

# **SIENA STONE® GEOGRID REINFORCED RETAINING WALL INSTALLATION SPECIFICATIONS**

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## **FOREWORD**

This outline specification has been prepared for the general guidance of specifiers, engineers, contractors and superintendents associated with the construction of Siena Stone® Geogrid Reinforced Retaining Wall. A qualified engineer must determine the suitability of the design, confirm site conditions and monitor the installation in critical applications.

## **CROSS SECTION EXAMPLES**

A comprehensive compilation of specific retaining wall scenarios can be found at [www.unilock.com](http://www.unilock.com). Also, under the Design Professional Resources section is the Risiwall software program, which can be used for site specific analysis for most Unilock® retaining wall systems.

Call 1-800-UNILOCK for engineering assistance.

## **SIENA STONE® GEOGRID REINFORCED RETAINING WALL INSTALLATION SPECIFICATION**

### **SECTION 02832- CONCRETE SEGMENTAL RETAINING WALL**

#### **PART 1 GENERAL**

##### **1.1. Description**

- A. The work covered by this section includes the furnishing of all labor, materials, equipment and incidentals for the design, inspection and construction of a modular concrete retaining wall including drainage system and reinforcement as shown on the Construction Drawings and as described by the Contract Specifications. The work included in this section consists of, but is not limited, to the following:
1. Design, inspection and certification by a registered professional engineer.
  2. Excavation and foundation soil preparation.
  3. Furnishing and placement of the leveling base.
  4. Furnishing and placement of the drainage system.
  5. Furnishing and placement of geotextiles.
  6. Furnishing and placement of segmental retaining wall facing units.
  7. Furnishing and placement of geosynthetic reinforcement.
  8. Furnishing and compaction of infill, drainage and retained soils.

##### **1.2. Related Work**

- A. Section 02100 - Site Preparation  
B. Section 02200 - Earthwork

##### **1.3. Reference Standards**

- A. Engineering Design
1. NCMA Design Manual for Segmental Retaining Walls, Second Edition.
  2. NCMA TEK 2-4 - Specifications for Segmental Retaining Wall Units.
  3. NCMA SRWU-1 - Determination of Connection Strength between Geosynthetics and Segmental Concrete Units.
  4. NCMA SRWU-2 - Determination of Shear Strength between Segmental Concrete Units.
- B. Segmental Retaining Wall Units
1. ASTM C 140 - Sampling and Testing Concrete Masonry Units
  2. ASTM C 1262 - Evaluating the Freeze - Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units.

3. ASTM C 33 - Specification for Concrete Aggregates
  4. ASTM C 90 - Standard Specification for Load-Bearing Concrete Masonry Units
  5. ASTM C 150- Specification for Portland Cement
  6. ASTM C 595 - Specification for Blended Hydraulic Cements
- C. Geotextile Filter
1. ASTM D 4751 - Standard Test Method for Apparent Opening Size
- D. Geosynthetic Reinforcement
1. ASTM D 4595 - Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.
  2. ASTM D 5262 - Test Method for Evaluating the Unconfined Creep Behavior of Geosynthetics.
  3. GRI GG-1: Single Rib Geogrid Tensile Strength
  4. GRI GG-5: Geogrid Pullout
  5. GRI GT-6: Geotextile Pullout
- E. Soils
1. ASTM D 698 - Moisture Density Relationship for Soils, Standard Method
  2. ASTM D 422 - Gradation of Soils
  3. ASTM D 424 - Atterberg Limits of Soils
  4. ASTM D G51 - Soil pH
- F. Drainage Pipe
1. ASTM D 3034 - Specification for Polyvinyl Chloride (PVC) Plastic Pipe
  2. ASTM D 1248 - Specification for Corrugated Plastic Pipe
- G. Where specifications and reference documents conflict, the Owner or Owner's Representative shall make the final determination of applicable document.

#### **1.4. Approved Products**

- A. Siena Stone Segmental Retaining Wall System as supplied by by Unilock®  
Unilock® Location (Address, Phone, Fax) \_\_\_\_\_
- B. Color to be [\_\_\_\_\_].

#### **1.5. The Contractor**

- A. The term Contractor shall refer to the individual or firm who will be installing the retaining wall.
- B. The Contractor must have the necessary experience for the project and have successfully completed projects of similar scope and size.

### **1.6. Delivery, Material Handling and Storage**

- A. The installing contractor shall check all materials delivered to the site to ensure that the correct materials have been received and are in good condition.
- B. The Contractor shall store and handle all materials in accordance with Unilock's recommendations and in a manner to prevent deterioration or damage due to moisture, temperature changes, contaminants, breaking, chipping or other causes.

### **1.7. Engineering Design and Certification**

- A. The term Engineer shall refer to the individuals or firms who have been retained by the Contractor to provide design and inspection services for the retaining wall. The Design Engineer may be a different individual or firm from the Inspecting Engineer as Unilock® may provide this service. The Engineer(s) must be qualified in the area of segmental retaining wall design and construction and must be licensed to practice engineering in the Province or State that the wall is to be constructed.
- B. The Engineer(s) will perform the following tasks:
  - 1. Produce sealed construction drawings and detailed design calculations, completed in accordance with the design requirements outlined in Part 3 of these specifications.
  - 2. Review the site soil and geometric conditions to ensure the designed wall is compatible with the site prior to construction.
  - 3. Inspect the site conditions, materials incorporated into the retaining wall, and the construction practices used during the construction.
  - 4. Provide the Contractor with a letter after completion, certifying the design meets the requirements of this specification, the design was compatible with the site and the wall was constructed according to design.

### **1.8. Submittals**

- A. The Contractor shall submit the following information for approval thirty (30) days prior to the construction of the segmental retaining wall.
  - 1. Design Submittal – Provide three (3) sets of stamped construction drawings and detailed design calculations, completed and sealed by the Engineer in accordance with the design requirements outlined in Part 3 of this specification. A detailed explanation of the design properties for the geosynthetic reinforcements shall be submitted with the design.
  - 2. Materials Submittal – Manufacturer's certifications, stating that the SRW units, the geosynthetic reinforcement, and imported aggregates and soils meet the requirements of this specification and the Engineer's design.
  - 3. Installer Qualifications - The Contractor must be able to demonstrate that their field construction supervisor has the necessary experience for the project by providing documentation showing that they have successfully completed projects of similar scope and size.

### 1.9. Measurement for Payment

- A. Payment for earthworks to prepare the site for the retaining wall construction will be based on the contract unit price per cubic meter (or cubic yard) for site cut and fill earthwork as detailed in the Site Plan. Additional earthwork as directed and approved in writing by the Owner, or Owner's representative, shall be paid for under a separate pay item.
- B. Payment for the retaining wall system will be based on the contract price per square meter (or square foot) of vertical wall face area as shown on the construction drawings. The vertical wall face area shall be measured from the top of the base or footing to the top of the coping course multiplied by the length of the wall. The contract unit price shall include the cost of all engineering, labor, materials, and equipment used to install the leveling base or spread footing, wall modules, drainage materials, infill soil, geosynthetic reinforcement, retained soil and site clean up. Additional vertical wall face area as directed and approved in writing by the Owner, or Owner's representative, shall be paid for under a separate pay item.

## PART 2 MATERIALS

### 2.1. Definitions

- A. Modular concrete retaining wall units are dry-cast solid concrete units that form the external fascia of a modular unit retaining wall system.
- B. Coping units are the last course of concrete units used to finish the top of the wall.
- C. Infill soil is specified material that is placed directly behind the drainage soil and within the reinforced zone, if applicable.
- D. Retained soil is an in-situ soil or a specified soil that is placed behind the wall infill soil.
- E. Foundation soil is the in-situ soil beneath the wall structure.
- F. Drainage aggregate is a free draining soil with natural soil filtering capabilities, or a free draining soil encapsulated in a suitable geotextile, or a combination of free draining soil and perforated pipe all wrapped in a geotextile, placed directly behind the modular concrete units.
- G. Drainage pipe is a perforated polyethylene pipe used to carry water, collected at the base of a soil retaining wall, to outlets in order to prevent pore water pressures from building up behind the wall facing modules.
- H. Non-woven geotextiles are permeable synthetic fabrics formed from a random arrangement of fibers in a planar structure. They allow the passage of water from one soil medium to another while preventing the migration of fine particles that might clog a drainage medium.
- I. Geogrid reinforcement is a polymer grid structure having tensile strength and durability properties that are suitable for soil reinforcement applications.

- J. All values stated in metric units shall be considered as accurate. Values in parenthesis stated in imperial units are the nominal equivalents.

## **2.2. Products**

### **A. Concrete Segmental Retaining Wall Units**

1. The concrete wall modules shall be 185 x 1200 x 500 mm (7.25 x 48 x 20 inches) with a maximum tolerance of plus or minus 3 mm (1/8 in.) for each dimension. In some Unilock® locations the concrete wall modules have the alternate dimensions of 185 x 1000 x 500 mm (7.25 x 39 x 20 inches).
2. The retaining wall modules shall be solid units and have a minimum weight of 259kg (570 lbs.) per unit, or 210kg (463 lbs.) in some Unilock® locations as noted above.
3. The concrete wall modules shall have a integral shear key connection that shall be offset to permit a minimum wall batter of 1H : 8V.
4. The concrete wall modules shall have a minimum 28-day compressive strength of 35 MPa (5000 psi) as tested in accordance with ASTM C 140. The concrete shall have a maximum moisture absorption rate of 5 percent to ensure adequate freeze-thaw protection.

### **B. Infill Soil**

1. The infill soil shall consist of free draining sands or gravels with less than 5% passing the #200 sieve size or as specified in the Construction Drawings.
2. The Engineer shall review and determine the suitability of the wall infill soil at the time of construction.

### **C. Retained Soil**

1. The retained soil shall be on site soils unless specified otherwise in the Construction Specifications or as directed by the Owner or Owner's Representative. If imported fill is required, it shall be examined and approved by the Engineer.

### **D. Foundation Soil**

1. The foundation soil shall be the native undisturbed on site soils. The foundation soil shall be examined and approval by the Engineer prior to the placement of the base material.

### **E. Leveling Base Material**

1. The footing material shall be non-frost susceptible, well graded compacted crushed stone (GW-Unified Soil Classification System), or a concrete leveling base, or as shown on the Construction Drawings.

### **F. Drainage Soil**

1. The drainage soil shall be a free draining angular granular material of uniform particle size smaller than 25 mm (1 inch) separated from the infill soil or retained soil by a geotextile filter. The drainage soil shall be installed

directly behind the SRW units if the infill soil is unable to provide adequate drainage capacity.

**G. Drainage Pipe**

1. The drainage pipe shall be perforated corrugated HDPE or PVC pipe, with a minimum diameter of 100 mm (4 inches), protected by a geotextile filter to prevent the migration of soil particles into the pipe, or as specified on the construction drawings.

**H. Geotextile Filter**

1. The non-woven geotextile shall be installed as specified on the construction drawings. Although selection of the appropriate geotextile specifications is site soil specific, a commonly used geotextile for filtration will have an Apparent Opening Size ranging between 0.149 and 0.210 mm (U.S. Sieve Sizes 100 to 70) and a minimum unit weight of 135 grams per square meter (4.0 oz /square yard). The coefficient of permeability will typically range between 0.1 and 0.3 cm/second.

**I. Geogrid Reinforcement**

1. The Engineer shall determine the type, strength and placement location of the reinforcing geosynthetic. The design properties of the reinforcement shall be determined according to the procedures outlined in this specification.

Detailed test data shall be submitted with the design calculations and shall include tensile strength (ASTM D 4595 or GGI GG-1), creep potential (ASTM D 5262), site damage and durability (GRI GG-4) and pullout resistance (GRI GG-5 or GRI-GT-6) and connection strength (NCMA SRWU-1).

## **PART 3 WALL DESIGN**

### **3.1. Design Standard**

- A. The Design Engineer is responsible for providing a design that shall consider the external stability, internal stability, and local stability of the SRW System. It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability, and/or, if the foundation soils will require special treatment to control total and differential settlement. The design life of the structure shall be 75 years unless otherwise specified in the construction drawings.
- B. The segmental retaining wall shall be designed in accordance with recommendations of the NCMA Design Manual for Segmental Retaining Walls, Second Edition. The following is a summary of the minimum factors of safety for the various modes of failure evaluated in the proposed design.

**External Stability**

Base Sliding	1.5
Overturning	2.0
Bearing Capacity	2.0
Global Stability	1.3

**Internal Stability**

Tensile Overstress	1.0
Pullout	1.5
Internal Sliding	1.5

**Local Stability**

Facing Shear	1.5
Connection	1.5

**3.2. Soil**

A. Design parameters: The following soil parameters shall be assumed for the design unless otherwise shown on the plans or specified by the Engineer.

**Infill Soil:**

Unit Weight	= [_____] kN/m <sup>3</sup> (lb/ft <sup>3</sup> )
Friction Angle	= [_____] deg
Cohesion	= 0 kPa (lb/sqft)

**Retained Soil:**

Unit Weight	= [_____] kN/m <sup>3</sup> (lb/ft <sup>3</sup> )
Friction Angle	= [_____] deg
Cohesion	= 0 kPa (lb/sq.ft)

**Foundation Soil:**

Unit Weight	= [_____] kN/m <sup>3</sup> (lb/ft <sup>3</sup> )
Friction Angle	= [_____] deg
Cohesion	= 0 kPa (lb/sq.ft)

**3.3. Design Geometry**

- A. The length, height, and overall elevations of the retaining wall must comply with the requirements of the proposed elevation detail, station information and site grading plan.
- B. The structures' design height, H, shall be measured from the top of the leveling pad to the top of the wall where ground surface intercepts the wall facing.

- C. Slopes above and below all sections of the segmental retaining wall are detailed in the site grading plan.
- D. The minimum wall embedment shall be the greater of :
  - 1. The height of a SRW unit,
  - 2. 150 mm (0.5 ft) or,
  - 3. The minimum embedment required because of the slope below the wall:

<b>Slope Below Wall</b>	<b>Minimum Embedment</b>
Level	H/10
3 : 1 (18.4 deg)	H/10
2 : 1 (26.5 deg)	H/7

- E. The following surcharges shall be applied to the top of each design cross section based on the following proposed uses above the wall.

<b>Use Above Wall</b>	<b>Minimum Surcharge</b>
No Traffic	0 kPa (0 lb/sq. ft)
Light Traffic	4.8 kPa (100 lb/sq. ft)
Heavy Traffic	12.0 kPa (250 lb/sq. ft)

**3.4. State of Stress**

- A. The lateral earth pressure to be resisted by the reinforcements at each reinforcement layer shall be calculated using the Coulomb coefficient of earth pressure,  $K_a$ , times the vertical stress at each reinforcement layer.
- B. The vertical soil stress at each reinforcement layer shall be taken equal to the unit weight of the soil times the depth to the reinforcement layer below the finished grade behind the facing units. A coefficient of active earth pressure,  $K_a$ , shall be used from the top to the bottom of the wall. The coefficient of active earth pressure,  $K_a$ , shall be assumed independent of all external loads except sloping fills. For sloping fills, the coefficient of active earth pressure,  $K_a$ , appropriate for the sloping condition, using Coulomb earth pressure shall be used in the analysis.

**3.5. Inclination of Failure Surface**

- A. A Coulomb failure surface passing through the base of the wall at the back of the reinforced zone up to the ground surface at or above the top of wall shall be assumed in design of walls.

**3.6. Geosynthetic Reinforcement**

- A. The allowable reinforcement tension,  $T_a$ , shall be determined in accordance with the method outlined in the NCMA Design Manual for Segmental Retaining Walls, Second Edition. This method calculates the Long Term Design Strength (LTDS) of the geosynthetic reinforcement by considering the time-temperature creep characteristics of the reinforcement, environmental degradation, construction induced damage and an overall factor of safety.

### 3.7. Geogrid Length

- A. The minimum soil reinforcement length shall be as required to achieve a minimum width of structure, B, measured from the front face of the wall to the end of the soil reinforcements. B must be greater than or equal to 60 percent of the total height, H. The length of the reinforcements at the top of the wall may be increased beyond the minimum length required to increase pullout resistance.

### 3.8. Settlement Control

- A. It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if the foundation soils will require special treatment to control total and differential settlement.

### 3.9. Global Stability

- A. It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability.

## PART 4 CONSTRUCTION

### 4.1. Inspection

- A. The Engineer is responsible for verifying that the contractor meets all the requirements of the specification. This includes the use of approved materials and their proper installation.
- B. The Contractor's field construction supervisor shall have demonstrated experience and be qualified to direct all work related to the retaining wall construction.

### 4.2. Construction Tolerances

- A. The following tolerances are the maximum allowable deviation from the planned construction

Vertical Control: +/- 1.25 inches over a 10 ft distance, +/- 3 inches total

Horizontal Control: +/- 1.25 inches over a 10 ft distance, +/- 3 inches total

Rotation: +/- 2 degrees from planned wall batter

Bulging: 1.0 inch over a 10 ft distance

### 4.3. Site Preparation

- A. The foundation soil shall be excavated or filled as required to the grades and dimensions shown on the Construction Drawings or as directed by the Owner or Owner's Representative.
- B. The foundation soil shall be proof rolled and examined by the Engineer to ensure that it meets the minimum strength requirements according to the design assumptions. If unacceptable foundation soil is encountered, the contractor shall

excavate the affected areas and replace with suitable quality material under the direction of the Engineer.

- C. In cut situations, the native soil shall be excavated to the lines and grades shown on the Construction Drawings and removed from the site or stockpiled for reuse as retained soil.

#### **4.4. Installing Drainage System**

- A. The approved non-woven geotextile shall be set against the back of the first retaining wall unit, over the prepared foundation, and extend towards the back of the excavation, up the excavation face and back over the top of the infill soil to the retaining wall, or as shown in the Construction Drawings.
- B. The drainage pipe shall be placed behind the leveling base, or lower course of facing units as shown in the Construction Drawings or as directed by the Engineer. The pipe shall be laid at a minimum gradient of 2% to ensure adequate drainage to free outlets.
- C. T - Sections and outlet pipes shall be installed on the drainage pipe at 15 m (50 ft.) centers or as shown on the Construction Drawings.
- D. The remaining length of geotextile shall be pulled taut and pinned over the face of the retained soil. Geotextile overlaps shall be a minimum of 300 mm (1 ft.) and shall be shingled down the face of the excavation in order to prevent the infiltration of retained soil into the wall infill.

#### **4.5. Leveling Base or Spread Footing Placement**

- A. The leveling base material shall be crushed stone compacted to 98% Standard Proctor Density, or vibrated concrete along the grades and dimensions shown on the Construction Drawings or as directed by the Engineer. The minimum thickness of the leveling base shall be 185 mm (7.25 inches)

#### **4.6. Installation of Modular Concrete Retaining Wall Units**

- A. The bottom row of retaining wall modules shall be placed on the prepared leveling base as shown on the Construction Drawings. Care shall be taken to ensure that the wall modules are aligned properly, leveled from side to side and front to back and are in complete contact with the base material.
- B. The wall modules above the bottom course shall be placed such that the tongue and groove arrangement provides the design batter (i.e. setback) of the wall face. Successive courses shall be placed to create a running bond pattern with the edge of all units being approximately aligned with the middle of the unit in the course below it.
- C. The wall modules shall be swept clean before placing additional levels to ensure that no dirt, concrete or other foreign materials become lodged between successive lifts of the wall modules.
- D. A maximum of 3 courses of wall units can be placed above the level of the infill soil at any time.

- E. The contractor shall check the level of wall modules with each lift to ensure that no gaps are formed between successive lifts that may affect the pullout resistance of geogrid reinforcement, if applicable.
- F. Care shall be taken to ensure that the wall modules and geosynthetic reinforcement are not broken or damaged during handling and placement.

#### **4.7. Drainage Soil**

- A. The drainage soil will be placed behind the retaining wall modules with a minimum width of 300 mm (1 ft.) and separated from other soils using the approved nonwoven geotextile.
- B. Drainage soil shall be placed behind the wall facing in maximum lifts of 6 inches and compacted to a minimum density of 95% Standard Proctor.
- C. No heavy compaction equipment shall be allowed within 1 meter (3 ft.) of the back of the wall fascia.

#### **4.8. Infill Soil**

- A. Wall infill soil shall be placed behind the first course of the wall facing units in maximum lifts of 150 mm (6 inches) and compacted to a minimum density of 95% Standard Proctor. At the specified elevations, geogrid reinforcement shall be placed, as described in section 4.09. The fill shall be placed and compacted level with the top of the wall modules at the specified geogrid elevations prior to placing the geogrid reinforcement.
- B. Wall infill soil shall be placed on top of the geogrid reinforcement layers in maximum lifts of 150 mm (6 inches) and compacted to a minimum of 95% Standard Proctor Density. Care shall be taken to ensure that the geogrid lays flat and taut during placement of the infill soil. This is best achieved by placing fill on top of the geogrid near the wall fascia and spreading toward the back of the infill soil zone.
- C. No tracked construction equipment shall be allowed to operate directly on top of the geogrid until a minimum thickness of 150 mm (6 inches) of fill has been placed. Rubber tired equipment may drive on top of the geogrid at slow speeds but should exercise care not to stop suddenly or make sharp turns. No heavy equipment shall be allowed within 1 meter (3 ft.) of the back of the wall.

#### **4.9. Geogrid Soil Reinforcement**

- A. Pre-cut sections of geogrid reinforcement shall be placed horizontally at the specified elevations and with longitudinal axis perpendicular to the wall face (i.e. machine direction), at the elevations shown on the Construction Drawings, or as directed by the Engineer.
- B. The geogrid shall be placed over the compacted infill soil and the wall facing units with the outside edge extending over the tongue of the bottom unit and to within 25 mm (1 in.) of the front facing unit. Care shall be taken to ensure that the wall modules are swept clean and that the geogrid is in complete contact with the top and bottom faces of the adjacent wall modules. The next course of wall modules

shall be carefully placed on top of the lower modules to ensure that no pieces of concrete are chipped off and become lodged between unit layers.

- C. The geogrid shall be pulled taut away from the back the wall modules during placement of infill soil. Alternatively, suitable anchoring pins or staples can be used to ensure that there are no wrinkles or slackness prior to placement of the infill soil. The geogrid shall lay perfectly flat when pulled back perpendicular to the back of the wall fascia.

#### **4.10. Retained Soil**

- A. Retained soils shall be placed and compacted behind the infill soil or drainage soil if applicable, in maximum lift thickness of 150 mm (6 inches). The retained soils shall be undisturbed native material or engineered fill compacted to a minimum density of 95% Standard Proctor.
- B. No heavy compaction equipment shall be allowed within 1 m (3 ft.) of the back of the wall modules.

#### **4.11. Finishing Wall**

- A. Items 4.5 to 4.10 shall be repeated until the grades indicated on the Construction Drawings are achieved.
- B. Coping units shall be secured to the top of the wall with two 10 mm (3/8 inch) beads of the approved flexible concrete adhesive positioned 50mm (2 inches) in front and behind the tongue of the last course of retaining wall units.
- C. Finish grading above the wall to direct surface run off water away from the segmental retaining wall. Use a soil with a low permeability to restrict the rate of water infiltration into the retaining wall structure.

**END OF SECTION**