4.3 Design Requirements for Retaining Structures

4.3.1 General Design Requirements

The FPPR requires BCTS and Timber Operations and Pricing Division to construct or maintain an FSR in a manner that ensures the road and the bridges, culverts, fords and other structures associated with the road are structurally sound and safe for use by industrial users.

Retaining structures associated with the **road prism** may be required at some locations to stabilize cut and fill slopes exceeding the natural angle of repose. They can be an important component of the road infrastructure to (1) optimize road layout and design and reduce overall construction costs, and (2) ensure slope stability and a stable road prism over the life of the road. To address safety and resource protection, retaining structures installed on FSRs will be suitably planned in layout and design of a road, and properly designed and built to ensure structural integrity, durability and serviceability.

This section describes the design requirements for conceptual and detailed design of retaining structures **greater than 1.5m high**, installed within or adjacent to the road prism to stabilize road cuts and fills or natural slopes. This section also describes the associated ministry acceptance / approval processes for such structures. Similar requirements and processes should be considered for retaining structures 1.5 m high and less.

The types of retaining structures captured by these design requirements include:

- conventional retaining walls that do not incorporate geosynthetic reinforcement, such as inter locking concrete block walls, gabion walls, steel bin walls, log cribs, and cast-in-place concrete cantilever walls;
- reinforced soil retaining walls using mechanically stabilized earth (MSE)1 or geosynthetic reinforced soil (GRS)[2]design methodologies;
- reinforced slope retention systems (no wall) using MSE or GRS design methodologies.

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Structure design responsibility

A professional engineer registered with the Association of Professional Engineers and Geoscientists of British Columbia (EGBC) **must** prepare designs for retaining structures that are **greater than 1.5m high**.

Conceptual design

During conceptual design and prior to detailed design, and based on a site visit, the design engineer will recommend a retaining structure type, and also facing materials for MSE[1] and GRS[2] retaining structures, to the ministry engineer for review. Selection of appropriate retaining structure type is typically based on an assessment of the design loading, depth to adequate foundation support, presence of deleterious environmental factors, physical constraints of the site, cross- sectional geometry of the road and natural slopes, foundation settlement potential, desired aesthetics, constructability, maintenance, and cost. Recommended retaining structure types (including facing materials for MSE and GRS retaining structures) will meet the performance, durability, and serviceability requirements established for the project by the ministry engineer.

[1]MSE technology uses a tied-back approach to the design of the geosynthetics and typically uses a wider spacing of the geosynthetic reinforcement compared to GRS technology.

[2]GRS technology consists of closely spaced layers of geosynthetic reinforcement and compacted fill materials to produce a composite reinforced soil mass.

Detailed design

Analysis and design calculations of retaining structures will conform to best engineering practices as outlined below:

- define project requirements, considerations, constraints, performance, durability and serviceability criteria; determine design methodology (analytical and design procedures), and confirm design service life;
- define structure geometry, design loads, lateral earth and water pressures, and effects of surcharge loads;
- assess external stability, and internal stability (if applicable), and facing material stability (if applicable);
- check global stability;
- produce design and construction drawings to show road site and general layout, retaining structure profile, existing and finished grades, cross-sections and details, materials specifications, connection details, guardrails or barriers (if applicable), construction guidelines, maintenance requirements;
- make reference to any supporting documentation.

Design variations

Variations from the design requirements described herein may be acceptable in certain special situations. All such variations will be documented and require approval from the ministry engineer prior to use.

Design service life

The design service life is potentially affected by the long-term effects of people, machinery, component material deterioration, seepage, flowing water, and other potentially deleterious environmental factors. Design retaining structures for a service life based on consideration of the potential long-term effects of material deterioration on each of the material components comprising the structure. Design drawings will clearly specify (1) whether the structure is permanent or temporary, and (2) the design service life of the structure.

- **Permanent** retaining structures installed on roads to stabilize road cuts and fills or natural slopes will have a minimum design service life of 45 years (same design service life as permanent bridges for FSRs) or longer service life as otherwise specified by the ministry engineer. Permanent retaining structures will be comprised of durable materials, and will not incorporate any components having a lesser service life than the specified design requirement service life.
- **Temporary** retaining structures installed on roads to stabilize road cuts and fills or natural slopes will have a minimum design service life of 15 years unless a lower design requirement service life is specified by the ministry engineer after consideration of operational objectives and durability of material types contemplated for structure components. The installation of temporary retaining structures on permanent term FSRs should only be permitted if sound justification (supported by cost effectiveness analysis) is provided and approval is given by the ministry engineer. The design of temporary retaining structures will not incorporate any components having a lesser service life than the specified design requirement service life.

Design lateral forces

In addition to lateral earth pressures from level or sloping backfill, the design of retaining structures will consider the effects of water pressure, surcharge loading (uniform area loads, point or line loads), compaction-induced pressures, frost-induced loads, and other forces acting behind the structures as appropriate.

Vehicle live load surcharge: As a minimum requirement, any in-service vehicle live load surcharge for engineering design of retaining structures will be based on a specific standard bridge design vehicle. See the Bridge Design & Construction Manual for Forest Service Roads.

Alternatively, to meet specific operational access needs, it may be required to design for a vehicle live load surcharge that is possibly greater than a ministry standard bridge design vehicle to allow for safe passage of heavy equipment or non-standard vehicles (in a normal transport configuration) that can reasonably be expected to regularly use the FSR, now or in the future. In this case, obtain relevant manufacturers' equipment / vehicle data for design.

Design methodology

Retaining structure systems installed steeper than 70 degrees will be designed as retaining walls.

Unless otherwise specified herein or approved by the ministry engineer, the design engineer will analyze the applied loads and induced stresses using the design methodologies provided in the reference documents below:

For both conventional retaining structure design (with no geosynthetic reinforcement) and MSE retaining structure design:

- Canadian Foundation Engineering Manual, **or**
- AASHTO Standard Specifications for Highway Bridges, Seventeenth Edition 2002, Section 5 "Retaining Walls."

For GRS retaining structure design:

- Canadian Foundation Engineering Manual (chapter sections as applicable), **and**
- Chapter 4 of US Department of Transportation, Federal Highway Administration (FHWA), Publication No. FHWA-HRT-11-026 (*Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide*). http://www.fhwa.dot.gov/publications/research/infrastructure/structures/11026/11026.pdf (PDF, 8.68 MB)

Design factors of safety

Use the following minimum factors of safety for external stability calculations:

Minimum factors of safety for external stability:

	Minimum Factor of

Condition	Safety
Bearing capacity	2.5
Sliding	1.5
Overturning	2.0
Global stability	1.5

On some forestry road applications, it may not be feasible to achieve some of these factors of safety, especially the global factor of safety on cut slope retention on steep slopes. For design, where a factor of safety is lower than shown in the above table, the design engineer will document the risks and benefits associated with a lower value and provide a recommendation to the ministry engineer for review and decision.

Minimum factors of safety for internal stability (MSE and GRS designs):

For MSE and GRS retaining structures, apply the minimum factors of safety for internal stability calculations of allowable reinforcement strength (or strength of the GRS composite mass) provided in the following guidelines or standards, unless the design engineer provides a rationale for using alternative factors of safety acceptable to the ministry engineer:

For MSE retaining structures:

- Canadian Foundation Engineering Manual, or
- AASHTO Standard Specifications for Highway Bridges, Seventeenth Edition 2002, Section 5 “Retaining Walls.”

For GRS retaining structures:

- Chapter 4 of US Department of Transportation, Federal Highway Administration (FHWA), Publication No. FHWA-HRT-11-026 (Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide). http://www.fhwa.dot.gov/publications/research/infrastructure/structures/11026/11026.pdf (PDF, 8.68 MB)

Maximum vertical spacing of geosynthetic reinforcement for GRS retaining structures: The maximum vertical spacing between horizontal layers of geosynthetic reinforcement used in GRS retaining structures will not exceed **300mm**.

4.3.2 Factors to Consider in Selecting Facing Materials for MSE & GRS Retaining Structures

Prior to final design, the ministry engineer will approve the type of facing materials for all MSE and GRS retaining structures proposed for installation on FSRs. To address durability and serviceability, the selection of facing element for a retaining structure will consider various factors:

- design service life
- economic implications of the structure length and potential environmental impact
- road safety considerations and traffic barricade requirements
- life cycle cost considerations, future maintenance and serviceability
- drainage requirements of the backfill
- durability for given exposure
- tolerances to movement during and after construction settlement, deflection, and rotation
- exposure of uncovered geosynthetic materials to potentially deleterious environmental factors or the loss of geosynthetic strength due to the long-term effects of ultraviolet (UV) light
- likelihood of possible damage to facing elements from stream abrasion and scour hazards
- likelihood of possible damage from grading and snow removal operations and vandalism
- aesthetics
- anticipated potential future transfer of the FSR to other agencies possibly necessitating the installation of specific materials for facing elements
- availability of materials
- horizontal alignment restrictions and space limitations.

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Facing materials for permanent MSE and GRS retaining structures

Permanent MSE and GRS retaining structures installed within or adjacent to the road prism to stabilize road cuts and fills or natural slopes along FSRs will have facing materials comprised of durable materials such as modular concrete panels or blocks, free draining rock fill (natural or imported cobbles, or broken rock), or other long-lasting material.

If prefabricated welded wire mesh forms are used in combination with stone fill or other durable facing materials, the design will ensure that the forms and all component connectors (including stiffeners and anchors) have adequate strength and are galvanized after fabrication, and that no backfill from the soil reinforced zones will migrate and escape through any voids or gaps in the front facing. For rock fill facing, the design will ensure that the rock fill is adequately sized to prevent any loss of cobbles or broken rock through the grid openings in the welded wire mesh forms.

The use of uncovered geotextile fabric at the front of galvanized welded wire mesh forms as a standalone facing material is not recommended for permanent GRS retaining structures on FSRs due to concerns for (1) loss of geosynthetic strength from long-term degradation effects of weathering, UV light, abrasion and other environmental factors and (2) other possible sources of damage to the exposed fabric (e.g., vandalism or road maintenance operations) that may affect the functional service life of the facing.

Any variance to these criteria will be approved and documented by the ministry engineer.

Facing materials for temporary MSE and GRS retaining structures

Temporary MSE and GRS retaining structures installed within or adjacent to the road prism to stabilize road cuts and fills or natural slopes along FSRs should (preferably) have facing materials comprised of durable materials as specified above for permanent retaining structures. Alternatively, the facing can be comprised of alternative materials provided that they do not have a lesser service life than the specified design requirement service life and their use is appropriate for the type of retaining structure.

The use of uncovered geotextile fabric at the front of galvanized welded wire mesh forms as a standalone facing material can be considered for temporary GRS retaining structures on FSRs after consideration of the various selection factors listed above and only after consultation with the ministry engineer. For this application, a double layer of geotextile fabric is recommended provided the design engineer has determined (after consideration of the site specific UV potential) that this double layer system of geotextile fabric will provide suitable UV protection and address other factors listed above to meet project durability and serviceability requirements over the design requirement service life.

Furthermore, the geotextile fabric product will be treated using carbon black (a UV absorber) meeting the following minimum specification to make the geotextile fabric less sensitive to UV light: minimum 70 percent strength retained after 500 hrs of UV exposure according to ASTM D4355-07 – “Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.”

Any variance to these criteria will be approved and documented by the ministry engineer.

4.3.3 Geotechnical Report

A geotechnical report will be prepared to assess and address possible:

1. foundation and construction difficulties,
2. effects on existing adjacent structures or slope stability, and
3. methods of overcoming any identified difficulties during the construction stage, or other

requirements.

The report should include a recommendation of the preferred type of foundation, and methods of scour protection (if applicable for the site).

4.3.4 Detailed Design Drawings & Specifications

The design engineer will prepare detailed design drawings prior to construction of any retaining structures. The detailed design drawings will be signed, sealed, and dated by the design engineer taking responsibility for the design. Produce drawings at a scale and format that are usable in the construction process and include any explanatory notes, details, illustrations and specifications for the materials and construction. This content may include, but is not limited to, the following:

- site location, site plan, and general notes to specify:
    - site location coordinates;
    - name of FSR, forest district and region;
    - whether the retaining structure is temporary or permanent, and design service life of the structure;
    - design surcharge loading (uniform area loads, point or line loads), including the vehicle live load surcharge and the specific design vehicle or equipment configuration and loads used in the structure design;
    - design methodology and considerations, assumptions, constraints, any performance design criteria, and other project requirements;
- longitudinal views and existing ground profile, cross-sections, site location coordinates, construction working points and elevations, finished ground profile and elevations (if applicable);
- specifications for soil / rock materials, erosion protection of backfills, adequate foundation preparation, including scour protection (if applicable), and provisions for drainage of backfill materials and all soil reinforced zones (if applicable);
- material specifications for all components (including connection hardware), and including specification of corrosion protection of component materials to meet the design service life;
- facing material specifications and associated connection details, and geosynthetic layer layout, spacing and length in the case of MSE and GRS retaining structures;
- preparation of foundation areas, installation and assemblage of structure components, sizing and extent of riprap (if applicable), and other important requirements to ensure proper construction of the retaining structure;
- reference to design aids, specific constraints dictated by the ministry, or works of others which significantly impacted the resulting design.

All engineering reports and detailed design drawings and specifications, and engineered cost estimates related to the design of retaining structures (if applicable) will be signed, sealed, and dated by the design engineer.

It is the responsibility of the design engineer to ensure that appropriate quality assurance (QA) measures have been included in the design process. This may include engaging a qualified QA reviewer to check the design assumptions, calculations, notes and final design drawings consistent with the requirements of EGBC Bylaw 14(b) (PDF).

4.3.5 Ministry Review of Externally-Prepared Designs

Concept review phase: During the conceptual design phase and well in advance of any detailed design work or procurement of materials, ministry staff will ensure that a ministry engineer is given an opportunity to review and comment on the suitability of a retaining structure proposed for construction on an FSR by the ministry. Failure to do this could delay acceptance of the detailed design drawings and/or project.

Review and acceptance of detailed designs: Design engineers that prepare retaining structure designs for the ministry will consult with ministry professional engineering staff during the detailed design stage. A ministry engineer **must** review all detailed designs of retaining structures for conformance with ministry standards and other site specific requirements, and accept the designs prior to the construction phase on FSRs.

Accepted design drawings (for a retaining structure that will be constructed on an FSR) are to be stamped “For Construction.”