# **RETAINING WALLS**

A retaining wall is a structure that retains or holds back a soil or rock mass. Retaining walls are used for many reasons including repairing landslides, minimizing right of way requirements, shortening bridges (abutment walls), widening roads, and providing property access. Retaining walls are typically high cost items and are only justified when other options such as purchasing right of way, constructing longer bridges, using reinforced slopes or realignment are not feasible.

The specific type of retaining wall utilized is dependent on several factors, including whether it is in a cut or fill, the subsurface conditions in the area around the proposed retaining wall, cost, aesthetics, etc. All potential retaining wall locations should be submitted to the Geotechnical Engineering Unit at an early stage of the project development process so that the Geotechnical Engineering Unit can determine the most feasible wall type and provide a preliminary cost estimate. The Project Engineer should initiate the retaining wall design process by submitting a request for retaining wall design to the Geotechnical Engineering Unit at the To Hydraulics (25% plan) stage. In all cases, the request for retaining wall design should be submitted no later than six months prior to the scheduled Combined or Final Design Field Inspection to ensure that a preliminary wall design can be prepared and any design/construction issues can be discussed at the field inspection.

Except for gravity retaining walls, walls should be shown on the cross-sections as a vertical graphic element one (1) foot thick, measured from the face of the wall, unless directed otherwise by the Geotechnical Engineering Unit. Cast-in-place gravity walls should be shown on the cross-sections as a graphical element as shown on Geotechnical Standard Drawing 453.01. Segmental and precast gravity walls should be shown on the cross-sections as a graphical element 2 and 4 feet thick, respectively, with a wall batter of 9.5 degrees per Geotechnical Standard Drawing 453.02/453.03 or geotechnical standard cells for precast gravity walls.

When referencing retaining walls on the roadway plans, each wall should be numbered sequentially along the -L- alignment (i.e., "Retaining Wall #1", "Retaining Wall #2", etc.). A retaining wall should be numbered, even if it is the only wall on the project. Where retaining walls are opposite each other and begin at the same station, number the wall on the left first. If a retaining wall is located along a -Y- alignment, the numbering sequence should be based on where the -Y- alignment crosses the -L- alignment. Do not renumber the retaining walls if a wall is added after preliminary wall envelope is submitted to the Geotechnical Engineering Unit. The Roadway Design Unit is responsible for showing the retaining wall(s) on the roadway plans and cross-sections.

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Construction limits to determine right of way and/or easements will vary depending on the geometry and wall type. The Geotechnical Engineering Unit will provide Roadway Design with right of way and easement requirements in the roadway foundation recommendations. During preliminary design, right of way or permanent easement approximately 1.2 times the maximum wall height (1.2H) can typically be shown behind a cut wall until the foundation recommendations are received. However, for cut walls taller than 15 feet in the coastal plain (generally Divisions 1-3 and parts of 4, 6 and 8), contact the Geotechnical Engineering Unit as more than 1.2H may be needed for right of way or permanent easement. For fill walls, the right of way limit should be at least 5 feet in front of the wall.

In general, retaining walls should be laid out straight for ease of design and construction. Curved walls may be used in order to maintain a constant offset from a survey line, but the minimum radius will vary depending on the type of wall selected. If a curved wall is specified, it is advisable to contact the Geotechnical Engineering Unit prior to preparing the preliminary wall envelope in order to determine whether a specific wall alignment is feasible.

If the wall is located within the clear zone, steel beam guardrail (Section 862 of the *Standard Specifications for Roads and Structures*), single-faced reinforced concrete barrier (Section 857 of the *Standard Specifications for Roads and Structures*) or concrete barrier rail with moment slab (Structure Pay Item) should be used to protect the hazard.

# Steel Beam Guardrail (Top or Bottom of Wall)

Steel beam guardrail may be placed at the bottom or top of a retaining wall to protect the hazard. Steel beam guardrail should be offset 5'-6" from the face of the guardrail to the nearest wall surface when standard Steel Beam Guardrail (6'-3" post spacing w/ 6 foot posts) is specified. The minimum offset distance from the face of the guardrail to the nearest wall surface is 4 feet at the top of the wall (6'-3" post spacing w/8 foot posts) and 3'-6" at the bottom of the wall (3'-1½" post spacing w/ 6' posts). When the offset distance from the wall surface to face of guardrail is between 3'-6" and 5'-6" at the bottom of the wall, specify 3' - 1½" post spacing at a point 25 feet prior to the wall and carry the 3'-1½" post spacing throughout the length of the wall. If the offset distance at the bottom of the wall is less than 3'-6" specify single-faced concrete barrier. A special detail or notes on the guardrail summary and plan sheets should be added to clarify the areas where 3' - 1½" post spacing and extra depth 8 foot posts are required. Coordinate with the Geotechnical Engineering Unit to ensure guardrail posts do not conflict with the retaining wall design. Figure 1 illustrates the offset requirements for steel beam guardrail in relation to the wall.



#### Figure 1

# Concrete Barrier Rail with Moment Slab (Top of Wall Only)

If the offset distance from the face of the guardrail to the top of a retaining wall is less than 4 feet, a concrete barrier rail with moment slab is required. Concrete barrier rail with moment slab should be located on top of the wall with no offset as illustrated in Figure 2. When concrete barrier rail with moment slab is required, coordinate with the Geotechnical Engineering Unit and the Structures Management Unit since the concrete barrier rail is a structure pay item.

The details for the concrete barrier rail with moment slab will be included as part of the retaining wall plans. Due to the high costs associated with a concrete barrier rail with moment slab, it should only be used when no other options are available. If guardrail is attached to the concrete barrier rail, the barrier should extend the entire length of the wall.

Guardrail with appropriate anchors can then be attached to the concrete barrier rail in accordance with the most current guardrail policies. The concrete barrier rail with moment slab is not designed to accommodate pedestrian traffic adjacent to the barrier rail. Please notify the Geotechnical Engineering Unit and Structure Management Unit if sidewalk is being proposed adjacent to the concrete barrier rail.

# Single-Faced Reinforced Concrete Barrier (Bottom of Wall Only)

Single-faced reinforced concrete barrier can be located next to a wall face when placed at the bottom of a retaining wall. If guardrail needs to be attached to the single-faced concrete barrier, the barrier should extend the entire length of the wall. Guardrail with appropriate anchors can then be attached to the single-faced concrete barrier in accordance with the most current guardrail policies. Figure 2 illustrates the placement of single-faced concrete barrier in relation to the bottom of wall. In some cases, the placement of single-faced concrete barrier at the bottom of wall can result in significant cost savings by reducing the wall height, since single faced barrier allows the wall face to be placed closer to the edge of travel lane as compared to placing steel beam guardrail. If future widening is not anticipated in the vicinity of the bottom of wall, coordinate with the Geotechnical Engineering Unit to determine if the use of single-faced concrete barrier will result in any cost savings.



**Figure 2** 

A typical section inset should be added to the roadway plans depicting the placement of the single-faced barrier or guardrail in relation to the retaining wall. The proposed offset distances, if any, should be clearly labeled on the inset. When a concrete barrier rail with moment slab is specified, ABC should be placed to fill the area between the subgrade and the top of moment slab.

## Fence or Handrail Placement

A fence or handrail should be placed when pedestrian traffic is anticipated in the vicinity of the top of wall. The Roadway Project Engineer should determine whether handrail or fence is appropriate, based on the height of the wall and the project conditions in the vicinity of the wall. It is preferred that fence or handrail be located no closer than one (1) foot from the back of wall. However, if it is necessary to attach a fence or handrail to a wall, only chain link fence or handrail posts should be attached to the top of a retaining wall with a cast-inplace face. When chain link fence or handrail is attached to a retaining wall, the Roadway Project Design Engineer should contact the Standards Squad Leader in the Contract Standards and Development Unit to prepare details for the attachment to the wall. The fence or handrail detail(s) should be incorporated into the roadway plans as 2-Series sheets. All chain link fence that is attached to a retaining wall should be shown in the appropriate fence summary and paid for under Section 866 of the *Standard Specifications for Roads and Structures* as Chain Link Fence, \_\_\_\_\_" Fabric per linear foot. Add a label to the fence summary to reference the detail sheet number (i.e., "\* SEE DETAIL SHEET 2-? FOR FENCE ATTACHMENT TO RETAINING WALL") for the section(s) of fence that are attached to a retaining wall. Standard chain link fence symbology should be used to denote the chain link fence on the roadway plans.

A generic fencing pay item, Special Provision (SP), should be used to pay for any handrail that is attached to the wall. The Roadway Project Design Engineer should list the handrail on their list of Special Provision items when they submit the final plans to the Contract Standards and Development Unit. Coordinate with the Geotechnical Engineering Unit when fence or handrails are warranted in the vicinity of a wall to ensure that the fence or handrail posts will not conflict with the retaining wall design.

The maintenance of vegetation behind the guardrail, fence, or handrail should be considered when placing these items in close proximity to the retaining wall. Asphalt or class A stone may be placed between the guardrail, fence, or handrail and the wall to help manage vegetation in inaccessible areas. A typical section inset or detail will be needed when specifying asphalt or class A stone to manage vegetation.

The Geotechnical Engineering Unit is responsible for coordinating the preparation of all retaining wall plans. The Geotechnical Engineering Unit will provide plans, special provisions, and pay item quantities for walls that they design. Retaining wall plans will be a part of the structure plans unless there are no other structures on the project. If there are no structure plans, the retaining wall plans will be placed in the roadway plans as W-series sheets.

Most retaining walls are either fill walls or cut walls. Fill walls are generally constructed from the bottom up by placing material behind the wall. Cut walls are generally constructed from the top down by removing material from in front of the wall.

# <u>Fill Walls</u>

The most common types of fill walls are (1) *Gravity Retaining Walls*, (2) *Mechanically Stabilized Earth (MSE) Retaining Walls*, and (3) *Cantilever Concrete Retaining Walls*.

(1) *Gravity Retaining Walls* are typically short walls (less than 10 feet in height) that develop stability from their own weight or mass. The most common types of gravity walls are *Cast-in-Place Gravity Retaining Walls*, *Segmental Gravity Retaining Walls* and *Precast Gravity Retaining Walls*.

*Cast-in-Place Gravity Retaining Walls* are constructed of cast-in-place unreinforced concrete and typically in accordance with Geotechnical Standard Drawing 453.01. *Segmental Gravity Retaining Walls* are constructed of segmental retaining wall (SRW) units and typically in accordance with Geotechnical Standard Drawing 453.02 or 453.03. For additional information regarding SRW units, please reference Article 1040-4 of the *Standard Specifications for Roads and Structures*. *Precast Gravity Retaining Walls* are constructed of precast retaining wall (PRW) units with typical depths ranging from 2 to 5 feet. For additional information regarding *Specifications for Roads and Specifications for Roads and Spec* 

- (2) *MSE Retaining Walls* consist of facing elements connected to layers of soil reinforcement within the retained backfill. For permanent MSE walls, steel or geogrid reinforcements are used with facing elements consisting of precast concrete panels or SRW units. For temporary (MSE) walls, steel, geogrid or geotextile reinforcements are used and facing elements consist of geotextile and wire forms.
- (3) *Cantilever Concrete Retaining Walls* are constructed of cast-in-place reinforced concrete that is connected to a footing. Cantilever concrete walls partially develop their stability from the weight of the backfill over the footing. Cantilever concrete walls are more expensive than MSE walls and as a result, are normally used only when MSE walls are not feasible.

For an all fill wall on existing ground, the existing ground line and bottom of wall are the same. A permanent underground easement or right of way is required for the reinforcement length or footing width behind the wall. Fill walls can be used in cuts but require either

# TYPES OF RETAINING WALLS (CONTINUED)

temporary shoring or a temporary slope to construct and may also require additional construction easements.

# Cut Walls

The most common types of cantilever cut walls are *Sheet Pile Retaining Walls*, *Soldier Pile Retaining Walls*, and *Pile Panel Retaining Walls*.

*Sheet Pile Retaining Walls* consist of interlocking sheet piles driven or vibrated into the ground. Sheet pile walls are common for temporary shoring. *Soldier Pile Retaining Walls* consist of steel H-piles driven or placed in drilled holes and partially filled with concrete with either precast panels set in pile flanges or a cast-in-place reinforced concrete face connected to the front of the piles. A *Pile Panel Retaining Wall* is a type of soldier pile wall with H-piles in drilled holes and concrete panels.

The depth of the piles below the bottom of the wall is called the embedment depth. The embedment depth for cantilever cut walls is typically about twice the wall height. For soldier pile walls, timber lagging is typically used for temporary support of the excavation during construction.

Cantilever cut walls can be constructed very close to the right of way since no part of the wall extends behind or in front of the wall. These walls are also commonly used in fill situations and usually do not exceed 13 feet in height.

The most common types of non-cantilever cut walls are (1) *Soil Nail Retaining Walls* and (2) *Anchored Retaining Walls*.

- (1) *Soil Nail Retaining Walls* can only be used in cut situations (no fill) and develop stability from passive elements (non-tensioned) that resist applied earth pressure on the wall. Soil nails consist of steel bars grouted in drilled holes inclined at an angle below the horizontal. A soil nail wall consists of soil nails spaced at a regular pattern and connected to a cast-in-place reinforced concrete face with nail heads embedded in the concrete. Shotcrete is used for temporary support of the excavation during construction.
- (2) Anchored Retaining Walls, also called "tieback walls", develop stability from tensioned anchors that resist applied earth pressure on the wall. Anchors consist of steel bars or strands in drilled holes inclined at an angle below the horizontal that are grouted and connected to steel piles. The piles are driven or placed in drilled holes filled with concrete below the bottom of the wall. The face is usually cast-in-place

# TYPES OF RETAINING WALLS (CONTINUED)

reinforced concrete connected to the piles and timber lagging is typically used for temporary support of the excavation during construction. Anchored walls can be used in partial cut and fill situations, but the anchors do not develop capacity in the unbonded length through the backfill.

For an all cut wall, the grade elevation is either at or above the existing ground line. A permanent underground easement or right-of-way is required for the nails and anchors behind the wall.

Figure 3 illustrates a typical retaining wall section. Key components have been labeled and definitions are provided.

Typical sections of the different types of retaining walls can be found as standard cells on the Geotechnical Engineering Unit's website at:

https://connect.ncdot.gov/resources/Geological/Pages/Geotech Forms Details.aspx

PART I

# **TYPES OF RETAINING WALLS (CONTINUED)**





- **Bottom of Wall** Where finished grade (typically cut walls) or existing ground (typically fill walls) intersects front of wall
- **Design Height** Difference between grade elevation and bottom of wall
- Embedment Difference between bottom of wall and bottom of footing, cast-in-place face or precast panels
- **Extension** Difference between top of wall and grade elevation
- **Grade Elevation** Elevation where finished grade (typically fill walls) or existing ground (typically cut walls) intersects back of wall
- **Top of Wall** Top of cast-in-place face or coping (or bottom of cap if abutment wall is part of end bent or embedded in cap)
- Wall Face Exposed face of front of wall
- Wall Height Difference between top and bottom of wall (i.e., exposed height)

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### **REQUEST FOR RETAINING WALL DESIGN**

In order to initiate the retaining wall design process, the Roadway Project Engineer must prepare a request for retaining wall design. A "Request for Retaining Wall Design" form letter can be downloaded by accessing the roadway form letters. The request for retaining wall design should be submitted to the Geotechnical Engineering Unit at the To Hydraulics (25% plan) stage. The request should be submitted no later than 6 months prior to the Combined or Final Design Field Inspection to ensure that a preliminary wall design can be prepared and any design/construction issues can be discussed at the field inspection. The following information needs to be provided with the request for retaining wall design:

- (1) Plan Sheet(s), Profile Sheet(s), and Cross Sections in the location of the proposed retaining wall(s)
- (2) Wall plan view(s) with offset centerline(s) and distances and curve data (if applicable)
- (3) Preliminary wall envelope(s)
- (4) Any other factors that need to be taken into account in the design of the wall(s) (i.e., drainage, utilities, lighting, fence, guardrail, barrier, etc.)

## Preliminary Wall Envelope

A wall envelope is a profile view of the exposed wall face area. A wall envelope can be defined as a scaled plot of the grade elevations and bottom of wall elevations, the existing ground elevations (if it intersects the wall) and temporary grade elevations (if applicable) on some frequent station interval along the wall. The bottom of wall elevations should reflect a 4 foot wide bench if the finished grade or existing ground in front of the wall is steeper than 6:1 or as directed by the Geotechnical Engineering Unit as shown in Figure 3. The grade and bottom of wall elevations should be shown both graphically and numerically. The existing ground line should always be depicted on the envelope, even if it differs from the grade or bottom of wall. Retaining walls should be referenced using centerline stations of offset alignments. However, separate wall alignments may be created for walls that change offset alignments such as abutment walls along streams. Please note that for some walls, the stations may be shown on the wall envelope in descending order, since the wall envelope depicts the wall face (the side of the wall that is exposed).

The grade and bottom of wall should be depicted and labeled at 50 foot station intervals (i.e., Sta. 10+00, 10+50, etc.) along the offset centerline from the beginning to the end of each wall. Where the grade lines are highly variable, the Geotechnical Engineering Unit may request that the elevations be labeled more frequently. Area calculations of the wall face should be included with the wall envelope.

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The following information should be labeled on the preliminary wall envelope:

- Station and offset distance at the beginning of wall, end of wall, and where the wall alignment changes (if applicable)
- The Grade and Bottom of Wall Elevation at 50 foot station intervals (i.e., 10+00, 10+50, etc.)

Figure 4 shows an example wall envelope for reference. The wall envelope also needs to show where the grade elevation intersects the bottom of wall (where the grade and bottom of wall elevations are equal, i.e. where the wall height is null). This will typically occur at the beginning and end of each wall. Station, offset, grade elevation, and bottom of wall elevation will also need to be shown at each point where the wall alignment changes (i.e., at each point where the wall alignment bends). Plus or minus station references (Sta. 10+12 + /-, etc.) can be used to label the estimated beginning and ending of each wall. The contractor that will construct the wall is required to survey the existing ground elevations shown on the wall profile view and submit a revised wall envelope to the Geotechnical Engineering Unit for review and approval prior to designing and constructing each wall.

Typically, wall envelopes are plotted with a vertical exaggeration so walls appear distorted. Also, walls that do not have a constant offset related to the centerline alignment and walls that are located in curves will not be depicted accurately on the wall envelope. For these cases, a note stating that "THE WALL ENVELOPE DOES NOT ACCURATELY DEPICT THE ACTUAL FACE OF THE WALL." should be added to the wall envelope. These wall face area calculations may need to be computed by hand, since the wall envelope will show a distorted view of the wall face.

## PART I

## **REQUEST FOR RETAINING WALL DESIGN (CONTINUED)**

6-7B



Figure 4

## **REQUEST FOR RETAINING WALL DESIGN (CONTINUED)**

6-7B

PART I

## Final Wall Envelope

A final wall envelope will need to be submitted to the Geotechnical Engineering Unit after the plans have been revised based on recommendations from the various units and comments from the Combined or Final Design Field Inspection. The information shown on the final wall envelope will be the same as that shown on the preliminary wall envelope. The main difference between the preliminary and final wall envelopes would be minor changes to the stations and elevations brought about during the design of the wall. Please note that drainage ditches in the vicinity of the wall may affect the grade elevations on the final wall envelope. Roadway Design should prepare the final wall envelope based on information from the Geotechnical Engineering Unit and when applicable, other units such as Hydraulics, Work Zone Traffic Control, Utilities, etc. The final wall envelope will be shown in the retaining wall plans and should not be shown in the roadway plans. An exception would be if there are no structure plans for the project, then the retaining wall plans will be inserted in the roadway plans as W-series sheets.

If a retaining wall is eliminated during the design of the project, a note should be added to the plans to clarify why the wall numbers are no longer in sequence. The note should be added to the plan sheet that depicts the next wall in the series. For example, if Retaining Wall #2 was eliminated, a note should be added to the plan sheet that contains Retaining Wall #3. The note should state that "RETAINING WALL #? HAS BEEN ELIMINATED." No note is needed if the retaining wall that was eliminated is the only wall on the project or where the wall numbering sequence is not affected.

# TEMPORARY SHORING

Temporary shoring is typically required to maintain traffic, but in rare cases may be used to protect wetlands, buildings, structures or for the removal of existing structures. Please reference the "Temporary Shoring" memorandum dated January 17, 2007 for additional information regarding unit responsibilities.

If temporary shoring is required for the maintenance of traffic, the Roadway Design Unit will show the temporary shoring on the roadway plans (plan view without stations) and reference the traffic control plans. If the temporary shoring is required at more than one location, the quantity for each location will be shown on the traffic control plans.

If the Roadway Design Unit is requesting the temporary shoring (rare occurrence), the temporary shoring location (stations and offsets), typical section(s) and notes will be shown in the roadway plans. If the temporary shoring is required at more than one location, the quantity for each location will be shown on the roadway plans.

If temporary shoring is required, the Geotechnical Engineering Unit may provide standard shoring details for insertion into the final plans. The number of detail sheets will be dependent on the notes referenced in the Temporary Shoring Recommendations from the Geotechnical Engineering Unit. The standard shoring details should be placed in the roadway plans as 2-series sheet(s).

GUIDELINES FOR USE OF PRESTRESSED	
CORED SLAB BRIDGE SPANS	6-8

Pre-stressed cored slab span bridges provide an excellent and economical structure under the right conditions, but they are not the most feasible structure for many sites.

The following guidelines should be used in determining the conditions where pre-stressed concrete cored slab spans should be considered for use in a bridge.