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SEGMENTAL RETAINING WALL DESIGN

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INTRODUCTION

Segmental retaining walls (SRWs) function as gravity structures by relying on self-weight to resist the destabilizing forces due to retained soil (backfill) and surcharge loads. Stability is provided by a coherent mass with sufficient width to prevent both sliding at the base and overturning about the toe of the structure under the action of lateral earth forces.

SRWs are durable and long lasting retaining wall systems. The units are placed without mortar (dry-stacked). The typical size of SRW units permits the construction of walls in locations with difficult access, as well as allowing the construction of tight curves or other complex architectural layouts.

Segmental retaining walls are used in many applications, including landscaping walls, structural walls for changes in grade, bridge abutments, stream channelization, waterfront structures, tunnel access walls, wing walls and parking area support. This TEK provides a general overview of design considerations and the influence that height, soil, load and geometry have on structural stability.

TYPES OF SEGMENTAL RETAINING WALLS

Conventional (Gravity) Segmental Retaining Walls

Conventional (gravity) SRWs retain soils solely through the self-weight of the units. They can be constructed with either a single depth of units or with multiple depths. The maximum wall height achievable using a conventional SRW is directly proportional to the unit's weight, width , site geometry, surcharge load and retained soil type. Graph F illustrates the affect of wall batter and unit width on height, where Graph G details the benefit of increasing the unit's in-place density (using either a solid unit or unit with aggregate core fill). Graph H demonstrates the benefits of placing and compacting quality backfill or conducting a geotechnical investigation to more accurately define the backfill materials.

Soil-Reinforced Segmental Retaining Walls

Soil-reinforced SRWs are composite systems consisting of SRW units in combination with a mass of retained soil, stabilized by horizontal layers of reinforcement, typically a geosynthetic material. The reinforcement increases the effective width and weight of the gravity mass. Geosynthetic reinforcement materials are high tensile strength polymeric sheet materials. They may be geogrids or geotextiles, though current SRW construction typically uses geogrids.

Figure 1 illustrates a typical soil-reinforced segmental retaining wall, and current design terminology. The geosynthetic reinforcement is placed between the units and extended into the soil to create a composite gravity mass structure. This mechanically stabilized wall system, comprised of the SRW units and a reinforced soil mass, offers the required resistance to external forces associated with taller walls, surcharged structures, or more difficult soil conditions. Soil-reinforced SRWs may also be referred to as mechanically stabilized earth (MSE) walls, the generic term used to describe all forms of fill-type reinforced soil structures.

DESIGN CONSIDERATIONS

Geosynthetic Length and Spacing

For soil-reinforced segmental retaining walls, geosynthetic reinforcement increases the mass of the composite SRW structure, and therefore increases its resistance to destabilizing forces. Geosynthetic length is typically controlled by external stability or internal pullout capacity calculations. Increasing the length of the geosynthetic layers increases the SRW's resistance to overturning, base sliding, bearing failure and geosynthetic pullout. In some cases, the length of the uppermost layer(s) is locally extended in order to provide adequate anchorage (pullout capacity) for the geosynthetic layers. The strength of the geosynthetic and the frictional interaction with the surrounding soil may also affect geosynthetic length necessary to provide adequate pullout capacity. In addition, the required length to achieve minimum pullout capacity is affected by soil shear strength, backslope geometry and surcharge load (dead or live).

The minimum geosynthetic length required to satisfy external stability criteria is also a function of the soil shear strength and structure geometry (including wall batter, backslope, toe slope and surcharge). As the external driving force increases, as occurs with an increase in backslope angle, reduction in soil shear strength, or increase in external surcharge load (dead or live), the length of the geosynthetic increases to satisfy minimum external stability requirements. Graphs A–D illustrate the affect of backslope geometry, surcharge and soil shear strength on the minimum required geosynthetic length to satisfy base sliding (FS=1.5).

A sufficient number and strength of geosynthetic layers must be used to satisfy horizontal equilibrium with soil forces behind the wall and to maintain internal stability. In addition, the tension forces in the geosynthetic layers must be less than the design strength of the geosynthetic and within the allowable connection strength between the geosynthetic and the SRW unit. The optimum spacing of these layers is typically determined iteratively, usually with the aid of a computer program. Typically, the vertical spacing decreases with depth below the top of the wall because earth pressures increase linearly with depth. Vertical spacing between geosynthetic layers should be limited to prevent bulging of the wall face between geosynthetic connection points and to prevent exceeding the shear capacity between SRW units. Decreasing the vertical spacing of the reinforcement reduces the potential for bulging of the wall face and decreases the load in the soil reinforcement and at the geosynthetic-SRW unit connection interface. Graph E demonstrates that by reducing the vertical reinforcement spacing reduces the geosynthetic reinforcement tensile load.

Drainage System

Drainage is an essential part of a properly designed SRW. Drainage materials are generally well-graded aggregates. The column of drainage aggregate relieves hydrostatic pressure in the soil, prevents retained soils from washing through the face of the wall when designed as a soil filter, and facilitates compaction behind the wall units. Surface water drainage should be designed to minimize erosion of the topsoil in front of the wall toe and to direct surface water away from the structure.

Wall Batter

Segmental retaining walls are generally installed with a small horizontal setback between units, creating a wall batter into the retained soil (ω in Fugre 1). The wall batter compensates for any slight lateral movement of the SRW face due to earth pressure and compliments the aesthetic attributes of the SRW system. For conventional (gravity) SRWs, increasing the wall batter increases the wall system stability.

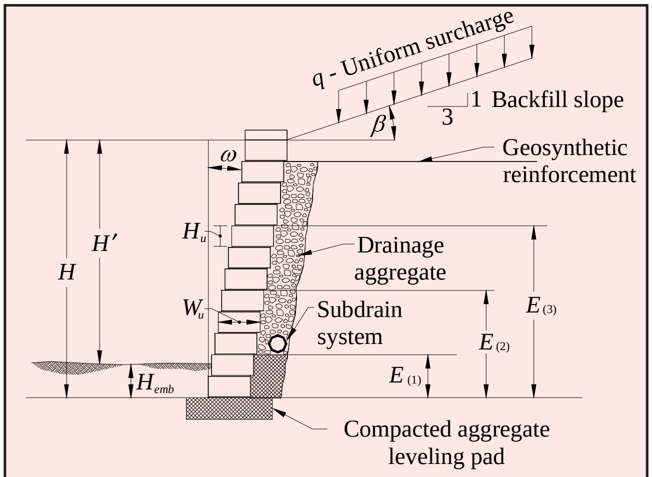
Unit Size and Shear Capacity

With conventional (gravity) SRWs, where the stability of the system depends primarily on the mass and shear capacity of the SRW units, increasing the SRW unit width or weight provides greater stability, larger frictional resistance, and larger resisting moments. In soil-reinforced SRWs, heavier and wider units may permit a greater vertical spacing between layers of geosynthetic, minimize the potential for bulging of the wall face, and influence the vertical spacing requirements of the geosynthetic reinforcement.

All SRW units provide a means of transferring lateral forces from one course to the next. Shear capacity provides lateral stability for this mortarless wall system. SRW units develop shear capacity by shear keys, leading lips, trailing lips, clips, pins or compacted columns of aggregate in open cores.

Wall Embedment

Wall embedment is the depth of the wall face that is below grade (H_{emb} in Figure 1). The primary benefit of wall embedment is to ensure the SRW is not undermined by erosion of the soil in front of the wall. Increasing the depth of embedment also provides greater stability when site conditions include weak bearing capacity of underlying soils, steep slopes near the toe of the wall, potential scour at the toe (particularly in waterfront or submerged applications), seasonal soil volume changes or seismic loads.



$E_{(n)}$ = elevation of geosynthetic reinforcement above top of leveling pad
H = total (design) height of wall
H' = exposed height of wall
H_{emb} = wall embedment depth
H_u = height of segmental retaining wall unit
L = minimum length of geosynthetic reinforcement, including facing connection
W_u = width of segmental retaining wall unit
β = backslope angle from horizontal
ω = wall batter

Figure 1—Soil Reinforced Segmental Retaining Wall

Surcharge Loadings

Often, vertical surcharge loadings are imposed behind the top of the wall in addition to load due to the retained earth (q in Figure 1). These surcharge loadings add to the lateral pressure on the SRW structure. The surcharge loading can be caused by a sloped backfill behind the wall, a uniform surcharge due to buildings, parking lots, etc., or by line or point loads due to heavy isolated footings or continuous footings close to the wall.

DESIGN RELATIONSHIPS

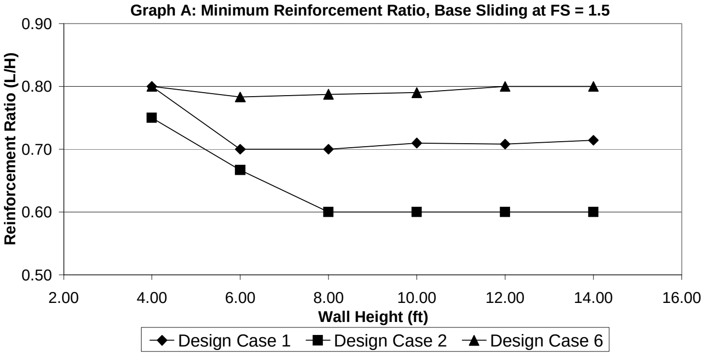
Graphs A - H summarize the influences wall geometry, backslope and soil shear strength have on the minimum required reinforcement length to satisfy base sliding and the maximum constructible height for a gravity SRW.

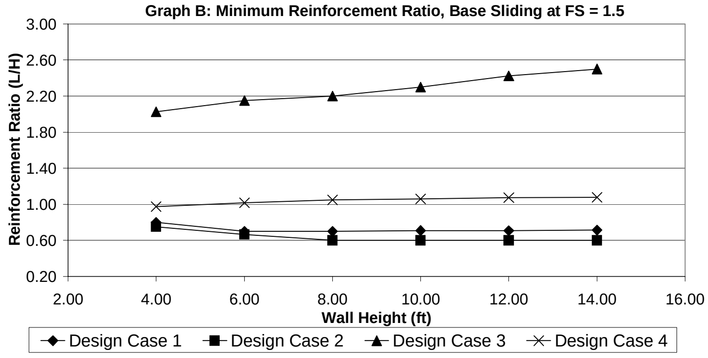
These tables were generated using conservative, generic properties of SRW units. They are not a substitute for project-specific design, since differences between properties assumed in the tables and project-specific parameters can result in large differences in final design dimensions or factors of safety. Although wall heights up to 6 ft (1.83 m) for conventional (gravity) walls and 14 ft (4.28 m) for soil-reinforced walls are presented, properly designed walls can exceed these heights.

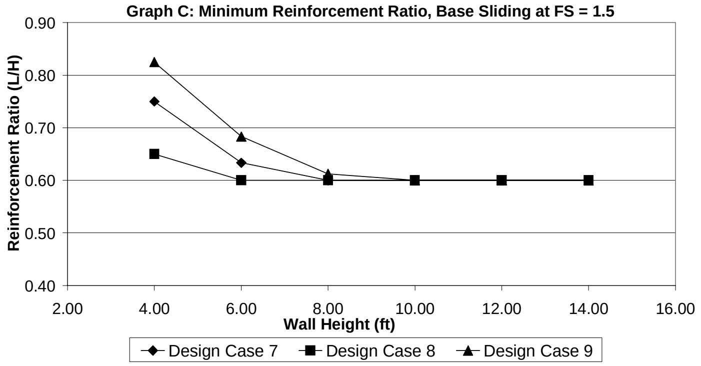
For a detailed discussion of design and analysis parameters, the *Design Manual for Segmental Retaining Walls* (ref. 1) should be consulted. The design parameters used to develop Graphs A - H are listed below. Design cases 1 through 14 are illustrated in Figure 2.

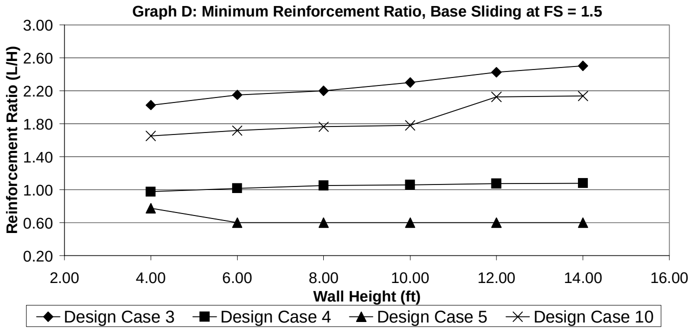
Design parameters for Graphs A Through E:

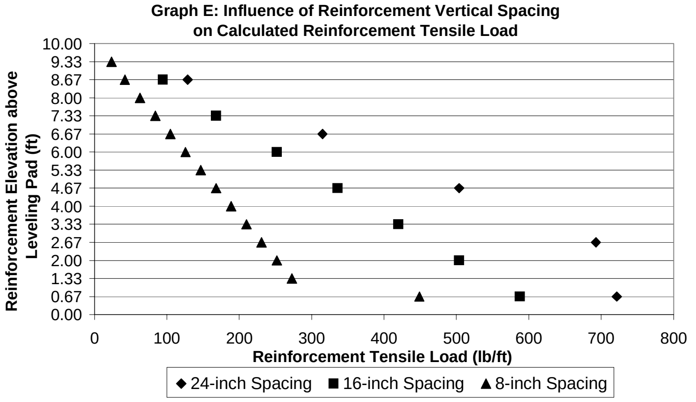
- Width of SRW unit, W_u, 12 in. (305 mm)
- SRW unit weight, 120 pcf (1,922 kg/m^3), includes aggregate core fill when required
- Wall batter, ω, 3^o or 8^o, as designated in graph; base inclination, 0^o
- Angle of friction between SRW units and geosynthetic, 40^o
- C_{ds} = direct sliding coefficient = 0.95 (min.)
- C_i = interaction coefficient = 0.7 (min.)
- Min. shear capacity between SRW units, 400 lb/ft (5.8 kN/m)
- Angle of friction between SRW units, 30^o
- Surcharge is initiated 2 ft (610 mm) from back of wall face
- See Ref. 1 for typical values of ϕ for various soil types

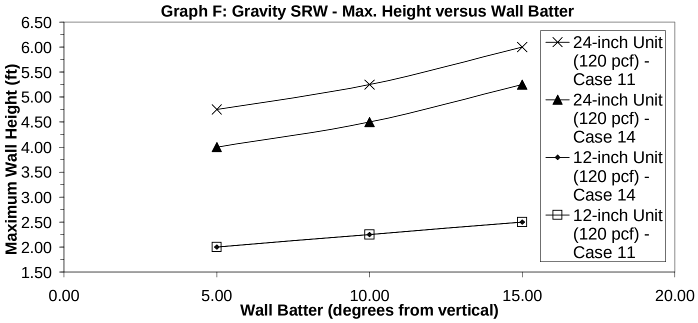


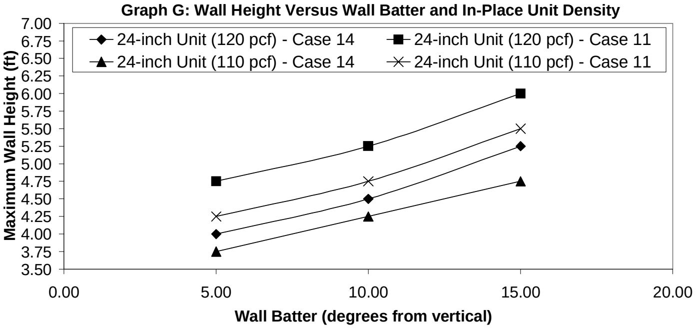


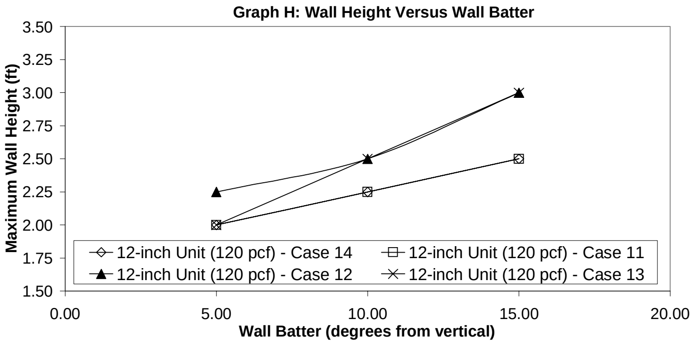


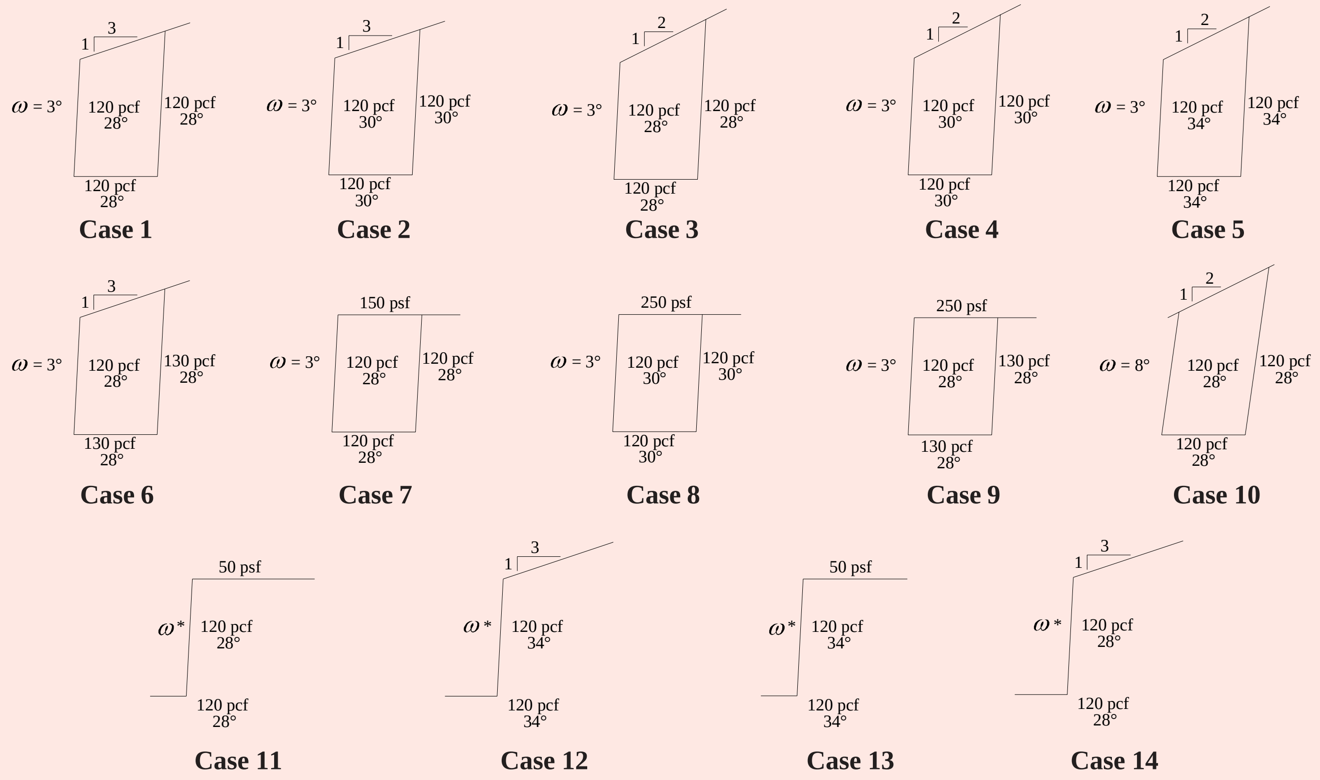












* Wall batter varies: 5°, 10° or 15°

Figure 2—Design Cases Corresponding to Graphs A Through H

Design parameters for Graphs F Through H:

- Minimum factor of safety for base sliding and overturning, 1.5
- Width of SRW unit, W_u, 12 in. or 24 in. (305 or 610 mm), as designated in graph
- SRW unit weight, 120 pcf or 110 pcf (1,922 or 1,762 kg/m^3), as designated in graph
- Wall batter, ω, 5°, 10°, or 15°, as designated in graph; base inclination , 0°
- Angle of friction between SRW units and geosynthetic, 40°
- Minimum masonry friction reduction factor, μ_b, between SRW unit and aggregate leveling pad, 0.7
- Min. shear capacity between SRW units, 400 lb/ft (5.8 kN/m)
- Angle of friction between SRW units, 30°
- Surcharge is initiated 2 ft (610 mm) from back of wall face
- Required embedment at toe, H_{emb}, 6 in. (152 mm)
- See Ref. 1 for typical values of ϕ for various soil types

REFERENCE

1. *Design Manual for Segmental Retaining Walls*, 2nd edition, 3rd printing. National Concrete Masonry Association, 2002.

NATIONAL CONCRETE MASONRY ASSOCIATION
13750 Sunrise Valley Drive, Herndon, Virginia 20171
www.ncma.org

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