710 Retaining Walls

710.1 General

Retaining walls and reinforced slopes are often designed when there is inadequate space available to construct stable slopes with other materials. Retaining walls also may be used at bridge abutments to support the structure. A retaining wall forms a vertical or near-vertical face through confinement and/or strengthening of a mass of earth or other bulk material. Similarly, a reinforced slope strengthens a mass of earth such that a steep slope can be formed. The difference between the two is that a wall generally uses a structural facing, whereas a steep reinforced slope is typically constructed on a flatter slope and does not require a structural facing. Reinforced slopes are seldom used for NMDOT projects; as such, this chapter focuses on retaining walls.

Retaining wall design requires an interdisciplinary approach, led by the New Mexico Department of Transportation (NMDOT) Project Development Engineer. Typically the NMDOT Geotechnical Section provides recommendations, and the Bridge Design Bureau is responsible for final design.

The purpose of this chapter is to provide references for design information and requirements, general background on retaining wall types, and information on the NMDOT design process for retaining walls.

710.2 References

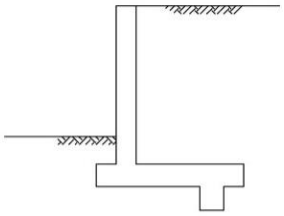
The following documents provide information on NMDOT's design practices related to retaining walls and reinforced slopes:

- American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications, current edition - NMDOT uses the current edition of the AASHTO LRFD Bridge Design Specifications and the current interim edition as the primary standards for the design of bridges and retaining walls in New Mexico.
- Federal Highway Administration (FHWA) Publication No. FHWA-NHI-07-071, Earth Retaining Structures, 2008.
- FHWA Publication No. FHWA-NHI-10-024, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Slopes - Volume I, November 2009.
- FHWA Publication No. FHWA-NHI-10-025, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Slopes - Volume II, November 2009.
- NMDOT Bridge Procedures and Design Guide, April 2013 - NMDOT developed this guide to supplement the AASHTO LRFD Bridge Design Specifications. It provides guidance as well as an interpretation of the AASHTO LRFD Bridge Design Specifications specific to New Mexico bridge design practice.
- NMDOT Standard Drawings.

710.3 Wall Types

Retaining walls can be classified in a variety of ways. General classifications, including load support mechanism, construction method, rigidity, and service life, are described below.

The load support mechanism classification is based on whether the wall is stabilized externally or internally. Externally stabilized walls use an external structure against which the stabilizing forces are mobilized. Cantilevered retaining walls are examples of externally stabilized walls. Internally stabilized walls use reinforcements that are



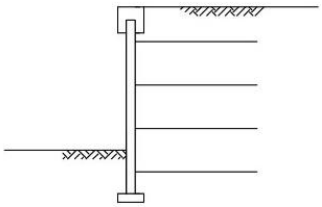
Cantilever Retaining Wall Section as an Example of an Externally Stabilized Wall

installed within the soil mass and extend beyond the potential failure surface. Mechanically stabilized earth (MSE) walls are an example of internally stabilized walls.

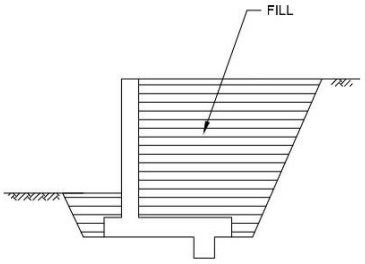
Walls are also classified based on the construction method used. The construction methods consist of fill or cut. Fill construction refers to a wall that is constructed from the base to the top (i.e., bottom-up construction). Conversely, cut construction refers to a wall that is constructed from the top to the base (i.e., top-down construction). It is important to realize that cut or fill designations refer to how the wall is constructed, not the nature of the earthwork. For example, a cantilever retaining wall could be placed in front of an excavated "cut" slope, but the wall would be classified as a "fill" wall because the construction is from the bottom-up.

The rigidity of the wall is fundamental to understanding the development of the earth pressures that develop behind and act on the wall. A rigid wall moves as a unit (i.e., rigid body rotation and/or translation) and does not experience bending deformations. A flexible wall undergoes not only rigid body rotation and/or translation, but also experiences bending deformations. In flexible walls, the deformations allow for the redistribution of the lateral (earth) pressures from the more flexible portion of the wall to the more rigid portion of the wall. Most gravity-type walls would be considered an example of a rigid wall. Almost all of the remaining wall systems would be considered flexible.

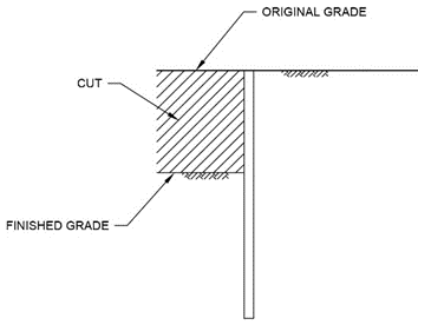
Classification by service life refers to whether the wall is temporary or permanent. The focus of this chapter is on permanent wall construction. Although the NMDOT Geotechnical Section may provide recommendations concerning temporary shoring, temporary shoring design is the responsibility of the contractor and it is not designed by the NMDOT.



MSE Wall Section as an Example of an Internally Stabilized Wall



Cantilever Retaining Wall Section as an Example of Fill Construction



Pile Retaining Wall Section as an Example of Cut Construction

A general list of possible retaining wall types follows, as adapted from FHWA Publication No. FHWA-NHI-07-071, Earth Retaining Structures. Other types and variations on these types may be available.

Externally Stabilized:

- In-situ walls (cut):
  - Sheet-pile
  - Soldier pile with lagging
  - Cast-in-situ slurry walls
  - Bored pile:
    - Contiguous:
      - Tangent pile
      - Secant pile
    - Non-contiguous:
      - Jet grout
      - Deep soil mix
- Gravity walls (fill):
  - Gravity:
    - Mass concrete
    - Stone masonry
  - Semi-gravity:
    - Cantilever
    - Counterfort
    - Buttress
  - Modular gravity:
    - Crib
    - Bin
    - Gabion
    - Modular concrete
    - Tire bale

Internally Stabilized:

- In-situ reinforced walls (cut):
  - Soil nail
  - Micro pile
- Mechanically stabilized walls (fill):
  - Metallic and polymeric reinforcing strips, grids, and sheets
  - Anchored earth
- Geosynthetic reinforced soil

Hybrid Externally/Internally Stabilized:

- Tailed segmental
- Low density fills

Commonly used retaining wall types for NMDOT projects are described below.

710.3.1 Cantilever Retaining Walls

Cantilever retaining walls are a type of semi-gravity wall. They resist loads primarily with the weight of the wall, footing, and backfill. NMDOT Standard Drawing 515 for reinforced concrete cantilever walls cover several load cases and a range of heights.

710.3.2 MSE Walls

MSE walls provide a mass of earth or other material to resist loads, with internal forces resisted by horizontal reinforcement elements and structural facing. Normally the geotechnical engineer provides recommendations for MSE wall design, and the bridge engineer provides the geometric layout. The design details are normally the responsibility of the contractor/supplier, who provides working drawings and calculations in accordance with Section 506 of the NMDOT Standard Specifications for Highway and Bridge Construction.

710.3.3 Gabion and Wire-Enclosed Tire Bale Retaining Walls

Gabion and wire-enclosed tire bale walls are for slope stabilization and are not intended for structural support. Details for gabion and wire-enclosed tire bale retaining walls can be found in NMDOT Standard Drawing 602.

710.4 Design Process

Retaining wall design follows this process:

1. Preliminary wall layout
2. Geotechnical investigation and analysis (performed by the Geotechnical Section)
3. Detailed design and plan development

The Bridge Design Bureau is normally responsible for producing the final wall plans and specifications, based on the recommendations of the Geotechnical Section and in coordination with the design team. The Geotechnical Section is responsible for geotechnical investigation and analysis. To ensure the success of the project, the Bridge Bureau and the Geotechnical Section should actively communicate throughout the design process.

710.4.1 Preliminary Wall Layout

The need for retaining walls should be identified as early as possible in the project development process. The need for walls often is identified during project development and scoping. During the Phase IA/IB analyses or scoping phase, the design team investigates the engineering, environmental, and cost factors that indicate whether walls are required for the project. At that point, design criteria have been established and many of the studies needed to begin the investigation of retaining wall options have been completed. These studies typically include the location survey, subsurface utility engineering (SUE), and the geotechnical scoping report. The Geotechnical Section is responsible for wall recommendations and will provide the feasible retaining wall options for consideration by the design team. The design team then evaluates the options using conceptual layouts and construction

cost estimates, as needed. Preliminary layouts of the proposed wall are normally prepared during Preliminary Design (Phase ID).

710.4.2 Geotechnical Investigation and Analysis

Before a retaining wall can be designed, a geotechnical investigation and analysis must be conducted. The process should be coordinated between the Geotechnical Section, the Bridge Bureau, and the design team. Information regarding geotechnical analysis is discussed in Chapter 610 of this Design Manual.

The preliminary wall layout and transverse section sheets are submitted to the Geotechnical Section. Loads, allowable settlement, deformation limits, and other information may also be required. The Geotechnical Section will use the layout sheets to plan the subsurface investigation of the site and to request field borings from the Geotechnical Exploration Unit.

Following completion of site and laboratory testing of subsurface samples, the Geotechnical Section will begin geotechnical design and preparation of the Geotechnical Report. The Geotechnical Report provides recommendations for retaining wall design. The geotechnical engineer should be apprised of construction phasing or other design constraints that need to be "designed around." Where walls are near waterways, the Bridge Bureau should consult with the NMDOT Drainage Design Bureau.

Deep foundations, such as piles or shafts, may require an iterative design process, coordinated between the Geotechnical and Structural Engineer. Designs for geosynthetic reinforced soil require consultation with the State Bridge Engineer.

710.4.3 Detailed Design and Plan Development

Detailed design and plan development can be the most time-consuming phase of retaining wall design. During this phase, design of each structural element is completed and detailed construction plans are developed. Because this phase can be labor intensive, it is important not to begin work until consensus on the proposed wall type and layout is obtained. Detailed wall design can run concurrently with the geotechnical investigation and analysis phase.

Retaining wall aesthetic treatment may be required as part of a context sensitive design approach or as an environmental commitment. Aesthetic recommendations may be requested from the NMDOT Landscape Architect.