NOTE TO CONSULTANTS: Edit with Track Changes turned on, any text in this section that appears in bold and italics then turn off the bold and italics for the final approved version. (Remove this Note).

PART 1 - GENERAL

1.01 Description:

A. Work shall consist of furnishing and construction of a Dry-Set Concrete Modular Unit retaining wall system 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, unit drainage fill and backfill to the lines and grades shown on the construction drawings.

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

1.02 Related Sections: Coordinate the work of this Section with the work of related specification sections including:

Section 03 30 00 - Cast-in-Place Concrete
Section 31 00 00 - Earthwork
Section 32 11 23 - Mineral Aggregates
Section 32 13 13 - Concrete Paving
Section 32 31 13 - Chain Link Fencing & Gates

1.03 Reference Standards:

A. American Society for Testing and Materials (ASTM), most recent edition of referenced Materials, Testing, or Procedural Specification.

1. ASTM C-1372 Specification for Segmental Retaining Wall Units.
2. ASTM D-422 Particle Size Analysis.
3. ASTM D-698 Laboratory Compaction Characteristics of Soil -Standard Effort.
4. ASTM D-4318 Liquid Limit, Plastic Limit and Plasticity Index of Soils.
5. ASTM D-4595 Tensile Properties of Geo-textiles - Wide Width Strip.
6. ASTM D-5262 Unconfined Tension Creep Behavior of Geo-synthetics.
7. ASTM D-3034 Polyvinyl Chloride Pipe (PVC).
8. ASTM D-1248 Corrugated Plastic Pip.

B. Geo-synthetic Research Institute (GRI):

1. GRI-GG4 Determination of Long Tern Design Strength of Geo-grids.
2. GRI-GG5 Determination of Geo-grid (soil) Pullout.

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. City of Seattle Standard Specifications and Plans for Road, Bridge, and Municipal Construction, (most recent edition).

1.04 Quality Assurance:

A. Inspection Notice: Notify the Engineer at least two (2) working days notice before inspection will be required. Call the **SPR Inspection Request Line @ (206) 684-7034 or by email at parksconstruction.inspection@seattle.gov** to make arrangements for inspections. Inspection will be required immediately prior to any intended placement of concrete.

B. The work shall be performed by, or under the direct supervision of, a Journey-level Mason.

C. The Work shall not commence until the preparation of the sub-grade and base, performed under other Sections of the Specifications, has been approved by the Engineer as adequate to receive the Work of this Section.

1.05 Pre-qualifications and Submittals:

A. The Contractor shall submit written certification, prior to start of work, that the following requirements related to the installation of the specified Concrete Modular Units have been met:

1. Have been successfully utilized on a minimum of three (3) similar projects, i.e., height, soil fill types, erection tolerances, etc.
2. Have been successfully installed on a minimum of 10 thousand (10,000) square feet of retaining wall.

B. The Contractor shall submit a list of three (3) 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. The Engineer shall provide soil testing and quality assurance inspection during earthwork and wall construction operations. The Engineer's quality assurance program does not relieve the contractor of responsibility for wall performance.

1.06 Delivery, Storage and Handling:

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

B. The 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. Concrete Modular Unit (CMU) - a concrete retaining wall element machine made from Portland cement, water, and aggregates.

B. Structural Geo-grid - a structural element 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 primarily as reinforcement.

C. Unit Drainage Fill - drainage aggregate 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.

2.02 Concrete Modular Units:

A. Concrete Modular Units shall conform to the following architectural requirements:

1. Face color - ***standard manufacturer's ' color'.***
2. Face finish - '***finish' concrete unit configuration. (Other face finishes will not be allowed without written approval of the Engineer)***.
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 under diffused lighting.

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

C. Concrete Modular Units shall conform to the following structural and geometric requirements measured in accordance with appropriate references:

1. Compressive strength = 3000 psi minimum;
2. Absorption = 8 % maximum (6% in northern states) for standard weight aggregates;
3. Dimensional tolerances = ± 1/8" from nominal unit dimensions not including rough split face, ±1/16" unit height - top and bottom planes;
4. Unit size - 8" (H) x 18" (W) x 21.5" (D) minimum;
5. Unit weight - 110 lbs/unit minimum for standard weight aggregates;

6. Inter-unit shear strength - 1500 plf minimum at 2 psi normal pressure;
7. Geo-grid/unit peak connection strength - 1000 plf minimum at 2 psi normal force.

D. Concrete Modular Units shall conform to the following constructability requirements:

1. Vertical setback = 1/8"± per course (near vertical) or 1"+ per course per the design;
2. Alignment and grid positioning mechanism - fiberglass pins, two per unit minimum;
3. Maximum horizontal gap between erected units shall be - 1/2 inch.

E. Recommended Manufacturers:

1. Keystone Retaining Wall Systems, Inc.: Minneapolis, MN, Ph. (800) 747-8971, and distributed locally by: Keystone Pacific Northwest, 12655 SW Center St. - Suite #310, Beaverton, OR 97005, Ph. 800-733-7470.
2. VERSA-LOK - Retaining Wall Systems: 6348 Hwy. 36 - Suite 1, Oakdale, MN, 55128, Ph 800-770-4525. www.versa-lok.com
3. Mutual Materials: 605-119th Ave NE, PO Box 2009, Bellevue, WA 98005, Ph. 425-452-2300.
4. Or, approved equal.

2.03 Shear Connectors:

A. Shear connectors shall be 1/2 inch diameter thermoset isopthalic polyester resin-pultruded fiberglass reinforcement rods or equivalent to provide connection between vertically and horizontally adjacent units. Strength of shear connectors between vertical adjacent units shall be applicable over a design temperature of 10 degrees F to + 100 degrees F.

B. Shear connectors shall be capable of holding the geo-grid in the proper design position during grid pre-tensioning and backfilling.

2.04 Base Leveling Pad Material:

1. Top Lift: Mineral Aggregate shall be Type 1 (typically 5/8” minus crushed rock).
2. Bottom Lift: Mineral Aggregate shall be Type 2 (typically, 1-1/4” crushed rock)

2.05 Unit Drainage Fill:

A. Unit drainage fill shall consist of Type 5 (typically 1" washed gravel) meeting the following gradation tested in accordance with ASTM D-422:

Sieve Size	Percent Passing
1 inch	100
3/4 inch	80-100

3/8 inch	10-40
No. 4	0-4
No. 200	0-0.05

B. One cubic foot, minimum, of drainage fill shall be used for each square foot of wall face. Drainage fill shall be placed within cores of, between, and behind units to meet this requirement.

2.06 Reinforced Backfill:

A. Reinforced backfill shall be free of debris and meet the following gradation tested in accordance with ASTM D-422-Type 15 (modified):

Sieve Size	Percent Passing
¾ inch	100-75
¼ inch	20-75
No. 200	0-20

Plasticity Index (PI) <15 and Liquid Limit <40 per ASTM D-4318.

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 geo-grid 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 or in the reinforced soil mass.

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.

2.07 Geo-grid Soil Reinforcement:

A. Geo-synthetic reinforcement shall consist of geo-grids manufactured specifically for soil reinforcement applications and shall be manufactured from high tenacity polyester yarn or high density polyethylene. Polyester geo-grid 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 geo-grid shall be coated with an impregnated PVC coating that resists peeling, cracking, and stripping.

B. Long Term Allowable Tensile Design Load, Ta: Ta of the geo-grid material shall be determined as follows:
Ta = Tult / (RFcr*RFd*RFid*FS)
Ta shall be evaluated based on a 75 year design life.

1. Tult, Short Term Ultimate Tensile Strength:

Tult is based on the minimum average roll values (MARV).

2. RFcr, Reduction Factor for Long Term Tension Creep:
   RFcr shall be determined from 10,000 hour creep testing performed in accordance with ASTM D5262. Reduction value = 1.60 minimum.
3. RFd, Reduction Factor for Durability:
   RFd shall be determined from polymer specific durability testing covering the range of expected soil environments. RFd = 1.10 minimum.
4. RFid, Reduction Factor for Installation Damage:
   RFid 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. RFid = 1.10 minimum.
5. FS, Overall Design Factor of Safety:
   FS shall be 1.5 unless otherwise noted for the maximum allowable working stress calculation.

C. The maximum design tensile load of the geo-grid shall not exceed the laboratory tested ultimate strength of the geo-grid/facing unit connection as limited by the "Hinge Height" divided by a factor of safety of 1.5. The connection strength testing and computation procedures shall be in accordance with NCMA SRWU-1 Test Method for Determining Connection Strength of SRW.

D. Soil Interaction Coefficient, Ci: Ci values shall be determined per GRI: GG5 at a maximum 0.75 inch displacement.

D. Manufacturing Quality Control: The geo-grid manufacturer shall have a manufacturing quality control program that includes QC testing by an independent laboratory. The QC testing shall include:

1. Tensile Strength Testing
2. Melt Flow Index (HDPE)
3. Molecular Weight (Polyester)

PART 3 - EXECUTION

3.01 Inspection: Do not commence the Work of this Section until preparation of the sub-grade, wall base, and any utility connections through the designed alignment of the wall have been completed and approved by Engineer. Report to the Engineer any physical conflicts between the Work of other trades and the construction of Modular Retaining Walls for resolution prior to commencing.

3.02 Layout Control: Coordinate vertical and horizontal control of the layout with control established per the requirements of other trades. Provide string-lines establishing alignment and level of each successive course. Provide a temporary fabricated or permanent manufactured jig to maintain design batter. Report conflicts to the Engineer for resolution prior to proceeding. Re-establish Layout Control and/or revise Layout as directed by the Engineer.

3.03 Excavation:

A. The Contractor shall excavate to the lines and grades shown on the construction drawings. The Engineer shall inspect the excavation and approve prior to placement of leveling material or fill soils. Proof roll foundation area as directed to determine if remedial work is required.

B. Over-excavation and replacement of unsuitable foundation soils and replacement with approved compacted fill will be compensated as agreed upon with the Owner.

3.04 Base Leveling Pad:

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" in front and behind the modular wall unit.

1. Place bottom lift aggregates in 6 inch lifts to attain a total depth shown on the Drawings. Compact each lift as noted below.
2. Place top lift aggregates in 6 inch lift to attain a total depth shown on the Drawings. Compact each lift as noted below.

B. Soil leveling pad materials shall be compacted to a minimum of 95 % Standard Proctor density per ASTM D-698.

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

3.05 Modular Unit Installation:

A. First course of units shall be placed on the leveling pad at the appropriate line and grade. Alignment and level shall be checked in all directions and insure that all units are in full contact with the base and properly seated.

B. Place the front of the Units side-by-side. Do not leave gaps between adjacent units. Layout of corners and curves shall be in accordance with manufacturer's recommendations.

C. Install shear/connecting devices per manufacturer's recommendations.

D. Place and compact drainage fill within and behind wall units. Place and compact backfill soil behind drainage fill. Follow wall erection and drainage fill closely with structure backfill.

E. Maximum stacked vertical height of wall units, prior to unit drainage fill and backfill placement and compaction, shall not exceed two courses.

3.06 Structural Geo-grid Installation:

A. Geo-grid shall be oriented with the highest strength axis perpendicular to the wall alignment.

B. Geo-grid reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction design drawings or as directed by the Engineer.

C. The geo-grid shall be laid horizontally on compacted backfill and attached to the modular wall units. Place the next course of modular concrete units over the geo-grid. The geo-grid shall be pulled taut, and anchored prior to backfill placement on the geo-grid.

D. Geo-grid reinforcements shall be continuous throughout their embedment lengths and placed side-by-side to provide 100% coverage at each level. Spliced connections between shorter pieces of geo-grid or gaps between adjacent pieces of geo-grid are not permitted.

3.07 Reinforced Backfill Placement:

A. Reinforced backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack in the geo-grid and installation damage.

B. Reinforced backfill shall be placed and compacted in lifts not to exceed 6 inches where hand compaction is used, or 8 - 10 inches where heavy compaction equipment is used. Lift thickness shall be decreased to achieve the required density as required.

C. Reinforced backfill shall be compacted to 95% of the maximum density as determined by ASTM D698. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer and shall be dry of optimum, + 0%, - 3%.

D. Only lightweight hand-operated equipment shall be allowed within 3 feet from the tail of the modular concrete unit.

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

F. Rubber tired equipment may pass over geo-grid 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. Use plastic sheeting as required to protect the Work.

3.08 Wall Ends:

A. Terminal End at Grade: When wall angles downward and "dies into grade", provide a minimum of two courses below grade. The terminal units of the top course shall be a whole unit, or half units, cut to size.

3.09 Handrail/Fence Post Installation:

A. Fence posts shall be placed on 6'-0" centers to correspond to voids in the modular retaining wall units. Place posts in front voids of full units and between units in alternating courses. Do not allow backfill material to collect in the void spaces of the units into which the posts will be placed.

B. Fill all voids spaces and spaces between voids in alternating courses containing posts with non-shrink grout. All posts shall be plumb and in alignment as shown on the Drawings. Protect handrail/fence posts from damage during placement.

C. Refer to Section 32 31 13 - Chain Link Fencing & Gates, for additional information about fence posts.

3.10 Coping Installation:

A. Coping to be cast in place Portland Cement Concrete (see Division 3). Coping shall be crowned slightly for positive drainage and finished with a light broom finish.

3.11 As-built Construction Tolerances:

A. Vertical alignment: ± 1.5" over any 10' distance.

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

C. Horizontal alignment: ± 1.5" over any 10' distance.
Corners, bends, curves: ± 1 ft to theoretical location.

D. Maximum horizontal gap between erected units shall be 1/2 inch.

3.12 Field Quality Control:

A. The Engineer 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. Testing and inspections services shall only be performed by qualified and experienced Technicians and Engineers.

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.

3.13 Cleaning: Leave premises clean and free of residue from work in this section, including trash, materials containers, mason line and CMU or grout.

END OF SECTION