Section 323223 (02830)

MODULAR CONCRETE RETAINING WALL

PART 1: GENERAL

1.01 Description

A. Work shall consist of furnishing and constructing a ***VERDURA***® Retaining Wall System (or approved equal) in accordance with these specifications and in reasonably close conformity with the lines, grades, design, and dimensions shown on the plans.

B. Work includes preparing foundation soil, furnishing and installing leveling pad (if required), plantable soil unit fill and backfill to the lines and grades shown on the construction drawings.

C. Work includes furnishing and installing geosynthetic soil reinforcement of the type, size, location, strength and lengths designated on the construction drawings.

D. Work includes furnishing and installing sub-drain, and other wall related drainage systems that may be shown on the construction drawings.

1.02 Related Sections

A. Section 02200 - Site Preparation
B. Section 02300 - Earthwork

1.03 Reference Documents

A. American Society for Testing and Materials (ASTM)

1.	ASTM C90	Std. Spec. for Load Bearing Concrete Masonry Units
2.	ASTM C140	Std. Spec. for Sampling and Testing Concrete Masonry Units
3.	ASTM C1372	Specification for Segmental Retaining Wall Units
4.	ASTM D1557	Laboratory Compaction Characteristics of Soil –Modified Proctor
5.	ASTM D1785	Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120
6.	ASTM D3034	Type PSM Poly Vinyl Chloride (PVC) Sewer Pipe and Fittings
7.	ASTM D3080	Direct Shear Test of Soils - Consolidated Drained Conditions
8.	ASTM D4318	Liquid Limit, Plastic Limit and Plasticity Index of Soils
9.	ASTM D4595	Tensile Properties of Geotextiles - Wide Width Strip
10.	ASTM D4829	Expansion Index of Soils
11.	ASTM D5262	Unconfined Tension Creep Behavior of Geosynthetics
12.	ASTM D6637	Tensile Properties of Geogrids
13.	ASTM D6638	Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units
14.	ASTM D6706	Geosynthetic Pullout Resistance in Soil
15.	ASTM D6913	Particle-Size Distribution (Gradation) of Soils
16.	ASTM D6916	Shear Strength Between Segmental Concrete Units

B. Geosynthetic Research Institute (GRI)

1.	GRI-GG4	Determination of Long Tern Design Strength of Geogrids

C. ICC Evaluation Services, Inc. (ICC)

1. ICC-ES Evaluation Report, ESR-3073, Verdura® Retaining Wall System

D. National Concrete Masonry Association (NCMA)

1. "Design Manual for Segmental Retaining Walls, 3rd Edition," (2009)

E. U.S. Department of Transportation – Federal Highway Administration (FHWA)

1. "Mechanically Stabilized Earth Walls and Reinforced Earth Slopes – Design & Construction Guidelines," FHWA-NHI-00-043 (March 2001)

1.04 Submittals/Certification

A. Contractor shall submit a Manufacturer's certification, prior to start of work, that the retaining wall system components meet the requirements of this specification and the structural design plans.

B. Contractor shall submit construction drawings and design calculations for the retaining wall system prepared and stamped by a Professional Engineer registered in the state of the project. The engineering designs, techniques, and material evaluations shall be in accordance with the referenced NCMA or FHWA Design Guidelines (whichever is applicable to designer).

C. Contractor shall submit a valid ICC ESR Report that complies with current building codes.

D. Contractor shall submit project specific manufacturers' block and geogrid certifications.

1.05 Quality Assurance

A. Contractor shall submit certification, prior to start of work, that the retaining wall system (modular concrete units and specific geosynthetic):

1. Has been successfully utilized on a minimum of five (5) similar projects that correspond in height, soil fill types, erection tolerances, etc.; and

2. Has been successfully installed on a minimum of 1 million square feet (93,000 m^2) of retaining walls.

B. Contractor shall submit a list of five (5) previously constructed projects of similar size and magnitude by the wall installer where the specific retaining wall system has been constructed successfully. Contact names and telephone numbers shall be listed for each project.

C. Contractor shall provide evidence that the design engineer has a minimum of five years of documentable experience in the design for reinforced soil structures. The design engineer shall provide proof of current professional liability insurance with an aggregate coverage limit of not less than $1,000,000.

D. Owner shall provide soil testing and quality assurance inspection during earthwork and wall construction operations. Owner's quality assurance program does not relieve the contractor of responsibility for wall performance.

1.06 Delivery, Storage and Handling

A. Contractor shall check all materials upon delivery to assure that the proper type, grade, color, and certification have been received.

B. Contractor shall protect all materials from damage due to jobsite conditions and in accordance with manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

PART 2: PRODUCTS

2.01 Definitions

A. Modular Unit - a concrete retaining wall element machine made from Portland cement, water, and aggregates.

B. Structural Geosynthetic (Geogrid) - a structural element formed by a regular network of woven and coated tensile elements which, when embedded within the soil mass and connected to the modular concrete units, will develop friction and interlock with the surrounding soil, rock, or earth and function primarily as reinforcement.

C. Unit Fill – plantable soil which is placed within and immediately behind the modular concrete units.

D. Reinforced Backfill - compacted soil which is placed within the reinforced soil volume as outlined on the plans.

E. Geosynthetic Reinforcement to Block Connection Pipe – Polyvinyl Chloride pipe (1-inch diameter schedule 80 PVC) which is used to interlock and form a positive connection between the block and structural geogrid.

F. Filter Fabric – Permeable non-woven geosynthetic material used to separate soil material from drainage aggregate to minimize potential for soil fines migration into and blockage of the drainage aggregate.

G. Drain Rock – Open graded rock allowing for free movement of water.

2.02 Modular Concrete Retaining Wall Units

A. Modular concrete units shall conform to the following architectural requirements:

1. Face color – **Gray or Buff/tan** - standard manufacturers' colors may be specified by the Owner.

2. Face finish - Standard, Elliptical concrete face, with angled profile permitting concave/convex curve installation. Face finishes will be **Smooth or Exposed Aggregate** finish as specified by the Owner. Other face finishes will not be allowed without written approval of Owner.

3. Bond configuration - running with bonds nominally located at midpoint vertically adjacent units, in both straight and curved alignments.

4. Exposed surfaces of units shall be free of chips, cracks or other imperfections when viewed from a distance of 10 feet (3 m) under diffused lighting.

B. Modular concrete materials shall conform to the requirements of ASTM C1372 - Standard Specifications for Segmental Retaining Wall Units.

C. Modular concrete units shall conform to the following structural and geometric requirements measured in accordance with Section 1.03 and other appropriate references:

1. Compressive strength = 5,000 psi minimum at 28 days;

2. Moisture absorption = 8 pcf max;

3. Dimensional tolerances = ±1/8 inch from nominal unit dimensions (not including exposed aggregate face texture), ±1/8 inch unit height - top and bottom planes;

Unit Type	**V40**	**V60**
Unit Size, Rail Height, in	8	8
Unit Size, Crown Height, in	10.75	11
Unit Size, Width, in	18.25	18
Unit Size, Depth, in	12.25	18
Unit Weight*, lbs	89	133

*Unit Weight has ± 5 percent tolerance.

D. Modular concrete units shall conform to the following constructability requirements:

1. Vertical setback = Vertical setback to be adjusted to meet requirements as set forth in construction documents. Vertical setback for VERDURA® products is a function of unit elliptical face thickness which may typically be adjusted from 45 to 76 degrees from the horizontal.

2. Maximum horizontal planting distance between horizontally adjacent units is limited to 9 inches.

2.03 Geosynthetic Reinforcement to Concrete Block Unit Connectors

A. Connectors shall be 1 inch diameter Schedule 80 PVC pipe per ASTM D1785 and must be capable of providing positive mechanical interlock between geosynthetic soil reinforcement material (geogrid) and block.

B. Connectors shall be capable of holding the geosynthetic soil reinforcement in the proper design position during geosynthetic pre-tensioning and backfilling procedures.

2.04 Base Leveling Pad Material (if required)

A. Material shall consist of a compacted crushed stone or miscellaneous/aggregate base material as shown on the construction drawings.

2.05 Unit Fill

A. Unit fill shall consist of plantable soils having sufficient nutrients to sustain plant growth. Unit fill shall conform to the mix characteristics as specified by the landscape architect.

2.06 Reinforced Backfill

A. Reinforced backfill shall be free of debris and meet the following gradation tested in accordance with ASTM D6913:

Sieve Size	Percent Passing
2 inch (50 mm)	100-75
3/4 inch 20 mm)	100-75
No. 40	0-60
No. 200	0-35

Expansion Index (EI) ≤ 50 per ASTM D4829

Plasticity Index (PI) < 20 and Liquid Limit < 40 per ASTM D4318.

B. The maximum aggregate size shall be limited to 3/4 inch unless field tests have been performed to evaluate potential strength reductions to the geosynthetic design due to damage during construction.

C. Material can be site-excavated soils where the above requirements can be met. Unsuitable soils for backfill (high plastic clays or organic soils) shall not be used in the backfill, in the reinforced soil mass, or in the foundation soils.

D. Contractor shall submit reinforced fill sample and laboratory test results to the Architect/Engineer for approval prior to the use of any proposed reinforced fill material.

E. Soil within 6 inches of a geogrid layer shall not contain particles larger than 6 inches.

2.07 Geosynthetic Soil Reinforcement (Geogrid)

A. Geosynthetic reinforcement shall consist of structural geogrids manufactured specifically for soil reinforcement applications and shall be manufactured from high tenacity polyester yarn, polypropylene or high density polyethylene. Polyester geogrid shall be knitted from high tenacity polyester filament yarn with a molecular weight exceeding 25,000 Meg/m and a carboxyl end group values less than 30. Polyester geogrid shall be coated with a material which is resistant to peeling, cracking, and stripping.

B. T_a, Long Term Allowable Tensile Design Load, of the geogrid material shall be determined as follows:

$T_a = T_{ult} / (RF_{cr}*RF_d*RF_{id}*FS)$
T_a shall be evaluated based on a 75-year design life.

1. T_{ult}, Short Term Ultimate Tensile Strength
   T_{ult} is based on the Minimum Average Roll Values (MARV) and shall be determined in accordance with ASTM D4595, ASTM D6637, or GRI-GG4

2. RF_{cr}, Reduction Factor for Long Term Tension Creep
   RF_{cr} shall be determined from 10,000-hour creep testing performed in accordance with ASTM D5262. RF_{cr} = 1.58 minimum.

3. RF_d, Reduction Factor for Durability
   RF_d shall be determined from polymer specific durability testing covering the range of expected soil environments. RF_d = 1.10 minimum.

4. RF_{id}, Reduction Factor for Installation Damage
   RF_{id} shall be determined from product specific construction damage testing performed in accordance with GRI-GG4. Test results shall be provided for each product to be used with project specific or more severe soil type. RF_{id} = 1.10 minimum.

5. FS, Overall Design Factor of Safety
   FS = 1.5 minimum, unless otherwise noted for the maximum allowable working stress calculation.

C. The maximum design tensile load of the geogrid shall not exceed the laboratory tested ultimate strength of the geogrid/facing unit connection divided by a factor of safety of 1.5. The connection strength testing and computation procedures shall be in accordance with ASTM D6638 – Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units.

D. Soil Interaction Coefficient, C_i
   C_i values shall be determined per ASTM D6706 at a maximum 0.75-inch displacement.

E. Manufacturing Quality Control

   The geosynthetic soil reinforcement manufacturer shall have a manufacturing quality control program that includes QC testing by an independent laboratory.

   The QC testing for PET-type geogrid shall include:
   Tensile Strength Testing
   Molecular Weight (Polyester)

2.08 Drainage Pipe

A. If required, the drainage pipe shall be perforated or slotted PVC pipe manufactured in accordance with ASTM D3034 or approved equivalent.

2.09 Filter Fabric

A. If required, provide filter fabric consisting of Mirafi 140N or approved equivalent as shown on construction drawings or as directed by the Engineer.

2.10 Drain Rock

A. If required, provide drain rock consisting of clean ¾" crushed rock or approved equivalent as shown on construction drawings or as directed by the Engineer.

PART 3 EXECUTION

3.01 Surface Conditions

A. Prior to work, carefully inspect previous grading work. Verify that all such work is complete to the point where this installation may properly commence.

B. Verify that work of this section may be installed in strict accordance with the original design, all pertinent codes and regulations.

C. Verify wall drainage system is coordinated with points of connection to storm drainage system or other approved outlet location.

D. In the event of discrepancy, immediately notify the project coordinator or civil engineer. Do not proceed with installation until all such discrepancies have been resolved.

3.02 Layout

A. Verify all staking and field engineering required to implement the work as shown on the drawings.

B. Protect all stakes and benchmarks. Replace all stakes and benchmarks damaged during the course of construction.

C. Set grade stakes at all critical wall geometry points using instrument technology, at maximum 50-foot grid intervals at areas where gradients are less than 2 percent and at maximum 25-foot intervals at areas where grades are greater than 2 percent.

D. Hand trim excavations to required elevations. Correct over-excavation with fill materials approved by the geotechnical engineer of record.

E. Remove large stones or other hard matter which would damage pipes or impede consistent backfilling or compaction.

F. Provide all equipment of such type, function, and design as required to achieve specific values. Where necessary, provide rubber-tired and vibratory sheepsfoot compaction equipment.

3.03 Subsurface Drainage System Installation (if required)

A. Excavate trenches for drainage piping shown on drawings or at lowest point possible that can be outlet.

B. Lay filter fabric in bottom of excavation prior to placing filter material. Place minimum 4-inch thick bed of filter material over fabric.

C. Install and join perforated pipe and pipe fittings in accordance with manufacturers' instructions. Install drainage piping with perforations down. Apply solvent to pipe ends then join pipe ends. Cap any free ends of perforated pipe.

D. Lay perforated pipe to slope gradients of the wall foundation or as noted on drawings.

E. Surround perforated pipe with drain rock.

F. Wrap filter fabric around drain rock. Cover and tuck loose edge with a minimum overlap of 12 inches of the fabric.

G. Extend non-perforated discharge pipes to approved outlet locations as shown on plans or at lowest point possible with a minimum 2% fall towards outlet location.

H. Provide trenching, bedding, and backfill as required for outlet drainage piping. Do not displace or damage pipe when compacting.

3.04 Excavation

A. Contractor shall excavate to the lines and grades shown on the construction drawings. Owner's representative shall inspect the excavation and approve prior to placement of leveling material or fill soils. Proof roll foundation area as directed by geotechnical engineer of record to determine if remedial work is required.

B. Over-excavation and replacement of unsuitable foundation soils and replacement with approved compacted fill shall be directed by the geotechnical engineer of record.

3.05 Base Leveling Pad (if required)

A. Leveling pad material shall be placed to the lines and grades shown on the construction drawings, to a minimum thickness of 6 inches and extend laterally a minimum of 6 inches in front and behind the modular wall unit.

B. Aggregate leveling pad materials shall be compacted to a minimum of 92% Modified Proctor density per ASTM D-1557

C. Leveling pad shall be prepared to insure full contact to the base surface of the concrete units.

3.06 Modular Unit Installation

A. First course of units shall be placed on approved foundation soils or leveling materials, as directed by the geotechnical engineer of record, at the appropriate lines and grades. Modular units shall be used for alignment. Alignment and level shall be checked in all applicable directions and insure that all units are in full contact with the base and properly seated.

B. Units shall be placed on the foundation soils with a maximum distance of 9 inches between adjacent units. The spacing between units installed in curved regions (concave or convex) must be adjusted accordingly and such that the running bond layout is maintained. Vertically adjacent units shall be centered on units above and below. All block layout and placement shall be in accordance with manufacturer's recommendations.

C. Modular units may be installed horizontally with respect to the profile wall alignment or may be made to follow the bottom of wall contours (“run with the grade”). Where bottom of wall contours are used to set the first row of modular blocks, grades may not slope more than 15% with respect to the wall profile base.

D. Place unit fill within the block cell and consolidate via foot pressure.

E. Place and compact reinforced backfill behind wall units.

F. Screed excess unit fill (rod-board) off to develop a flat base upon which subsequent units can be positioned. Clear notch in rail if geosynthetic reinforcement is required.

G. Follow wall erection and unit fill closely with reinforced backfill. Maximum stacked vertical height of wall units, prior to unit fill and reinforced backfill placement and compaction, shall not exceed one course.

3.07 Geosynthetic Soil Reinforcement (Geogrid) Installation

A. Geosynthetic soil reinforcement shall be oriented with the highest strength axis perpendicular to the wall alignment.

B. Geosynthetic soil reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction design drawings or as directed by the Engineer. Where geosynthetic placement elevations vary from facing unit increments, geosynthetic elevations may be adjusted up or down by 4 inches maximum.

C. The geosynthetic soil reinforcement shall be laid horizontally on compacted backfill and attached to the modular wall units in accordance with these specifications and as noted on the construction drawings. A tolerance from face to tail of reinforcement of 6 inches in 10 feet is acceptable relative to horizontal geosynthetic orientation. Place the next course of modular concrete units over the geosynthetic soil reinforcement. The geosynthetic soil reinforcement shall be pulled taught and laid flat prior to backfill placement on the geosynthetic soil reinforcement.

D. Geosynthetic soil reinforcement shall be continuous throughout the length of embedment. Spliced connections between shorter pieces of geosynthetic soil reinforcement will not be permitted.

3.08 Reinforced Backfill Placement

A. Reinforced backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack in the geosynthetic soil reinforcement and installation damage.

B. Reinforced backfill shall be placed and compacted in lift thicknesses not to exceed the “rail height” of the units being placed. Where heavy compaction equipment is used, compaction lift thicknesses of up to 8 inches may be employed. Lift thickness shall be decreased to achieve the required density.

C. Reinforced backfill shall be compacted to 90% of the maximum density as determined by ASTM D1557. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer and shall be within +/- 2% of optimum moisture content, or as directed by Engineer.

D. Only lightweight hand-operated equipment shall be allowed within 1-foot from the back of the modular concrete unit.

E. Tracked construction equipment shall not be operated directly upon the geosynthetic soil reinforcement. A minimum fill thickness of 6 inches is required prior to operation of tracked vehicles over the geosynthetic soil reinforcement. Tracked vehicle turning should be kept to a minimum to prevent tracks from displacing the fill and damaging the geosynthetic soil reinforcement.

F. Rubber tired equipment may pass over geosynthetic soil reinforcement at slow speeds, less than 10 MPH. Sudden braking and sharp turning shall be avoided.

G. At the end of each day's operation, the Contractor shall slope the last lift of reinforced backfill away from the wall units to direct runoff away from wall face. The Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

H. Care should be taken during excavation for and construction the V-ditch (if necessary) and all other surface improvements adjacent to the wall structure to prevent damage the upper geogrid layers. If the geogrid layers are damaged, they may need to be properly replaced.

3.09 Erosion Control

A Provide dust and erosion control protection plan in accordance with the contract documents.

3.10 As-built Construction Tolerances

A. Vertical alignment: ± 1.5 inch over any 10 ft distance.

B. Wall Batter: within 2 degrees of design batter.

C. Horizontal alignment: ± 1.5 inches over any 10 ft distance.

D. Corners, bends, curves: ± 1 ft to design location.

E. Maximum horizontal gap between erected units shall be 9 inches.

3.11 Field Quality Control

A. The Owner shall engage inspection and testing services, including independent laboratories, to provide quality assurance and testing services during construction. This does not relieve the Contractor from securing the necessary construction control testing during construction.

B. Qualified and experienced technicians and engineers shall perform testing and inspections services.

C. As a minimum, quality assurance testing should include foundation soil inspection, soil and backfill testing, verification of design parameters, and observation of construction for general compliance with design drawings and specifications.

D. Field quality control shall be performed by the geotechnical engineer of record.

3.12 Special Inspections

A. Per ICC-ES Evaluation Report ESR-3073, special inspection during installation must be provided in accordance with the 2013 California Building Code (CBC) Sections 1705.1.1, 1705.4 and 1705.6. Inspection responsibilities include verifying the following:

1. Block type and unit dimensions.
2. Verification of block unit for compliance with ASTM C1372, including compressive strength and water absorption, as described in Section 3.2.1 of ESR-3073
3. Product identification, including evaluation report number (ESR-3073).
4. Foundation preparation

5. Verdura® block unit placement, including proper alignment and inclination within design tolerances.
6. PVC pipe connections, including installation locations, proper fit within the blocks, and installation sequence with respect to the geogrid placement.
7. Geogrid reinforcement type (see Tables 2 and 3 in ESR-3073), location and placement.
8. Placement of approved backfill and compaction.
9. Drainage provisions.

B. Special inspections may be completed by the project engineers or an independent inspection service.

PART 4 MEASUREMENT AND PAYMENT

June 2017