on which the retaining wall is located is responsible for:

- having the recommended monitoring and maintenance completed;
- undertaking any remedial measures identified by the monitoring program; and
- having a qualified professional engineer, familiar with the design and construction of the wall, review any proposed changes to the wall. Such changes include: increasing the height, removing fill from in front of the wall, alterations to the drainage, different loading, and construction of a structure above or below the wall.

6.0 PART D: DESIGN GUIDELINES

6.1 General

The design engineer must complete a checklist for all retaining walls permitted by the City. The checklist confirms that the retaining walls have been designed to meet the specified performance criteria, and permanent wall lateral deformations will meet the requirements for service level performance and damage level performance. Checklists are provided in Appendix B.
6.1.1 Global Stability

The global (i.e. overall) stability of the slope, including the retainer wall, retained material, and foundation, must be evaluated for all walls using at least a limit equilibrium method of analysis. Alternative approaches, such as those based on Finite Element Strength Reduction techniques, may also be used.

The global stability analysis should include an evaluation of the seismic stability as per the APEGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in B.C.

For Class II and III walls, a minimum horizontal bench width of 1,200 mm should be provided in front of walls founded on slopes unless the designer can demonstrate that is not necessary.

6.1.2 Lateral Earth Pressures

Walls should be designed to support the appropriate full lateral earth, surcharge, and water pressures as well as earthquake loadings. Lateral earth pressures under both static and seismic loadings should be determined using the methods given in CFEM 2006, CHBDC 2006, or other recognized code. Specific lateral earth pressure aspects relating to all walls should:

- Include the compaction pressures that will be imposed by the compaction plant to be used in the wall construction (see CFEM 2006 and CHBDC 2006 for guidance on typical values).
- Be “at-rest” earth pressures for retained slopes subject to long-term creep.
- Disregard passive resistance in the top 300 mm of material in front of the wall or more if removal or disturbance is anticipated in the future. In determining the embedment depth to mobilize passive resistance, consider planes of slickensides, bedding, and joint sets, or other factors that could reduce the intact strength.
- Be based on the 1-in-2,475-year earthquake mandated in BCBC 2012.

6.1.3 Deformations

Deformations for slopes and walls under static loads should be determined using the methods given in CFEM 2006.

Seismic deformations of slopes and walls may be estimated using the approaches developed by Bray as outlined in APEGBC 2008 and Bray 2010, using the 1-in-2475-year earthquake mandated in BCBC 2012.

6.2 Drainage

The following drainage requirements apply to all retaining walls:

- Provide adequate drainage behind all walls unless the wall has been designed for full hydrostatic pressure or the geotechnical report demonstrates the backfill is free-draining. Adequate drainage implies a minimum 300 mm wide blanket drain consisting of minus 20 mm drain rock (or equivalent free-draining material) connected to a footing drain behind the wall.
- The blanket drain may be replaced with a geosynthetic drainage mat pinned to the back of the wall if the geotechnical engineer provides information in the geotechnical report that demonstrates the
drainage mat will not clog with time and the backfill is sufficiently free-draining to prevent the build-up of seepage pressures within the active zone behind the wall.

- Footing drains may be replaced with weep holes through the wall if hydraulic continuity is maintained between the blanket drain and the weep holes.
- Provide cleanouts to wall drains to facilitate maintenance.
- Minimize the impact of external sources of water, and control stormwater by directing runoff away from the wall.

As a guide, free-draining backfill consists of material with no more than 5% passing the 0.075 mm sieve on the fraction smaller than 2 mm.

6.3 Precast and Cast-in-Place Reinforced Concrete Cantilever Walls

Classify the wall in accordance with Table 2, and determine Design Requirements.

6.3.1 Professional Responsibilities (refer to BCBC, Schedule B)

- **Geotechnical Engineer:** Conduct geotechnical investigation; determine soil parameters for design; provide lateral soil pressures, ultimate bearing resistance, and factored friction coefficient for basal sliding; and conduct limit-equilibrium check of global stability.
- **Structural Engineer:** Undertake structural analysis and design for internal and external stability (i.e., concrete dimensions, reinforcing requirements, overturning and sliding stability), detailing, and design drawings including concrete strength, mix, and durability requirements.

6.3.2 Design Method

- Satisfy requirements of the BCBC including Appendix and Commentary.
- For geotechnical, refer to CFEM 2006 and CHBDC 2006.
- Satisfy requirements of applicable Canadian Standards Association (CSA) standards including:
  - CSA A23.1-09/A23.2-09 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete
  - CSA A23.3-04 Design of Concrete Structures
  - CSA A23.4-09 Precast concrete - Materials and construction

6.3.3 Specific Design Criteria

- Structural engineer to demonstrate that the design life given in Table 2 will be achieved.

6.3.4 Field Review Requirements During Construction

- In accordance with BCBC and APEGBC recommendations for field reviews
- **Geotechnical Engineer:** As a minimum, review temporary excavation stability and foundation bearing surfaces prior to placing concrete, and confirm drainage measures are adequate to prevent hydrostatic pressures developing behind the wall. Conduct continuous field review of backfilling if the backfill could affect the structural integrity of adjacent structures.

- **Structural Engineer:** Refer to the Guidelines for Professional Structural Engineering Services for Part 3 Building Projects. Field reviews should be carried out at intervals appropriate to the stage of construction to observe the quality and the progress of the construction of those elements designed by the Structural Engineer of Record (SER). When construction is complete, a final field review should also be carried out. The timing and number of field reviews are at the discretion of the RP having responsibility.

### 6.4 Gravity Walls

This covers gravity walls such as mass concrete and segmental block gravity walls, but does not include MSE or rock stacked walls.

Classify the wall in accordance with Table 2, and determine Design Requirements.

#### 6.4.1 Professional Responsibilities (refer to BCBC, Schedule B)

- **Geotechnical Engineer:** Conduct geotechnical investigation; determine soil parameters for design; provide lateral soil pressures, ultimate bearing resistance, and friction coefficient for basal sliding; and conduct limit-equilibrium check of global stability.

- **Design Engineer/Structural Engineer:** Undertake analysis and design for internal and external stability (i.e., wall dimensions, overturning and sliding stability), detailing, and design drawings including concrete strength, mix, and durability requirements, if applicable.

#### 6.4.2 Design Method

- Satisfy requirements of the BCBC including Appendix and Commentary.

- For geotechnical refer to CFEM 2006 and CHBDC 2006.

- Satisfy requirements of applicable Canadian Standards Association (CSA) standards including those listed in the BCBC under Section 4.3 Design Requirements for Structural Materials

#### 6.4.3 Specific Design Criteria

- Structural engineer/materials engineer to demonstrate that the design life given in Table 2 will be achieved.

#### 6.4.4 Field Review Requirements During Construction

- In accordance with BCBC and APEGBC recommendations for Field Reviews

- **Geotechnical Engineer:** As a minimum, review temporary excavation stability and foundation bearing services prior to installing wall, and confirm drainage measures are adequate to prevent hydrostatic
pressures during the design life. Conduct continuous field review of backfilling if the backfill could affect the structural integrity of adjacent structures.

- **Structural Engineer:** Refer to the Guidelines for Professional Structural Engineering Services for Part 9 Building Projects. Field reviews should be carried out at intervals appropriate to the stage of construction to observe the quality and the progress of the construction of those elements designed by the SER. When construction is complete, a final field review should also be carried out. The timing and number of field reviews are at the discretion of the RP having responsibility.

### 6.5 MSE Walls

Classify wall in accordance with Table 2, and determine Design Requirements.

#### 6.5.1 Professional Responsibilities (refer to BCBC, Schedule B)

- **Geotechnical Engineer:** Conduct geotechnical investigation; determine soil parameters for design; provide lateral soil pressures, ultimate bearing resistance, and friction coefficient for sliding and conduct limit-equilibrium check of global stability.

- **Design Engineer:** Provide soil reinforcement design for internal stability of the reinforced soil mass, and undertake external stability design (i.e., wall dimensions, overturning, bearing capacity, and sliding stability), detailing, and design drawings.

- **Structural Engineer:** Input may be required for the design and detailing of the facing and facing connections where complex tie-in of the wall to the facing is required.

#### 6.5.2 Design Method

- Satisfy requirements of the BCBC including Appendix and Commentary.

- For wall facings, satisfy requirements of applicable Canadian Standards Association (CSA) standards, including those listed in the BCBC under Section 4.3 Design Requirements for Structural Materials.

- For geotechnical, refer to CFEM 2006 and CHBDC 2006, as well as AASHTO, FHWA, NCMA, and other Codes and Guidelines.

#### 6.5.3 Specific Design Criteria

- Where stacked rock is used as the facing of an MSE wall, the maximum height must not exceed 4.6 m.

- Design Engineer to demonstrate that the design life given in Table 2 will be achieved.

- Typical minimum soil reinforcement length to be 70% of the wall height as measured from the levelling pad (i.e., including embedment depth).

- Unless constructed on rock foundations, the embedment at the front face of the wall shall not be less than:
  - The frost depth
− 600 mm on sloping ground (4H:1V or steeper) or where the soil in front of the wall toe could be removed due to erosion or future excavation

6.5.4 Field Review Requirements During Construction

- In accordance with BCBC and APEGBC recommendations for Field Reviews
- Geotechnical Engineer: As a minimum, review temporary excavation stability and foundation bearing surfaces prior to installing wall, and confirm that drainage measures are adequate to prevent hydrostatic pressures during the design life. Conduct continuous field review of backfilling if the backfill could affect the structural integrity of adjacent structures.
- Structural Engineer: May be required for specific designs.

6.6 Stacked Rock Walls

Stacked rock walls are not permitted for Wall Class III, and maximum height may not exceed 3.7 m for gravity walls (and 4.6 m for MSE walls – see section 6.5).

Classify wall in accordance with Table 2, and determine Design Requirements

6.6.1 Professional Responsibilities (refer to BCBC, Schedule B)

- Geotechnical Engineer: Conduct geotechnical investigation, determine soil parameters for design, provide lateral soil pressures and ultimate bearing resistance, and conduct limit-equilibrium check of global stability.
- Design Engineer: Undertake detailed analysis and design of external and internal stability, and specify the quality and dimensions of the rock to be used.

6.6.2 Design Method

- Satisfy requirements of the BCBC including Appendix and Commentary.
- Refer to CFEM 2006 for general geotechnical requirements, and undertake internal and external stability analyses using a design method such as that given in FHWA 2006.
- For walls adjacent to self-supporting slopes (e.g., hard glacial till slopes), prescriptive wall dimensions (e.g., City of Seattle 2004) may be used.
- For general rock stack wall guidance and specifications, the City accepts ARC (2009), City of Seattle (2004), and BC MoT (2010) as references.

6.6.3 Specific Design Criteria

- Design engineer to specify rock sizes and quality to satisfy the design requirement.
- Design engineer to demonstrate that the durability of the rock will allow the design life given in Table 2 to be achieved.
6.6.4 **Field Review Requirements During Construction**

- In accordance with BCBC and APEGBC *Guidelines for Field Reviews*.

- Detailed construction review is particularly important for rock stack walls because performance depends on the individual rock quality and quality of construction to achieve optimal placement of individual rocks to produce an integral structure; for example:
  
  - Rocks must be intact and massive with no open fractures, foliation, or other planes of weakness.
  - Prevent continuous or horizontal joints within the wall.
  - Provide good contact between adjacent rocks, especially on the front face of the wall.
  - Fill voids left between rocks with smaller pieces to prevent migration of the backfill.

- **Geotechnical Engineer**: As a minimum, review temporary excavation stability, foundation bearing surfaces prior to installing wall, check rock quality and placement quality as outlined above, and confirm that drainage measures are adequate to prevent hydrostatic pressures during the design life.
REFERENCES


BCBC (BC Building Code), (2012), Published by the Office of Housing and Construction Standards, BC Ministry of Forests and Range.


Canadian Standards Association (CSA), A23.1-09/A23.2-09 *Concrete Materials and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete*.

Canadian Standards Association (CSA), A23.3-09, *Design of Concrete Structures*.

Canadian Standards Association (CSA), A23.4-09, *Pre-cast Concrete – Materials and Construction*.
CHBDC-S6-06 (Canadian Highway Bridge Design Code S6-06), Canadian Highway Bridge Design Code, Canadian Standards Association, Mississauga, Ontario, CAN/CSA-S-6-06.

City of Nanaimo, Building Bylaw 2003 No. 5693, April 2012.

City of Nanaimo, Zoning Bylaw 2011 No. 4500, January 2014.

City of Nanaimo, Retaining Wall Guide (Residential), August 2011.

City of Nanaimo, Steep Slope Development Permit Area Guidelines, June 2005.

City of Seattle (2004), Client Assistance Memo 321, Rockeries: Prescriptive Design and Installation Standards, City of Seattle, Department of Planning and Development.

Earthquakes Canada website: http://www.earthquakescanada.nrcan.gc.ca


FIGURES

Figure 1  Terminology and Wall Definitions
Figure 2  Terminology and Wall Definitions
Figure 3  Terminology and Wall Definitions
Figure 4  Flow Chart of Slope and Retaining Wall Regulatory Requirements
Figure 5  Flow Chart for the Design of MSE Walls
FIGURE 2

Wall Height

Less Than 2H:1V

Figure 2a

Wall Height

Greater Than 2H:1V

Figure 2b
FIGURE 3

Horizontal movement due to Rotation

a) Rotation

Horizontal movement due to Translation

b) Translation
FIGURE 5

Establish Design Method

Confirm Height of Wall, Soil Stratigraphy and Groundwater Conditions

Determine External Loading

Establish Facing Type

Select Geogrid Type

Select Fill Materials

Define Soil Parameters

Global Stability Analysis

Establish Soil Reinforcement Length (if required)

Internal Stability Analysis

Refine Soil Reinforcement Lengths and Types (if required)

Develop Retaining Wall Section

Develop Technical Specifications

Complete Design Review

Documentation of the Final Design
Building Inspections

Retaining Wall Guide (Residential)

**General Information:**
- All retaining walls, or any portion thereof, shall be located entirely on the applicable parcel, and shall not be located within any Right-of-Way, Easement or Covenant area.
- All retaining walls must conform to the maximum fence height in SECTION 6.10 of BYLAW 4500. For further information, please contact the City of Nanaimo Planning Division at 755-4429. For all Single Family Residential Zones the maximum fence heights are:
  - Front yard = 1.2m (3.94 ft)
  - Side & rear yard = 2.4m (7.87 ft)
  - Flanking street side yard = 1.8m (5.90 ft)
- Where a guard rail is required by the BC Building Code, the minimum required guard rail is not included in the calculation of fence height.
- All retaining walls require a Building Permit when they are greater than 1.5m (5'-0") in height.
- All retaining walls require a Building Permit when they support ground that is critical to the stability of building foundations. [See 2006 BCBC A-9.3.2.9(4)]

**Concrete Retaining Walls:**
- Concrete retaining walls require a Building Permit and Structural Engineer’s certification when they are greater than 1.5m (5'-0") in height.

**Interlocking Block Retaining Walls:**
- Interlocking block retaining walls require a Building Permit and Geotechnical Engineer’s certification when required by manufacturer’s specifications or when they are greater than 1.5m (5'-0") in height, whichever is lower.

**Wood Retaining Walls:**
- All wood retaining walls & cribbing shall be pressure-treated [BCBC 9.3.2.9(4)] when:
  - they support ground that is critical to the stability of building foundations (regardless of height), or [See BCBC A-9.3.2.9(4)]
  - when they are greater than 1.2m (4'-0") in height.

  and require a Building Permit and Geotechnical Engineer’s certification when:
  - they support ground that is critical to the stability of building foundations (regardless of height), or [See BCBC A-9.3.2.9(4)]
  - when they are greater than 1.5m (5'-0") in height.

**Other Types of Retaining Walls:**
- For all other types of retaining walls, please confirm with the Building Inspection Division as to whether a Building Permit is required.
General (all retaining walls):
Check that the following items have been addressed:

☐ 1. Reviewed BC Building Code and City requirements, and referenced all other Codes, Specifications, and Guidelines used.

☐ 2. Classified wall according to Retaining Wall Guideline for Nanaimo, BC (Table 2).
   *Class 0 walls do not require a building permit. Class IV walls require special design.*

☐ 3. Established design criteria based on applicable Codes and Wall Class.

☐ 4. Conducted geotechnical investigation to determine site conditions and appropriate geotechnical parameters for analysis and design.

☐ 5. Determined external loading conditions (e.g., traffic and construction surcharge loads, potential scour, or flooding).

☐ 6. Provided lateral earth pressures recommendations for static and seismic loading (these will vary based on the type of wall used).

Overall Design (all retaining walls):
Check that the following items have been addressed:

☐ 1. Analyzed global stability of slope – Minimum factor of safety >1.5

☐ 2. Analyzed seismic global stability of slope – Minimum factor of safety 1.1

☐ 3. Provided minimum 1.2 m wide bench in front of walls on slopes.

☐ 4. Assessed liquefaction potential (provide mitigation measures, if required).

☐ 5. Provided recommendations for general site and wall drainage.


☐ 7. Assessed the potential impact of wall construction on the slopes above and below the wall.

Gravity Walls:
Check that the following items have been addressed:

☐ 1. Analyzed for overturning, sliding, and bearing capacity.

☐ 2. Analyzed for overturning, sliding, and bearing capacity under seismic conditions.

☐ 3. Completed internal design of the wall (structural design).

☐ 4. Detailed an adequate drainage system.

☐ 5. Demonstrated that design life will be met.

☐ 6. Provided appropriate information and guidance for wall construction, including placement specifications, temporary slopes, drainage works, quality control requirements, monitoring and maintenance.
Rock Stacked Walls:

Check that the following items have been addressed:

☐ 1. Analyzed for overturning, sliding, and bearing capacity.
☐ 2. Analyzed internal stability including sliding between rocks at different heights within the wall.
☐ 3. Analyzed for overturning, sliding, and bearing capacity under seismic conditions (note limitation in Table 2 for rock stack walls).
☐ 4. Detailed an adequate drainage system.
☐ 5. Demonstrated by previous performance or laboratory testing that the rock proposed for use in the wall will be durable and design life will be met.
☐ 6. Provided appropriate information and guidance for wall construction, including placement specifications, rock sizes/weights and stacking requirements, temporary slopes, drainage works, quality control requirements, monitoring, and maintenance.

Mechanically-Stabilized Earth Walls:

Check that the following items have been addressed:

☐ 1. Analyzed for overturning, sliding, and bearing capacity and pullout failure.
☐ 2. Analyzed for overturning, sliding, and bearing capacity and pullout failure under seismic conditions.
☐ 3. Provide specifications for geosynthetic reinforcement including consideration to achieve design life.
☐ 4. Minimum geosynthetic reinforcement length is 70% of the wall height or minimum 2.4 m.
☐ 5. Maximum 0.8 m vertical spacing of reinforcement.
☐ 6. Detailed an adequate drainage system.
☐ 7. Provided appropriate information and guidance for wall construction, including placement specifications, temporary slopes, drainage works, quality control requirements, monitoring, and maintenance.

Reinforced Concrete Cantilever Walls:

Check that the following items have been addressed by the geotechnical and structural engineer as appropriate:

☐ 1. Analyzed for overturning, sliding, and bearing capacity.
☐ 2. Analyzed for overturning, sliding, and bearing capacity under seismic conditions.
☐ 3. Completed internal design of the wall (structural design).
☐ 4. Detailed an adequate drainage system.
☐ 5. Demonstrated that design life will be met.
☐ 6. Provided appropriate information and guidance for wall construction, including placement specifications, temporary slopes, drainage works, quality control requirements, monitoring, and maintenance.

Submittals:

Check that the following items have been addressed:

☐ 1. Site plan showing wall location, wall footprint, existing and proposed ground slopes behind and in front of wall, location of roads, structures, utilities, etc., in the vicinity of the wall, and discharge location of the wall foundation drains.
☐ 2. Profile along the length of the wall showing variations in wall height, fill height behind the wall, invert elevations of wall foundations drains, etc.
☐ 3. Cross-section showing typical wall details, including wall batter, foundation preparation, leveling pad details, drainage provisions, erosion protection of exposed slopes above the wall, guardrail details (if required), etc.
☐ 4. Specifications for backfill and retained soil gradation, placement and compaction requirements, field inspection and compaction testing to meet BCBC requirements, erosion control during construction, etc.
☐ 5. Monitoring and maintenance plan.
Name (print)______________________________________________________________________________________________

Signature ____________________________________________________________________________________________ Date ________________________________________________________________________________________________

__________________________________________________________________________________________

Address ______________________________________________________________________________________________

Phone __________________________________________________________________________________________ (Affix Professional seal here)

If the Qualified Professional is a member of a firm, complete the following:

I am a member of the firm _________________________________________ and I sign this letter on behalf of the firm.  
(Print name of firm)__________________________________________________________________________________________