Segmental Block Retaining Wall Design

SELECTED LINKS TO SECTIONS WITHIN THIS DOCUMENT

SECTION 1
INTRODUCTION – SRW

(Last revised 6/18/10)

The following division has been established to assist engineers with the design of Segmental Retaining Walls (SRW) where applications involve public structures within the jurisdiction of the Town of Clayton. The methods, procedures, design factors, formulas, graphs, and tables presented in this division are intended to establish minimal guidelines for SRW design. The

Town of Clayton believes that the following design criteria are sufficient to ensure the welfare and safety of the general public and to protect the economic investment of the citizens of our City.

Alternative design methods may be considered by the Engineer/Designer on a case-by-case basis; however, there should not be extensive variations from the criteria and procedures within this division without the expressed approval of the Town Engineer.

1.1 TOWN OF CLAYTON TOWN ENGINEER

The Town Engineer and Stormwater Program Manager shall be responsible for interpretation and implementation of the SRW design criteria for the Town of Clayton. Approval from other applicable agencies may be required.

Provided that SRW's are located on publicly maintained Streets and/or established public easements where such structures are an integral part of a public BMP, the City may accept SRW systems for maintenance if they have been designed and constructed in accordance with the provisions of this specification or as otherwise instructed in writing by the Town Engineer.

SECTION 2
SEGMENTAL RETAINING WALL DESIGN

For Retaining Walls and Stormwater Management (SWM) Ponds

2.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions apply to this specification.

B. Design Manual for Segmental Retaining Walls, NCMA

C. 02275 – TRENCHING, BACKFILLING, & COMPACTION OF UTILITIES

D. 02632 – SEGMENTAL CONCRETE RETAINING WALL SYSTEMS

2.2 DEFINITIONS

A. **NCMA** National Concrete Masonry Association

B. **AASHTO** American Association of State Highway and Transportation Officials

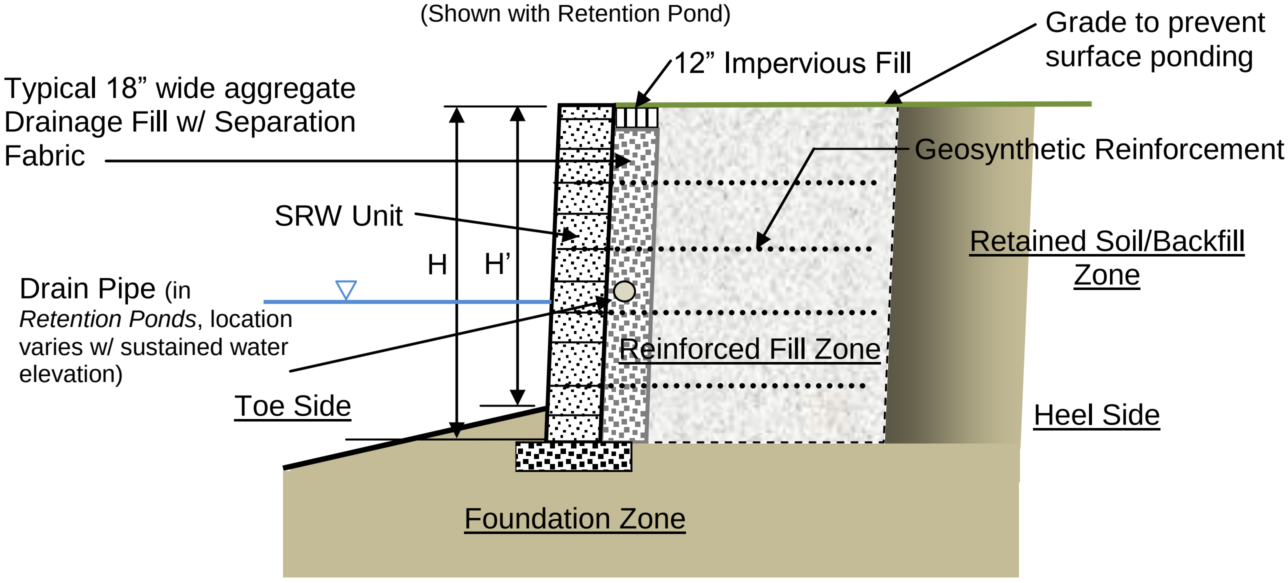
C. **NCMA** National Concrete Masonry Association

D. **USC** Unified Soil Classification

E. **SRW** Segmental Retaining Wall

COMMON COMPONENTS OF SEGMENTAL RETAINING WALLS

(Shown with Retention Pond)



H = Design Wall Height H’ = Height above Grade (exposed Ht) H - H’ = Total Embedment

2.3 WALL DESIGN ENGINEER.

The wall design shall be performed by a Professional Engineer licensed in the State of North Carolina that prepares and seals the design drawings and submittals as required herein.

2.4 MINIMUM DESIGN REQUIREMENTS - GENERAL

A. To ensure that segmental block retaining walls placed on public rights-of-way, easements and those constructed as part of a BMP structure achieve the desired life and performance, the designer shall incorporate the minimum design guidelines specified herein. The designer shall consider all internal and external forces imposed by the loading conditions that the wall system may encounter which includes, but is not necessarily limited to, hydrostatic pressures, rapid drawdown, seismic, surcharge, backslope loading, global stability, pedestrian/guardrail forces, etc.

B. Retaining walls shall be manufactured in accordance with ASTM C90 and designed in accordance the recommendations of the National Concrete Masonry Association (NCMA) Design Manual for Segmental Retaining Walls. **Table 2.1** summarizes the minimum design criteria required by the Town of Clayton and is based upon the structure being critical.

Table 2.1
Minimum Design Criteria for SRW's

External Stability	**Minimum Factor of Safety**
Sliding, FS_{sl}	1.5
Overturning, FS_{ot}	2.0
Bearing Capacity, FS_{bc}	2.0 (soil footing)
	3.0 (concrete footing)
Global Stability, FS_{gs}	1.3
Internal Stability	**Minimum Factor of Safety**
Tensile Overstress, FS_{to}	1.2
Pullout, Fs_{po}	1.5
Local Stability	**Minimum Factor of Safety**
FS_{sl} (Maximum Unreinforced Height)	1.5
FS_{ot} (Maximum Unreinforced Height)	2.0
Shear Facing Units, FS_{sc}	1.5
Facing Connection Strength, FS_{cs}	1.5
Uncertainties	1.5
Surcharge (heel side)	**Live Load (psf)**
Landscaping Walls	0
Pedestrian traffic, light storage	50
Light Traffic, auto parking	100
Highway Loading, heavy traffic	250
Tiered Walls	Footnote 1

Table 2.1 Minimum Design Criteria for SRW's	
Soil Reinforcement	**Minimum Length** (measured from face)
All conditions except Highway Loading	0.6H
AASHTO Highway Loading	0.7H or 8 ft, whichever is >
Miscellaneous Requirements	
Bearing Capacity	2,000 psf minimum
Differential Settlement (to be evaluated by Engineer for walls 10' or greater)	1% (NCMA)

1. Generally, if a tiered retaining wall is placed within a horizontal distance (wall face to face) less than 2 times the height of the underlying wall, a surcharge load will be applied to the lower wall. Design to compensate for tiered wall surcharge.

C. **Gravity Walls vs. Reinforced Soil Walls**:

i. Gravity walls rely solely on its mass and geometry to resist the earth pressure forces acting it. All walls that do not utilize soil reinforcement are considered gravity walls by definition.

Wall Height for Gravity Walls: A simple rule of thumb is to restrict the wall height to no greater than 3 times the unit depth unless referring to design charts for site specific design recommendations. For example:

SRW Unit Depth	Maximum Height
9"	27"
12"	36"
21"	63"

ii. Reinforced soil walls are composite structures that utilize structural SRW units and Geosynthetic soil reinforcement to create a stable mass that can be designed and constructed to much greater heights than simple gravity walls. These structures are commonly referred to as mechanically stabilized earth structures or reinforced soil SRW's.

D. **Soil Parameters**: The Engineer shall provide the following soil parameters in the design. Where blank below, provide design assumptions based on soil types used in the design either in the following form or shown in the calculations.

Soil	ϕ' (º)	**c'** (psf)	γ (pcf)
Reinforced Backfill	30º (min)	0	
Retained Backfill			
Foundation Backfill			

Walls Less than 8 Feet: The Town Engineer, at their discretion, *may require* that this information be obtained through a Geotechnical Investigation; evaluating both the Foundation soils and the Retained soils.

Walls Greater than 8 Feet: A geotechnical evaluation of the soils *is required* for walls taller than 8 feet. A global stability analysis *may also be required* at the discretion of the Town Engineer and *is required* for walls greater than 12 feet.

Special Conditions: For walls proposed to be located adjacent to streams that are subject to rapid drawdown, scour, tiered wall systems, or highway traffic, a geotechnical evaluation may be required by the Town Engineer.

E. **Minimum Embedment**:

Small GRAVITY Walls: For small Gravity walls, a minimum of 1-inch of embedment is recommended for every unit of height (i.e. H/8). However, the minimum embedment shall be no less than 1 block in depth.

REINFORCED Soil Walls: For reinforced soil wall, the minimum depth of embedment as a ratio to wall height may be determined in Table 2.2.

Table 2.2

Reinforced Soil Walls Minimum Wall Embedment, H_{emb}	
Slope in Front of Wall	**Minimum H_{emb} to top of Leveling Pad**
Minimum Requirement	0.5 ft
Horizontal (Walls)	H'/20
Horizontal (Abutments)	H'/10
4:1 or steeper	See Table 2.3

a. Partially excerpted from Table 4.3 from NCMA Design Manual (1997)
b. H' = exposed height; the wall height above finished grade.

Negative Grade in Front of Wall: Consideration shall be given for negative grade (sloping) toe slopes which may require additional embedment over and above the minimum embedment shown in Table 2.2, above. The minimum embedment required with a slope in front of the wall (toe side) should be based on the establishment of a minimum of a 4 ft horizontal bench in front of the wall and then establishing a minimum embedment from that point (i.e. from 4' bench down to top of footing = bench embedment). Fill slopes usually have poor compaction near the edge of slope and all slopes are subject to erosion and surficial instability. See Table 2.3 below.

Table 2.3

Recommended Wall Embedment, H_{emb}		
Toeslope Condition	**Bench Embedment[a]**	**Total Embedment**
4H:1V	10% H'	1' + 10% H'
3H:1V	10% H'	1.33' + 10% H'
2H:1V	10% H'	2' + 10% H'

H' = Height of wall above finished grade point on toe side. See diagram at beginning of section 2.

[a]Bench embedment is the distance from the 4' level bench down to the top of the footing. The depth of fill (measured up and along the face of the wall) above the 4' bench is added to the bench embedment derive the "total embedment."

Other Considerations for Embedment: The depth of embedment should be increased when any of the following conditions occur:

- Weak bearing soils
- Potential scour of wall toe
- Submerged wall applications
- Significant shrink/swell/frost properties of foundation wall.

F. **Leveling Pad**: Leveling pads, upon which the walls are embedded, shall be either a minimum of 6 inches of #57 stone or concrete (Table 2.2).

G. **Wall Batter**: Unless otherwise approved by the Town Engineer, it is preferred that walls have a minimum batter of 4.40º or greater.

H. **Design Methodology**: It is common practice for engineers to define the active earth pressure loading for simple retaining structures in terms of Equivalent Fluid Pressure (EFP) in pcf. Most design codes define minimum EFP as a means of establishing a simple retaining wall design criteria without site specific analysis since an active earth pressure calculation without considering surcharges or complex loadings yields a simple triangular earth pressure distribution, the similarity to a fluid pressure analysis at some equivalent weight is reasonable. EFP's for various soils types, based on Unified Soil Classification, has been excerpted from the NCSBC and is located in the appendix, Table A.4. [2]

I. Soil Reinforcement:

1) Provide a minimum reinforcement length of 60% the total height of the wall, or longer as required by calculation, for each layer. However, reinforcing may not be required in short SRW's where it can be demonstrated that the wall will function as a gravity wall meeting all the applicable Factor of Safety requirements noted in Table 2.1.

2) Provide continuous, 100% Geosynthetic coverage at each reinforcement layer (no gaps).

3) Use a maximum spacing between vertically adjacent reinforcing layers of no more than 2 times the actual (not nominal) SRW unit depth (face to tail).

4) Only the weight of the mass vertically over the plane of sliding shall be included in the resisting forces for sliding and overturning.

5) Hinge height shall only apply to wall systems with $\geq 10^\circ$ of batter. Hinge height is the height at which a vertical line at the front face of the top SRW unit, extended down vertically, intersects and passes the back of a lower SRW unit in the same wall.

B. **Unit Drainage Fill:** All SRW's shall incorporate unit drainage fill in their design to provide a means for relieving hydrostatic pressure within and behind the wall. Two options are available.

1) **Option 1**: The wall shall have unit drainage fill, 24 inches in depth (measured from the front face of the wall) consisting of #57 or #67 stone used in conjunction with a Geotextile fabric. The Geotextile shall provide positive filtration and soil retention between the stone unit drainage fill and the reinforced soil backfill.

2) **Option 2**: Hollow Segmental Retaining Walls may have the nonwoven Geotextile separator placed against the tail of the units in lieu of the full 24-inch drainage zone in order to improve construction efficiency without significantly reducing drainage capacity. The backfill can be placed against the Geotextile first followed by the drainage fill within the units.

Geotextile media shall be of needle punched nonwoven type.

C. **Location of Geotextile fabric in relation to roadway elements**:

Table 2.4

Location of Wall Reinforcement	Min. Vertical Clearance	Remarks
Beyond back side of S/W On Public R/W or Utility Easement	4' Clear Below top of SW	Warning Sign Required advising public of buried Geotextile
Street side of S/W On Public R/W	8' clear below Edge of Pavement	Warning Sign Required advising public of buried Geotextile
Adjacent to and off of Public R/W	N/A	N/A
Detention/Retention Pond Easements	As Required by Design	Reinforcing must be located within Maintenance easement

1) **Obstructions within the reinforced soil zone**: Provide structural details addressing unavoidable interferences/obstructions located within the reinforced soil zone (i.e. manholes, drop inlets, light standards).

B. **Signing**: Designer shall annotate on his drawings the location(s) of a warning sign(s) in areas where destruction of fabric may be possible due to routine maintenance.

2.5 WALLS USED FOR RETENTION/DETENTION BASINS

A. **Walls used for Retention/Detention Basins** (accounting for hydrostatic pressure near the wall face): Wall design shall consider the affects of temporary inundation, either partial or full, on the wall where groundwater flow is expected such as with floodplain or retention basin structures. The Town Engineer may require a 24-inch depth of unit drainage fill for Retention/Detention basins. See Unit Drainage Fill, Option 1.

B. **Rapid Drawdown**: Wall structures constructed adjacent to water can experience a wide range of conditions and instability as water levels rise and fall. AASHTO code specifies *"For structures along rivers and canals, a minimum differential hydrostatic pressure equal to 3 feet of water shall be considered in the design…".* Liberal use of free-draining backfill material minimizes internal drawdown conditions associated with pressure differential.

C. **Saturated Foundation/Shallow Groundwater Conditions**: The designer shall take into consideration the impact of shallow groundwater or saturated subgrade where such condition are evident or otherwise determined to exist. Subgrade strengthening (or allowances for reduced strength) and the potential for excessive foundation subsidence shall be considered.

2.6 WALLS USED FOR STREAM OR CHANNEL LINERS:

For segmental retaining walls used as stream or channel liners, a Mannings "n" value of 0.023[1] may be used.

2.7 PEDESTRIAN BARRIERS/HANDRAILS:

Where the difference in elevation between the exiting grade and the retained grade level is 30 inches or more, a handrail or guard barrier shall be provided. Guard rails that perform as a protective barrier for pedestrians shall be a minimum of 42 inches in height. See the latest edition of the NCSBC, section 1012.

Where handrails or guard barriers are required, the rails or barriers are to be designed to accommodate the applicable lateral load:

Table 2.5

Facility	Railing and Guardrail Loadings[a]
Exit facilities serving an occupant load greater than 50	50 plf[b]
AASHTO Pedestrian/Bicycle Railing (W)	50 plf
Other than exit facilities	20 plf[b]
Minimum point loading at top of rail	200 lbs[b]
AASHTO Traffic Barrier (P)	10,000 lbs
Vehicle Traffic Barrier	See NCSBC 1607.7

[a]Applied at the top in any direction
[b]2006 NCSBC, Section 1607.7.1

[1] Design Procedures for Channel Protection and Streambank Stabilization IECA 1996 Water Effects on Keystone – Utah State University 1991.

SECTION 3
BIBLIOGRAPHY

1. *2006 NC State Building Code* (2003 IBC w/ NC Amendments)

2. American Association of State Highway and Transportation Officials (AASHTO), *Standard Specifications for Highway Bridges*, Washington DC, 16th Edition, 1996 with 1997 and 1998 Interims

3. *Design Manual for Segmental Retaining Walls*, NCMA, 2302 Horse Pen Road, Herndon, VA 20171

4. *Keystone Design Manual & Keystone Operating Guide*, Keystone Retaining Wall Systems, Inc., August 2001, Revised July 2006

5. *Basics of Retaining Wall Design*, 5th Edition, Hugh Brooks, Civil & Structural Engineer, HBA Publications, Inc., PO Box 826, Corona del Mar, CA 92625

6. *Foundation Analysis and Design*, 3rd Edition, Joseph E. Bowles, McGraw-Hill Book Company, New York, NY

SECTION 4
APPENDIX OF TABLES

The following Tables are being provided for reference.

Table A.1

Approximate Soil Design Parameter Ranges					
Wall Backfill Classification	**Common Description**	**UNSC Classification**	**Φ range**	**γ range (moist)**	**Comments**
Good	Sand, Gravel, Stone	GW, GP, GM, GC, SW, SP	32° - 36°	100 -135 pcf	Poor grading lowers weight (i.e. #57 stone)
Moderate	Silty Sands Clayey Sand	SM, SC	28° - 32°	110 – 130 pcf	Moisture Sensitive
Difficult	Silts, Low Plastic Clays	ML, CL, CL	25° - 30°	110 – 125 pcf	PI<20 LL<40
Bad	High Plastic Silts & Clays, organics	CH, MH OH, PT	0° - 25°	50 – 110 pcf	PI<20 LL<40

Table A.2

PRESUMPTIVE BEARING CAPACITIES[a]		
CLASS	**MATERIAL**	**ALLOWABLE BEARING (tons per sq. ft.)[b]**
3	Hard weathered rock	30
4	Soft weathered rock	15
5	Hard residual silt/dense sand	5
6	Residual silt/sand	1 to 3
7	Dense sand	3
8	Stiff clay	2
9	Loose sand	1
10	Soft clay	1
11	Compacted controlled fill	1.5

a. Partially excerpted from Table 1804.2(2) of the 2006 NCSBC.

b. The allowable bearing value given in this section or when determined in accordance with the provisions of Section 1804.2.1 of the 2006 NCSBC will assure that the soils will be stressed within limits that lie safely below their strength. However, such allowable bearing pressures for class 6 and classes 8 through 11 do not assure that the settlements will be within tolerable limits for a given structure.

c. Alternatively the allowable bearing value may be calculated from soil properties determined by field or laboratory tests.

TABLE A.3

ALLOWABLE LATERAL PRESSURE[e]			
CLASS OF MATERIALS	LATERAL BEARING (psf/f below natural grade)[d]	LATERAL SLIDING	
		Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	1,200	0.70	--
2. Sedimentary and foliated rock	400	0.35	--
3. Sand gravel and/or gravel (GW and GP)	200	0.35	--
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	150	0.25	--
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	100	--	130

a. Coefficient to be multiplied by the dead load.
b. Lateral sliding resistance value to be multiplied by the contact area, as limited by Section 1804.3 of the 2006 NCSBC.
c. Deleted
d. An increase of one-third is permitted when using the alternate load combination in Section 1605.3.2 that includes wind or earthquake loads.
e. Excerpted from Table 1804.2(1) of the 2006 NCSBC

TABLE A.4[c]

SOIL LATERAL LOAD			
DESCRIPTION OF BACKFILL MATERIALS	UNIFIED SOIL CLASSIFICATION	DESIGN LATERAL SOIL LOAD[a] (pound per square foot per foot of depth)	
		Active pressure	At-rest pressure
Well-graded, clean gravels; gravel-sand mixes	GW	30	60
Poorly graded clean gravels; gravel-sand mixes	GP	30	60
Silty gravels, poorly graded gravel-sand mixes	GM	40	60
Clayey gravels, poorly graded gravel-and-clay mixes	GC	45	60
Well-graded, clean sands; gravely sand mixes	SW	30	60
Poorly grades clean sands; sand-gravel mixes	SP	30	60
Silty sands, poorly graded sand-silt mixes	SM	45	60
Sand-silt clay mix with plastic fines	SM-SC	45	100
Clayey sands, poorly graded sand-clay mixes	SC	60	100
Inorganic silts and clayey silts	ML	45	100
Mixture of inorganic silt and clay	ML-CL	60	100
Inorganic clays of low to medium plasticity	CL	60	100
Organic silts and silt clays, low plasticity	CL	Note b	Note b
Inorganic clayey silts, elastic silts	MH	Note b	Note b
Inorganic clays of high plasticity	CH	Note b	Note b
Organic clays and silty clays	OH	Note b	Note b

a. Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.
b. Unsuitable as backfill material
c. Excerpted from Table 1610.1, 2006 NCSBC

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