SRW HISTORY ARTICLE SERIES

SRW SPECIFICATIONS

This is the fifth article in a series of ten articles on the history of segmental retaining walls developed under a grant from the NCMA Education and Research Foundation.

NCMA SPECIFICATIONS

NCMA SPECIFICATIONS—SRW SYSTEMS

Specifications are legal contract documents forming an agreement between the Owner (the person or company wanting a SRW retaining wall) and the Contractor (person or company installing the retaining wall). The purpose of the specification is to form an agreement between the Owner and the Contractor as to what is desired for the retaining wall including: labor, material costs, installation, equipment costs, inspections, and management. It is also a document that defines the scope of work for the Contractor. The specification defines what is expected in terms of material requirements (color, strength, face type, etc.) and gives requirements for testing and performance specifications.

In previous articles we wrote about production, durability, quality control and SRW products options. When a retaining wall is needed, the Owner pulls from all the previous knowledge and specifies the product and installation requirements desired. When everything is defined a competitive quote should be provided by the Contractor to complete the work as desired.

NCMA provides sample specifications in the SRW Design Manual (NCMA 2009 Ref. 3) and in published Tek Notes; these are excellent resources.

CSI SPECIFICATIONS

The Construction Specifications Institute (CSI) is an organization that maintains and advances the standardization of construction language as it pertains to building specifications. CSI provides structured guidelines for specification writing in their Project Resource Manual, (formerly called the Manual of Practice (MOP)). (Wikipedia.org) All the sample documents in the NCMA Design Manual follow the CSI format and have the following three major sections:

1. General
2. Materials
3. Execution

In the following sections we will describe each section and the important items in each.

PART 1: GENERAL

1.01 Description

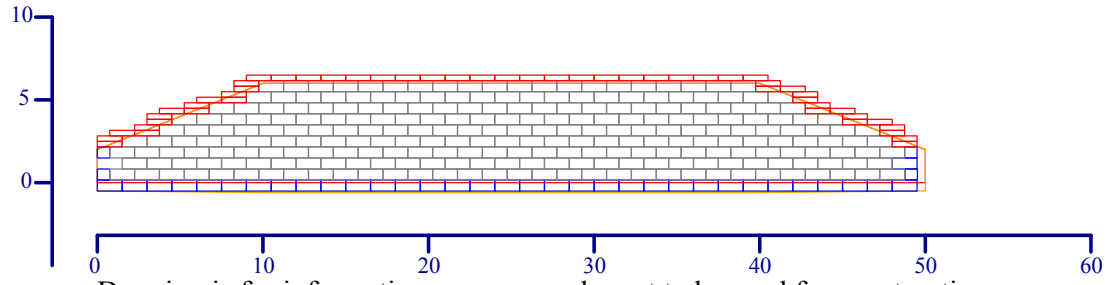
The general section describes the scope of the work, related sections of the specification that may apply to the work, published reference standards that are included in the body of the document, approved SRW systems, submittals (if required), delivery storage, and handling of the delivered products.

1.01 Description

Work shall consist of furnishing all materials, labor, equipment, and supervision to install a segmental retaining wall (SRW) system in accordance with these specifications and in reasonably close conformity with the lines, grades, design and dimensions shown on the plans or as established by the owner or owner's engineer.

The two most important items in the specification are for the contractor to supply ***all the materials*** and labor to install the wall as designed. It is equally important that the supervision and management costs be included in the quote. The final item in the scope of work is to have a defined wall area defined by the plans included with the project. For example if the wall is 50 feet (15.2 m)

long and varies in height from 2 ft to 6 ft (0.6 to 1.8 m), the total block area including the embedment depth could be 310 square feet (29 m^2) (shown on Fig. 1).



Drawing is for information purposes only, not to be used for construction.

Block Summary Table

Block	Count	Area	Block Name
BaseBlock	34	1.00	PRO
CapBlock	51	0.50	Cap
HalfBlock	4	0.50	PRO
WallBlock	248	1.00	PRO
Area	309.50 sf		
Contingency	0.00 sf		
Total Area	309.50 sf		

Figure 1. Defined Wall Area

In most cases the Contract will have an add item for wall area based on a stated cost of say $20 / sf ($215/m^2) of face area (contract unit cost for labor, materials and supervision for wall area installed). Additional wall area can become a significant addition change to the contract. Therefore a good design and wall layout protects both the Owner and the Contractor from contract extras.

1.02 Related Work

In large projects there may be other contracts with related work that will be done under this section. Coordination of work between contractors is important. In a typical project other sections could include:

1.02 Related Work
Section_____ Section–Information Available to Bidders: Geotechnical
Section_____ Report Section–Testing and Inspection Services
Section _____ Section–Site Preparation
Section _____ Section–Earthwork

For work to proceed, the site will need earthwork (Section–Earthwork) and site preparation (Section–Site Preparation) that may be done by the Contractor of this contract, or may be accomplished by the General Contractor on the project. Work on the retaining wall needs to be coordinated so there is access to the site, the required excavations are completed (or site fill operations), and if testing will be included it is done in a timely manner. Testing and Inspection may be included as part of the general contract, or it could be required for the retaining wall contract alone. The source of the fill soils may be determined from the description of subsurface conditions at the site (Information Available to the Bidders: Geotechnical). A Contractor may bid a project using on-site fill soils (no fill material costs) or

if importing soils is required, will include fill soil costs and transportation. More important is the contract item that would state the site excavation and fill soils would be provided by the earth work contractor, separate from the wall contactor. If the wall contractor is waiting on the fill, there could be extra charges.

1.03 Referenced Standards

The Owner and the Contractor will be referencing published standards for design, testing, and material properties for items supplied to the project. There are five major areas that are addressed: Engineering Design, Segmental Retaining Wall Units, Geosynthetic Reinforcement, Soils, and Drainage Pipe.

1.03 Referenced Standards
Engineering Design
NCMA Design Manual for Segmental Retaining Walls 3rd Edition

The *NCMA Design Manual* is the standard of practice for commercial projects. The design method defines the minimum depth of embedment below grade, recommended factors of safety for design: sliding, overturning, and bearing; minimum reinforcement lengths (0.6 x height or 4 ft (1.2 m)), and required information for design such as connection testing (ASTM D6638), and shear testing (ASTM D6916). Any items of design should be addressed in this reference and become part of the contract documents.

Segmental Retaining Wall Units
ASTM C140 – Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units [Ref. 5]
ASTM C1262 – Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units [Ref. 5]
ASTM C1372 – Standard Specification for Dry-Cast Segmental Retaining Wall Units [Ref. 80]
ASTM D6638 – Standard Test Method for Determining the Connection Strength Between Geosynthetics Reinforcement and Segmental Concrete Units [Ref. 5]
ASTM D6916 – Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units [Ref. 5]

ASTM C1372 describes the minimum design requirements for SRW units (dimensional tolerances, minimum compressive strengths and maximum absorption) and if installed in areas of repeated freezing and thawing, references minimum requirements for testing in conformance with ASTM C1262. The specifier can increase the minimum requirements to address other special project conditions. In the article on SRW research, references were made to minimum design strengths for SRW units and minimum design requirements if the units are installed in areas of repeated freezing and thawing. Units delivered from the supplier should meet the standards called out in these ASTM testing standards or specified requirements stated in the contract specification.

Note: These are referenced standards and they do not address the type of SRW unit, the color or the face design. Those items are defined by the Owner/ designer and covered in the Materials section of this specification.

Geosynthetic Reinforcement
ASTM D4595 – Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method [Ref. 5]
ASTM D5262 – Standard Test Methods for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics [Ref. 5]
ASTM D5321 – Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method [Ref. 5]
ASTM D5818 – Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics [Ref. 5]
ASTM D6637 – Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method [Ref. 5]
ASTM D6706 – Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil [Ref. 86]
ASTM D6992 – Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using Stepped Isothermal Method [Ref. 5]

Geosynthetics are an important part of all soil reinforced walls mechanically stabilized earth (MSE). These are polymeric materials that are subject to long-term creep, installation damage from granular materials, and have different interaction coefficients with different soils. The list of references are industry test methods to determine all of the important properties of geosynthetics.

Soils
ASTM D422 – Standard Test Method for Particle-Size Analysis of Soils
ASTM D698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3(600 kN-m/m^3))
ASTM D1556 – Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D1557 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
ASTM D2487 – Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D4318 – Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
ASTM G51 – Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing

The soils behind the retaining wall, on-site, or imported, are the most important part of the retaining wall because they represent the earth loads the wall structure must support. They are the structure that supports the loads placed above the wall. The NCMA Design Manual suggests a granular fill material, SW, SP, SM, GW, GP, GM (ASTM C2487), with less than 35 percent fines (ASTM D6913) and with low plastic fines (ASTM D4318). The NCMA specification references soil compaction to 95 percent of the standard proctor density (ASTM C698) and placed within 2 percent points of the optimum moisture content.

This is a 'master specification' and all the possible references are included. The user should select the references that are used in the body of the specification and remove references that are not used.

Drainage Pipe
ASTM F405 – Standard Specification for Corrugated Polyethylene (PE) Pipe and Fittings
ASTM F758 – Standard Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Plastic Underdrain Systems for Highway, Airport, and Similar Drainage

A drainage pipe is a standard detail behind the SRW wall facing and these references are standards for PVC drainage pipes.

1.04 Approved Segmental Retaining Wall Systems

The Owner may have specific requirements as to the type of SRW system installed and may provide a list of approved retaining wall systems. SRW systems mentioned in this section list specify segmental retaining wall units and geosynthetic reinforcement combinations that cannot be exchanged without the approval of the Owner's Engineer.

1.04 Approved Segmental Retaining Wall Systems
A. Suppliers of segmental retaining wall system material components shall have demonstrated experience in the supply of similar size and types of segmental retaining walls on previous projects, and shall be approved by the Owner's Engineer. Each supplier must be approved two weeks prior to bid opening. Suppliers currently approved for this work are:
Segmental Wall Systems (SRW Units + Geosynthetic Reinforcement)
1._____
2._____
3._____

The Owner may also require design submittals to approve unit face design, colors, etc.

1.05 Submittals

A. Material Submittals –No less than 30 days prior to the start of the project, the Contractor shall submit manufacturer's certifications, stating that the SRW units, geosynthetic reinforcement, reinforced backfill, and gravel fill meet the requirements of Part 2.0 of this

specification. The Contractor shall provide a list of successful projects with references showing that the installer for the segmental retaining wall is qualified and has a record of successful performance.

The final part of the General section is the delivery and storage of the materials.

1.06 Delivery, Storage, and Handling

A. The Contractor shall inspect the materials upon delivery to assure that proper type and grade of material has been received.

B. The Contractor shall store and handle materials in accordance with manufacturer's recommendations and in a manner to prevent deterioration or damage due to moisture, temperature changes, contaminants, corrosion, breaking, chipping or other causes.

C. The Contractor shall protect the materials from damage. Damaged material shall not be incorporated into the segmental retaining wall.

It is important that the materials delivered are the correct materials and while stored they are not damaged (cracked or broken) or discolored by placing the materials in soils.

PART 2: MATERIAL

Part two of the contract specifications are definitions of the materials to be used in the construction of the SRW project. There are four materials required for construction of an SRW wall:

1. Concrete facing unit;
2. Geogrid soil reinforcement;
3. Drainage pipe; and
4. Fill soils and gravel fill.

SRW products delivered to the site should meet the requirements of the accepted industry standards as published in the referenced ASTM standard (ASTM C1372).

2.01 Concrete Segmental Retaining Wall Units

A. Concrete segmental units shall conform to the requirements of ASTM C1372 [Ref. 5] and have a minimum net average 28 days compressive strength of 3,000 psi and a maximum absorption of 13 pcf (208 kg/m^3) (for normal weight) as determined in accordance with ASTM C140 [Ref. 5]. For areas subject to detrimental freeze-thaw cycles, as determined by the Owner or Owner's Engineer, the concrete shall have adequate freeze/thaw protection and meet the requirements of ASTM C1372 [Ref. 5] when tested in accordance with ASTM C1262 [Ref. 5].

B. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or significantly impair the strength or permanence of the construction. Any cracks or chips observed during construction shall fall within the guidelines outlined in ASTM C1372 [Ref. 5].

C. SRW units dimensions shall not differ more than $+^1/_8$ in. (3.1 mm), as measured in accordance with ASTM C140 [Ref. 5]. This tolerance does not apply to architectural surfaces, such as split faces.

D. SRW units shall match the color, surface finish, and dimension for height, width, depth, and batter as shown on the plans.

E. If pins or clips are used by the retaining wall supplier to interconnect SRW units, they shall consist of a nondegrading polymer, fiberglass, or galvanized steel and be made for the express use with the SRW units supplied.

F. Cap adhesive shall meet the requirements of the SRW unit manufacturer.

2.02 Geosynthetic Reinforcements

Geosynthetic reinforcement products are polymeric materials manufactured for specific use as soil reinforcement materials. Polymeric materials manufactured for snow fence or safety barriers are not acceptable for use as soil reinforcements and will not conform to the requirements of the contract specifications. There are two major polymers used for soil reinforcement, high tenacity polyester knitted or woven geogrids, or high density polyethylene extruded products. Polymeric materials are subject to long term creep under loading, so it is important the material properties are correct for the application.

2.02 Geosynthetic Reinforcements

A. Geosynthetic Reinforcements shall consist of high tenacity PET geogrids, HDPE geogrids, or geotextiles manufactured for soil reinforcement applications. The type, strength and placement location of the reinforcing geosynthetic shall be as shown on the plans. The design properties of the reinforcement shall be determined according to the procedures outlines in this specification and the NCMA Design Manual for Segmental Retaining Walls (3rd Edition, 2009). Detailed test data shall be submitted to the Owner's Engineer for approval at least 30 days prior to construction and shall include tensile strength (ASTM D4595 [Ref. 5] or ASTM D6637 [Ref. 5]), creep (ASTM D5262 [Ref. 5]), site damage (ASTM D5818 [Ref. 5]), durability (FHWA guidance (FHWA NHI-00-043, FHWA NHI-00-044)), pullout (ASTM D6706 [Ref. 5]), direct shear (ASTM D5321 [Ref. 5], and connection (ASTM D6638 [Ref. 5]) test data.

B. Included with the raw test data shall be a report that shows that the proposed geosynthetic reinforcements have the following minimum properties:

Property	Geosynthetic Reinforcement		
	Type 1	Type 2	Type 3
Long-Term Design Strength LTDS (lb/ft)	_____	_____	_____
Coefficient of Pullout Interaction Ci	_____	_____	_____
Coefficient of Direct Sliding – Cds	_____	_____	_____

Calculation of the allowable reinforcement tension shall use the following method:

The Long-Term Design Strength (LTDS) at the end of the service life shall consider the time-temperature creep rupture characteristics of the reinforcement, environmental degradation, construction induced damage, and an overall factor of safety.

$$LTDS = \frac{Tult}{RF_D \times RF_{ID} \times RF_{CR}}$$

where:

Tult = Ultimate (or yield tensile strength) from wide width tensile strength tests (ASTM D6637 [Ref. 5] for geogrids or ASTM D4595 [Ref. 5] for geotextiles), based on minimum average roll value (MARV) for the product.

RF_D = Durability reduction factor is dependent on the susceptibility of the geosynthetic to attack by microorganisms, chemicals, thermal oxidation, hydrolysis and stress cracking, and can vary typically for 1.05 to 2.0. The minimum reduction factor shall be 1.05.

RF_{ID} = Installation damage reduction factor can range from 1.05 to 3.0, depending on backfill gradation and product mass per unit weight. The minimum reduction factor shall be 1.1 to account for testing uncertainties.

RF_{CR} = Creep reduction factor is the ratio of the ultimate strength (*Tult*) to the creep limited strength from laboratory creep tests for each product or product family, and can vary typically from 1.50 to 5.0.

In no case shall the product $RF_{ID} \times RF_D \times RF_{CR}$ be less than 2.0.

2.03 Drainage Pipe

Drainage pipe is installed behind the wall facing in the clean granular fill to collect seepage and direct it to a disposal area, or route it through the face panel. Drainage pipe can also be used at the back of the MSE cut section to collect seepage coming from underground sources.

2.03 Drainage Pipe

A. The drainage collection pipe shall be a perforated or slotted PVC or corrugated HDPE pipe. The pipe and gravel fill may be wrapped with a geotextile that will function as a filter.
B. Drainage pipe shall be manufactured in accordance with ASTM F405 [Ref. 5] or ASTM F758 [Ref. 5].

2.04 Gravel Fill

The fill used in the SRW unit and for the area directly behind the facing unit should be a clean (less than 5% fines), crushed stone material. It is important the fill drains well and is easy to place and compact.

2.04 Gravel fill

Gravel fill shall be a clean crushed stone or granular fill meeting the following gradation as determined in accordance with ASTM D422 [Ref. 5]:

Sieve Size	Percent Passing
1 in.	100
¾ in.	75 - 100
No. 4	0 - 60
No. 40	0 - 50
No. 200	0 - 5

2.05 Reinforced Backfill

Reinforced backfill is the soil behind the wall face and is reinforced by geosynthetic or metallic reinforcements. It is important that this material be a low plastic material (does not shrink or swell) and has well defined strength parameters. In transportation projects, the reinforced backfill may be a granular, free draining soil since it may be used with geosynthetic or metallic reinforcement materials. Residential and commercial projects generally use the on-site or locally available fill soils. Clean granular soils drain well and are preferred. However performance and research (Geocomp) [Ref. 4]) has shown lower quality fills perform well if installed correctly.

2.05 Reinforced Backfill

A. The reinforced backfill shall be free of debris and consist of one of the following inorganic USCS soil types: GP, GW, SW, SP, SM, meeting the following gradation as determined in accordance with ASTM D422 [Ref. 5].

Sieve Size	Percent Passing
1 in.	100
No. 4	100 - 20
No. 40	0 - 60
No. 200	0 - 35

The maximum size should be limited to 1.0 in. for geosynthetic reinforced soil SRWs unless tests have been performed to evaluate potential strength reduction in the geosynthetic due to installation damage.

The plasticity of the fine fraction of the reinforced soil shall be less than 20.

B. The pH of the backfill material shall be between 3 and 9 when tested in accordance with ASTM G51 [Ref. 5].

A geotextile filter may be placed between the fill soils and the granular drainage area to prevent piping of fines from the fill to the drain area. A filter is important in water applications where there is a constant flow of water in and out of the system.

2.06 Geotextile Filter

Drainage geotextile shall have the following minimum properties or shall meet the criteria recommended by the Wall Design Engineer.

AOS	ASTM D4751 [Ref. 5]	_____
Grab Tensile	ASTM D4632 [Ref. 5]	_____
Trap Tear	ASTM D4533 [Ref. 5]	_____
Water Flow Rate	ASTM D4491 [Ref. 5]	_____
Puncture	ASTM D4833 [Ref. 5]	_____

PART 3 CONSTRUCTION

At this point in the project we assume we have a good site investigation and understand the site parameters. We also have a design prepared by a design professional that has designed an SRW wall for the site and for the loading required. Quality materials have been ordered and delivered to the site. As the last step, we need to be sure the construction is completed by an experienced Contractor providing the system that was anticipated.

In the construction section, the specifications call out for verification of site parameters and materials delivered to the site. It also defines each step of construction so that a quality product is installed.

3.01 Construction Observation

A. The Owner or Owner's Engineer should verify the materials supplied by the contractor meet all the requirements of the specification. This includes all submittals and proper installation of the system.

B. The Contractor's field construction supervisor shall have demonstrated experience and be qualified to direct all work at the site.

3.02 Excavation

Foundation trenches and cut walls will require site excavation. It is important that the excavation be completed to the lines and grades provided. If soft soils are encountered, they should be removed and replaced with structural fill soils.

3.02 Excavation

A. The Contractor shall excavate to the lines and grades shown on the plans. The Contractor shall take precautions to minimize over-excavation. Excavation support, if required, shall be designed by the Contractor.

3.03 Foundation Preparation

After excavation it is important to examine the site and confirm the soils encountered are the soils used in design. It is more important to be sure the surfaces are compact and will meet the design requirements to support the SRW system.

3.03 Foundation Preparation

A. Following excavation for the leveling pad and the reinforced soil zone, foundation soil shall be ex-

amined by the Owner's Geotechnical Engineer to assure the actual foundation soil strength meets or exceeds the assumed design bearing strength. Soils not meeting the required strength shall be removed and replaced with soil meeting the design criteria, as directed by the Owner's Geotechnical Engineer.

3.04 Leveling Pad Preparation

Facing units for SRW walls are precast concrete units. The leveling pad is provided to give the units a level base for construction and to provide a good bearing area for the units setting on soil foundation. A minimum 6 in. (150 mm) crushed stone leveling pad is typical. An unreinforced concrete leveling pad may be used but is generally used on transportation projects.

3.04 Leveling Pad Preparation

A. A minimum 6 in. (150 mm) thick layer of compacted granular material shall be placed for use as a leveling pad up to the grades and locations as shown on the construction drawings. The granular base shall be compacted to provide a firm, level bearing pad on which to place the first course of concrete segmental retaining wall units. A leveling pad consisting of 6 in. (150 mm) (minimum) thick lean, unreinforced concrete may be used at the wall contractor's option, or if so detailed on the plans. The leveling pad should extend a minimum of 6 in. (150 mm) from the toe and from the heel of the SRW unit.

3.05 SRW and Geosynthetic Reinforcement Placement

The SRW facing will be seen for the life of the project and should be the most important step in construction. The units need to be placed level so as the wall is viewed from the side the horizontal joints are level and straight. The alignment of the wall should follow the proposed alignment so the top is straight and batter does not vary in and out.

The geosynthetic reinforcement materials provide the horizontal support to the soil mass and provides the structural attachment of the SRW facing units to the compacted soil mass. It is important the right material is used, the proper orientation is used and the materials are tensioned to remove any looseness from the layers.

3.05 SRW and Geosynthetic Reinforcement Placement

A. All materials shall be installed at the proper elevation and orientation as shown in the wall details on the construction plans or as directed by the Owner's Engineer. The segmental concrete wall units and geosynthetic reinforcement shall be installed in general accordance with the manufacturer's recommendations. The drawings shall govern in any conflict between the two requirements.
B. Overlap or splice connections of the geosynthetic in the design strength direction shall not be permitted unless the location and necessary detailing is approved by the SRW Design Engineer. The design strength direction is that length of geosynthetic reinforcement perpendicular to the wall face and shall consist of one continuous piece of material. Adjacent sections of geosynthetic shall be placed in a manner to assure that the horizontal coverage shown on the plans is provided.
C. Geosynthetic reinforcement should be installed under tension. A nominal tension shall be applied to the reinforcement and maintained by staples, stakes, or hand tensioning until the reinforcement

has been covered by at least 6 inches of soil fill.

D. Overlapping adjacent layers of geosynthetic reinforcement shall be separated by a 3 in. (75 mm) thickness of fill.
E. Broken, chipped, stained or otherwise damaged units shall not be placed in the wall unless they are repaired, and the repair method and results are aproved by the SRW Design Engineer.

Placed soils are the backbone of the system supporting the loads applied above the wall and holding the facing units in place. Density of the soils and gradation are important as these parameters define the long-term performance of the wall. From experience and testing we know that soils cannot be compacted in lifts thicker than about 8 inches (200 mm). If thicker lifts are used, post construction settlements may occur requiring a repair to the wall.

We also know that compaction equipment exerts a lot of force on the soils, which in turn gets translated into horizontal stresses during compaction. If the equipment is operated too close to the facing units, the units may rotate forward, requiring repair steps. It is therefore suggested that heavy compaction equipment not be operated within 3 ft (1 m) of the facing units and that 1 ft (300 mm) of gravel fill be placed behind the facing units.

Site drainage and control of surface water is important. It is suggested that at the end of the day the construction site be graded to direct surface water away from the construction area.

3.06 Backfill Placement

A. The reinforced backfill shall be placed behind the gravel fill as shown in construction plans in maximum compacted lift thickness of 8 in. (200 mm) and shall be compacted to a minimum 95% of standard Proctor density (ASTM D698 [Ref. 5]) at a moisture content within -1% to +3% of optimum. Backfill shall be placed, spread and compacted in such a manner that minimizes the development of wrinkles or movement of the geosynthetic reinforcement and the wall facing units.
B. Only hand-operated compaction equipment shall be allowed within 3 ft (1 m) of the front of the wall face. A maximum compacted lift thickness of 8 in. (200 mm) shall be used in this zone. Soil density in this area shall not be less than 95% standard Proctor density without affecting wall alignment. Soil density testing in this area should be verified by field density testing.
C. Tracked construction equipment shall not be operated directly on the geosynthetic reinforcement. A minimum backfill thickness of 6 in. (150 mm)is required prior to operation of tracked vehicles over the geosynthetic reinforcement. Turning of tracked vehicles should be kept to a minimum to prevent displacing the fill and damaging or moving the geosynthetic reinforcement.
D. Rubber-tired equipment may pass over the geosynthetic reinforcement, if in accordance with the manufacturer's recommendations, at low speeds. Sudden braking and sharp turning should be avoided.
E. At the end of each day's operation, the wall contractor shall slope the last level of backfill away from the wall facing to direct runoff of rainwater away from the wall face. The general contractor is responsible for ensuring surface runoff from adjacent areas is not allowed to enter the wall construction area.

As we mentioned above, control of surface and groundwater is very important to the long-term performance of the wall. The drainage gravel fill is an open graded, free draining crushed stone. Collected ground water will flow freely through the stone therefore it is important to get sufficient thickness to support the flow and grade the base soils so water will flow to the outlet point.

Where the water is collected in a drain pipe it is also important the pipe be sloped to the outlet and that sufficient outlets are provided to remove water from the SRW system.

3.07 Gravel Fill and Drainage Placement

A. Gravel fill shall be placed to the minimum finished thickness and widths shown on the construction plans and shall be appropriately compacted with a hand operated compaction equipment to meet the specifications. The gravel fill shall fill any cavities in, between, and a minimum of 12 in. (305 mm) behind the units.
B. Drainage collection pipes shall be installed to maintain gravity flow of water outside of the reinforced soil zone. The drainage collection pipe should daylight into a storm sewer manhole or along a slope at an elevation lower than the lowest point of the pipe within the aggregate zone.
C. The main collection drain pipe, just behind the block facing, shall be a minimum of 3 in. (75 mm) in diameter. The secondary collection drain pipes should be sloped a minimum of two percent to provide gravity flow into the main collection drain pipe. Drainage laterals shall be spaced at a maximum 50 ft (15 m) spacing along the wall face.

Cap units for the SRW walls are usually solid, dry-cast concrete units. It is the general practice to cut and fit the units to the wall and then glue the units in place with a quality masonry adhesive.

3.08 Cap Block Placement

A. The cap block and/or top SRW unit shall be bonded to the SRW units below using cap adhesive described in Part 2.01F. The block shall be dry and swept clean prior to adhesive placement.

PART 4 MEASUREMENT AND PAYMENT

Payment terms for the SRW wall may be on a lump-sum contract price or on unit price bases based on the projected face area of the wall. Any extras for the wall (e.g. over-excavation and replacement) should be included in the payment terms.

4.01 Measurement

A. The unit of measurement for furnishing the segmental retaining wall system shall be the vertical square foot (m^2) of wall surface from the top of the leveling pad to the top of the wall, including coping. The quantity to be paid shall include supply and installation of the segmental retaining wall system. Excavation of unsuitable materials and replacement with select fill, as directed and approved in writing by the Owner or Owner's Engineer shall be paid for under separate pay items.

4.02 Payment

A. The accepted quantities of segmental retaining wall system will be paid for per vertical square foot (m^2) in place as measured from the top of the leveling pad to the top of wall (including coping) block. The quantities of the segmental retaining wall system as shown on plans or as approved by the Owner or Owner's Engineer shall be used to determine the area supplied. Payment will be made under:

Pay Item	Pay Unit
Geosynthetic Reinforced SRW	SQ. FT. (m^2)

REFERENCES

1. "Design Manual for Segmental Retaining Walls, 1st ed.," TR 127, National Concrete Masonry Association, Herndon, VA. 1993.
2. "Design Manual for Segmental Retaining Walls, 2nd ed." TR 127A, National Concrete Masonry Association, Herndon, VA. 1997.
3. "Design Manual for Segmental Retaining Walls, 3rd ed.," TR 127B, National Concrete Masonry Association, Herndon, VA. 2009.
4. Geocomp Corporation, Report on Full-Scale Test Walls, Leominster, MA, Geocomp Corporation, Boxborough, MA, 2009.
5. All ASTM standards mentioned are published by ASTM International (2012)