SECTION 02834 (32 32 23)

SEGMENTAL CONCRETE RETAINING WALL SYSTEM

1.0 GENERAL

1.1 Description

The work includes furnishing and constructing a segmental concrete retaining wall (SRW) system, including leveling pad, soil reinforcement, unit drainage fill, reinforced backfill, and incidental materials required for SRW construction to the lines and grades shown on the construction drawings and specified herein.

1.2 Reference Standards

A. American Society for Testing and Materials (ASTM)

1.	ASTM C1372	Specification for Segmental Retaining Wall Units
2.	ASTM D422	Particle Size Analysis
3.	ASTM D698	Laboratory Compaction Characteristics of Soil -Standard Effort
4.	ASTM D1388	Stiffness of Fabrics
5.	ASTM D2166	Unconfined Compressive Strength of Cohesive Soil
6.	ASTM D3034	Polyvinyl Chloride Pipe (PVC)
7.	ASTM D3080	Direct Shear Test of Soils
8.	ASTM D4218	Carbon Black Content
9.	ASTM D4318	Liquid Limit, Plastic Limit and Plasticity Index of Soils
10.	ASTM D4475	Horizontal Shear Strength of Pultruded Reinforced Plastic Rods
11.	ASTM D4595	Tensile Properties of Geotextiles - Wide Width Strip
12.	ASTM D5262	Unconfined Tension Creep Behavior of Geosynthetics
13.	ASTM D6638	Connection Strength – Reinforcement/Segmental Units
14.	ASTM D6916	Shear Strength Between Segmental Concrete Units
15.	ASTM G51	Measuring pH of Soils
16.	ASTM G57	Measurement of Soil Resistivity

B. Geosynthetic Research Institute (GRI)

1.	GRI-GG2	Determination of Geogrid Junction Strength
2.	GRI-GG4	Determination of Long Term Design Strength of Geogrids
3.	GRI-GG5	Determination of Geogrid (soil) Pullout
4.	GRI-GG7	Determination of Carboxyl End Group Content
5.	GRI-GG8	Determination of the Number Average Molecular Weight

C. National Concrete Masonry Association (NCMA)

1. NCMA SRWU-1 Test Method for Determining Connection Strength of SRW
2. NCMA SRWU-2 Test Method for Determining Shear Strength of SRW

D. American Association of State Highway and Transportation Officials (AASHTO)

1.	Standard Specifications for Highway Bridges, 17th Edition, 2002	
2.	AASHTO M 252	Corrugated Polyethylene Drainage Pipe
3.	AASHTO M 288-96	Specifications for Geotextiles

1.3 Design Requirements

A. Design Method - Design of SRW's using geosynthetic reinforcement shall be in accordance with the NCMA Design Guidelines for Segmental Walls, AASHTO or NCMA utilizing AASHTO earth pressure and stability design criteria. Metallic reinforcement systems shall be designed in accordance with AASHTO Standard Specification for Highway Bridges, Section 5.8, using the Coherent Gravity Method. All designs shall conform to the minimum safety factors in this Specification. Design submittals not meeting this design criteria or technical/administrative criteria specified will be rejected in their entirety until complete compliance is achieved.

B. Design Parameters - The design of the SRW system shall be based on the following soil parameters provided by the Owner.

Soil	ϕ'	c'	γ
Reinforced Backfill	30º (min)	0	_____pcf (kN/m3)
Retained Backfill	_____º	____psf (kPa)	_____pcf (kN/m3)
Foundation Backfill	_____º	____psf (kPa)	_____pcf (kN/m3)

C. Design Requirements - Unless otherwise indicated below, the SRW design shall be performed in strict compliance with Section 1.3.A of this Specification and the following clarifications of the Owner's intent.

Internal Stability	Minimum Factor of Safety
Tension (Peak)	1.5
Pullout (Peak	1.5
Facing Connection (Peak/serviceability)	1.5/NA
Facing Shear (Peak/serviceability)	1.5/NA
External Stability	
Base Sliding (static)	1.5
Overturning	2.0
Bearing	2.0
Global	1.3

In addition, to further clarify the Owner's intent, the design shall:

1. Address hydrostatic, seismic, surcharge and backslope loading as shown on the plans. Minimum live loads of 100 psf (4.8 kPa) and 250 psf (12 kPa) shall be for all walls and walls supporting areas subject to traffic, respectively.
2. Provide a minimum reinforcement length of 60% the total height of the wall for each layer or longer as required by calculation.
3. Provide continuous, 100% geosynthetic coverage at each reinforcement layer (no gaps).
4. 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).
5. Only the weight of the mass vertically over the plane of sliding shall be included in the resisting forces for sliding and overturning.

1.4 Submittals

The SRW contractor shall provide to the Owner a minimum of 14 days prior to the anticipated start date for the SRW a submittal package including the following:

A. A set of detailed SRW design plans sealed by a registered professional engineer licensed in the state of the project. The SRW plans shall include plan and elevation views of each wall, cross sections and all details, dimensions and quantities necessary to construct the SRW.

B. Product literature indicating specifically which SRW units and soil reinforcement are proposed for use on the project including color, face style and texture.

C. Documentation for the SRW units and soil reinforcement demonstrating compliance with the requirements of this specification including but not limited to SRW compressive strength and absorption; SRW/soil reinforcement connection and shear; and reinforcement strength.

D. Manufacturer's certification that the SRW units and soil reinforcement meet the requirements of this specification.

E. SRW system engineer's certification that the design complies in all respects with this specification and proof of current professional and general liability insurance with an aggregate coverage of not less than $2,000,000.00 per occurrence.

F. Contractor's certification that

1) The specific SRW system proposed for use on this project has been successfully used on a minimum of 5 similar projects and has been successfully installed on a minimum of 1,000,000 square feet (100,000 m2) of retaining walls.

2) The contractor has a minimum of 200,000 square feet (18,000 m2) of experience with the proposed SRW system. Contact names and telephone numbers shall be listed for projects used to document the 200,000 square feet (18,000 m2).

1.5 Delivery, Storage and Handling

The contractor shall check all materials upon delivery to assure that the proper type, grade, color and material certification have been received. Contractor shall protect materials from damage due to jobsite conditions and in accordance with the manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

2.0 PRODUCTS

2.1 Definitions

A. Segmental Concrete Units - a modular concrete facing unit machine made from Portland cement, water and mineral aggregates.

B. Soil Reinforcement - geosynthetic or steel reinforcement formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function as reinforcement. Soil reinforcement shall be specifically manufactured for soil reinforcement.

C. Unit Drainage Fill - drainage aggregate that is placed within and behind the segmental concrete units.

D. Reinforced Backfill - compacted soil that is within the reinforced soil volume as shown on the plans.

E. Foundation Soil – compacted, imported or in-situ soil beneath entire wall.

F. Retained Soil – compacted, imported or in-situ soil behind reinforced zone of the retaining wall.

G. Base Leveling Pad - level compacted gravel or unreinforced concrete pad upon which the first course of segmental concrete facing units is placed.

2.2 Segmental Concrete Units shall meet the following requirements

A. Modular concrete unit face color - concrete gray, unless otherwise specified. The Owner may specify standard manufacturers' color.

B. Manufactured in accordance with ASTM C1372 with a minimum 28-day compressive strength of 3000 psi (21 MPa) (4000 psi (28 MPa) for steel reinforced systems) and a maximum moisture absorption of 8% (6% in northern climates). SRW units finish and appearance shall be per ASTM C1372. Exposed faces shall be free of chips, cracks or other imperfections when viewed from a distance of 20 feet (6 m) under diffused lighting. Color shall be concrete gray and the face finish shall be a sculptured rock face in an angular multi-planar configuration unless shown otherwise on the Plans.

C. Provide shear pins or connection devices to provide a mechanical connection between vertically and horizontally adjacent units so as to provide at a 2 psi (13 kPa) normal pressure a minimum inter-unit shear strength of 600 plf (8 kN/m) per ASTM D6916 (NCMA SRWU-2) and a geosynthetic to SRW unit peak connection strength of 500 plf (7 kN/m) per ASTM D6638 (NCMA SRWU-1). Shear devices shall protrude at least 7/8 inch (22 mm) into receiving openings of the SRW units. At least one shear connector is required per linear foot (300 mm) of wall for each course. The shear connector must fit within an aperture of the soil reinforcement and be capable of holding the reinforcement in the proper position during tensioning and backfilling. Connectors shall result in a design wall batter of 1º to 10º.

2.3 Soil Reinforcement

A. Geosynthetic Reinforcement - shall be evaluated in accordance with NCMA Section 3.5 with the following additions and clarifications.

1. The minimum RF_{ID} shall be ≥ 1.05.
2. The minimum RF_D shall be ≥ 1.10.
3. The minimum FS_{UNC} shall be ≥ 1.5.
4. Geogrids not providing a minimum junction strength of 40 lbs per foot (0.6 kN/m) per GRI: GG2 and all geotextiles shall have a minimum mass of 8 oz/sy (1.4 kg/m2) and meet the strength requirements of AASHTO M-288-96 Class 1 geotextile.
5. Geogrids not providing a minimum stiffness (flexural rigidity) of 30,000 mg-cm per ASTM D1388 and all geotextiles shall be staked during placement per Section 3.1.B.
6. PET geosynthetics shall be coated with a suitable coating immutably bonded to the PET bundles. The coating shall contain a minimum of 1-% carbon black measured per ASTM 4218. Geogrids not meeting this requirement and all geotextiles shall use a minimum $RF_D = 1.6$.

7. PET geosynthetics shall possess a Molecular Weight ≥ 25,000 g/m per GRI: GG8 and a carboxyl end group number ≤ 30 per GRI: GG7. PET geosynthetics not meeting this criteria shall use a minimum $RF_D = 2.0$.
8. HDPE geogrids shall have a melt flow index value≥ 0.88. HDPE geogrids not meeting this criteria shall use a minimum $RF_D = 2.0$.
9. Manufacturing Quality Control - The geosynthetic manufacturer shall have a quality control program that includes QC testing no less frequently than each 400,000 sf (40,000 m2) of production. The testing, as a minimum, shall include Tensile Strength per ASTM D4595.

B. Steel Reinforcement - shall meet the requirements of and possess the minimum strength and durability at the end of the 75-year design life per the AASHTO Standard Specifications for Highway Bridges. Allowable tensile stress shall not exceed $0.55F_y$ at the end of the design service life.

2.4 Unit Drainage Fill

Shall consist of clean 1" (25 mm) minus crushed stone or crushed gravel meeting the following gradation per ASTM D422. Geotextile shall not be substituted for unit drainage fill.

Sieve Size	Percent Passing
1 inch (25 mm)	100
3/4 inch (19 mm)	75-100
No. 4 (4.75 mm)	0-10
No. 50 (300 um)	0-5

2.5 Reinforced Backfill

A. Shall consist of soil with
1. Less than 35% passing the No. 200 sieve per ASTM D422 with a maximum size of 3/4 inches (19 mm) (4 inch (100 mm) maximum for steel reinforced systems). If site-specific geogrid installation damage testing has been performed to determine RFID, the maximum size may be increased to 2" (50mm);
2. A plasticity index less than 10 per ASTM D4318;
3. An effective internal angle of friction $\geq 30^o$ per ASTM D2166 or D3080 at the compaction standard;
4. Less than 0.5% organic material;
5. Material can be site-excavated soils where the above requirements can be met. Unsuitable soils for backfill including ML, CL, MH, CH, OH or Pt shall not be used in the backfill or in the reinforced soil mass.

B. Use of an effective friction angle greater than 30 degrees for design shall be verified by appropriate testing submitted to and approved by the owner's engineer prior to construction.

C. Backfill reinforced with geosynthetic shall have a pH in the range of 3 to 9 per ASTM G51.

D. Backfill reinforced with steel reinforcement shall have a pH in the range of 5 to 10 per ASTM G51, minimum resistivity of 3000 ohm-cm at 100% saturation per ASTM G57 and free of sulfates > 200 ppm or chlorides > 100 ppm. If the resistivity is ≥ 5000 ohm-cm, the chloride and sulphate requirements are waived. Subject to approval, the owner's engineer may allow slightly wider ranges of pH for higher resistivities.

2.5 Base Leveling Pad

Base leveling pad shall be constructed of dense graded crushed stone or crushed gravel. A concrete leveling pad consisting of lean unreinforced concrete may be used at the wall contractor's option.

3.0 CONSTRUCTION

3.1 General – Construction and construction tolerances shall be in accordance with NCMA Section 6 and 7 or AASHTO Section 7 with the following additions or clarifications.

A. A minimum of 1 cubic foot (0.028 m3) of unit drainage fill shall be used for each square foot (0.093 m2) of wall face and shall be placed within the cores, between and behind the SRW units and shall extend back from the face of the wall a minimum of 2 feet (600 mm). Geotextile is not an acceptable substitute for unit drainage fill unless the entire reinforced backfill zone meets the requirements of AASHTO Section 7.3.6.3 and connection strength requirements can be met without unit drainage fill.

B. Reinforcement not meeting the minimum stiffness requirement of Section 2.3.A (5) or wider than 12 feet (4 m) shall be staked at the corners and on 12 foot (4 m) centers along the roll edges to prevent wrinkling or other distortion of the reinforcement during backfill placement.

3.2 Field Quality Control and Assurance

A. Field Quality Assurance - The Owner shall engage inspection and testing services, including independent laboratories, to provide quality assurance and testing services during construction. As a minimum, quality assurance testing should include foundation soil inspection, inspection for the need for any additional drainage, soil and backfill testing, verification of design parameters, and observation of construction for general compliance with design drawings and specifications. This does not relieve the Contractor from securing the necessary construction quality control testing during construction.

B. Field Quality Control - The Contractor's quality control testing and construction inspection services shall only be performed by independent, qualified and experienced technicians and engineers. The Contractor's quality control testing, as a minimum, shall include:

1. Field density testing
   a. Subgrade: one test for every 2500 square feet (230 m2) of subgrade.
   b. Reinforced Backfill: one test for every 2500 square feet (230 m2) per lift with a minimum of one test for every other lift.
   c. Retained and Foundation Soil: per Section 02300 (31 00 00).
2. Laboratory Moisture Density - minimum one test per soil type.
3. Gradation Analysis
   a. Unit Fill: one test per 500 CY (400 m3)
   b. Backfill: one test per 1000 CY (800 m3)

4.0 MEASUREMENT AND PAYMENT

4.1 Measurement - The unit of measurement for furnishing and fabricating the SRW shall be the vertical square foot (square meter) of wall surface from the top of the leveling pad to the top of the wall or wall coping.

4.2 **Payment** - The accepted quantities of SRW will be paid at the contract unit price, which shall be full compensation for design, supply, and installation of the SRW including face units, caps, leveling pad, unit drainage fill, soil reinforcement and reinforced backfill.