PART 1 – GENERAL

1.01 SUMMARY

A. This Section includes furnishing all materials and labor required for the design and construction of a precast concrete modular block retaining wall with geosynthetic reinforcement. Precast modular blocks under this Section shall be cast utilizing a wet-cast concrete mix and exhibit a final handling weight in excess of 1,000 pounds (450 kg) per unit.

B. Scope of Work: The work shall consist of furnishing materials, labor, equipment and supervision for the construction of a precast modular block retaining wall structure in accordance with the requirements of this Section and in acceptable conformity with the lines, grades, design and dimensions shown in the project site plans.

C. Drawings and General Provisions of the Contract, including General and Supplementary Conditions also apply to this Section.

1.02 PRICE AND PAYMENT PROCEDURES

A. Allowances. No allowance shall be made in the price of the retaining wall for excavation beyond the limits required for retaining wall construction as shown on the project plans. The cost of excavation or fill placement for the purposes of site access shall be the responsibility of the General Contractor.

B. Removal of unsuitable soils and replacement with select fill shall be as directed and approved in writing by the Owner or Owner’s Representative and shall be paid under separate pay items.

C. Unit Prices. In addition to a lump sum price pursuant to completion of the scope of work described in Paragraph 1.01 of this Section, the General Contractor shall provide a unit price per square foot of vertical wall face that shall be the basis of compensation for up to a ten (10) percent increase or reduction in the overall scope of the retaining wall work.

D. Measurement and Payment.
   1. The unit of measurement for furnishing the precast modular block retaining wall system shall be the vertical area of the wall face surface as measured from the top of the leveling pad to the top of the wall including coping or cap. The final measured quantity shall include supply of all material components and the installation of the precast modular block system.
   2. The final accepted quantities of the precast modular block retaining wall system will be compensated per the measured vertical face area as described above. The quantities of the precast modular block retaining wall as shown on the plans and as approved by the Owner shall be the basis for determination of the final payment quantity. Payment shall be made per square foot of vertical wall face.

1.03 REFERENCES

A. Where the specification and reference documents conflict, the Owner’s designated representative will make the final determination of the applicable document.

B. Definitions:
   2. Geotextile – a nonwoven geosynthetic fabric manufactured for use as a separation and filtration medium between dissimilar soil materials.
3. Geogrid – a geosynthetic material comprised of a regular network of tensile elements manufactured in a mesh-like configuration of consistent aperture openings. When connected to the PMB units and placed in horizontal layers in compacted fill, the geogrid prevents lateral deformation of the retaining wall face and provides effective tensile reinforcement to the contiguous reinforced backfill material.

4. Drainage Aggregate – clean, crushed stone placed between and immediately behind the precast modular block units to facilitate drainage and reduce compaction requirements immediately adjacent to and behind the precast modular block units.

5. Unit Core Fill – clean, crushed stone placed within the hollow vertical core of a precast modular block unit. Typically, the same material used for drainage aggregate as defined above.

6. Foundation Zone – soil zone immediately beneath the leveling pad and the reinforced zone.

7. Reinforced Zone – structural fill zone within which successive horizontal layers of geogrid soil reinforcement have been placed to provide stability for the retaining wall face.

8. Retained Zone – soil zone immediately behind the reinforced zone.

9. Reinforced Backfill – structural fill placed within the reinforced zone.

10. Retained Backfill – structural or soil fill placed behind the reinforced zone.

11. Leveling Pad – hard, flat surface upon which the bottom course of precast modular blocks is placed. The leveling pad may be constructed with crushed stone or cast-in-place concrete. A leveling pad is not a structural footing.

C. Reference Standards

1. Design
   g. CDOT Standard Specifications for Road and Bridge Construction, 2017

2. Precast Modular Block Units
   g. ASTM C1776 – Standard Specification for Wet-Cast Precast Modular Retaining Wall Units.
   h. ASTM D6638 – Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks).
   i. ASTM D6916 – Standard Test Method for Determining Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks).

3. Geosynthetics


l. ASTM D5321 – Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.

m. ASTM D5818 – Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics.


4. Soils

a. AASHTO M 145 – AASHTO Soil Classification System.

b. AASHTO T 104 – Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.


f. ASTM D448 – Standard Classification for Sizes of Aggregates for Road and Bridge Construction.

g. ASTM D698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort. (12,400 ft-lbf/ft (2,700 kN-m/m)).


i. ASTM D1556 – Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.

j. ASTM D1557 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. (56,000 ft-lbf/ft (2,700 kN-m/m)).

k. ASTM D2487 – Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).


q. ASTM D6938 – Standard Test Method for In-Place Density and Water Content of Soil and Aggregate by Nuclear Methods (Shallow Depth).


5. Drainage Pipe
c. ASTM F2648 – Standard Specification for 2 to 60 inch [50 to 1500 mm] Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications.

1.04 ADMINISTRATIVE REQUIREMENTS

A. Preconstruction Meeting. As directed by the Owner, the General Contractor shall schedule a preconstruction meeting at the project site prior to commencement of retaining wall construction. Participation in the preconstruction meeting shall be required of the Owner’s Representative, Civil Engineer, Geotechnical Engineer, Landscape Architect, General Contractor, Surveyor, Retaining Wall Design Engineer, Retaining Wall Installation Contractor, Grading Contractor, Utility Contractor, Landscape Contractor, and Inspection Engineer. The General Contractor shall provide notification to all parties at least 10 calendar days prior to the meeting.

1. Preconstruction Meeting Agenda:
   a. The Retaining Wall Design Engineer shall explain all aspects of the retaining wall construction shop drawings.
   b. The Civil Engineer shall explain all aspects of the retaining wall alignment and staking.
   c. The Retaining Wall Design Engineer shall explain the required bearing capacity of soil below the retaining wall structure and the shear strength of in-situ soils assumed in the retaining wall design to the Inspection Engineer.
   d. The Retaining Wall Design Engineer shall explain the required shear strength of fill soil in the reinforced, retained and foundation zones of the retaining wall to the Inspection Engineer.
   e. The Retaining Wall Design Engineer shall explain any measures required for coordination of the installation of utilities or other obstructions in the reinforced or retained fill zones of the retaining wall.
   f. The Retaining Wall Installation Contractor shall explain all excavation needs, site access and material staging area requirements to the General Contractor and Grading Contractor.

1.05 SUBMITTALS

A. Product Data. At least 14 days prior to construction, the General Contractor shall submit an electronic copy of the retaining wall product submittal package to the Owner’s Representative for review and approval. The submittal package shall include technical specifications and product data from the manufacturer for the following:
1. Precast Modular Block System brochure
2. Precast Modular Block concrete test results specified in Paragraph 2.01.B of this Section as follows:
   a. 28-day compressive strength
   b. Air content
   c. Slump or Slump Flow (as applicable)
3. Drainage Pipe
4. Geotextile
5. Geogrid. The contractor shall provide certified manufacturer test reports for the geogrid material in the manufactured roll width specified. The test report shall list the individual roll numbers for which the certified material properties are valid.

B. Installer Qualification Data. At least 14 days prior to construction, the General Contractor shall submit the qualifications of the business entity responsible for installation of the retaining wall, the Retaining Wall Installation Contractor, per Paragraph 1.07.A of this Section.
C. Retaining Wall Design Calculations and Construction Shop Drawings. At least 14 days prior to construction, the General Contractor shall furnish an electronic copy of construction shop drawings and an electronic copy of the supporting engineering calculations report to the Owner for review and approval. This submittal shall include the following:

1. Signed, sealed and dated drawings and engineering calculations prepared in accordance with these specifications.
2. Qualifications Statement of Experience of the Retaining Wall Design Engineer as specified in Paragraph 1.07.B of this Section.
3. Certificate of Insurance of the Retaining Wall Design Engineer as specified in Paragraph 1.06.B of this Section.

1.06 CONSTRUCTION SHOP DRAWING PREPARATION

A. The General Contractor shall facilitate coordination of the retaining wall construction shop drawing preparation with the project Civil Engineer, project Geotechnical Engineer and Owner’s Representatives. The General Contractor shall furnish the Retaining Wall Design Engineer the following project information required to prepare the construction shop drawings. This information shall include, but is not limited to, the following:

1. Current versions of the site, grading, drainage, utility, erosion control, landscape, and irrigation plans;
2. Electronic CAD files of the civil grading plans listed in (1);
3. Report of geotechnical investigation and all addenda and supplemental reports;
4. Recommendations of the project Geotechnical Engineer regarding total unit weight, effective stress shear strength and total stress shear strength (when applicable) parameters for in-situ soils in the vicinity of the proposed retaining wall(s) and for any fill soil that may potentially be used as backfill in retained and/or foundation zones of the retaining wall.

B. The Retaining Wall Design Engineer shall provide the Owner with a certificate of professional liability insurance verifying the minimum coverage limits of $1 million per claim and $1 million aggregate.

C. Design of the precast modular block retaining wall shall satisfy the requirements of this Section. Where local design or building code requirements exceed these specifications, the local requirements shall also be satisfied.

D. The precast modular block design, except as noted herein, shall be based upon

1. AASHTO Load and Resistance Factor Design (LRFD) methodology as referenced in Paragraph 1.03.C.1.a, or
2. NCMA, Design Manual of Segmental Retaining Walls, as referenced in Paragraph 1.03.C.1.f

E. In the event that a conflict is discovered between these specifications and a reasonable interpretation of the design specifications and methods referenced in Paragraph D above, these specifications shall prevail. If a reasonable interpretation is not possible, the conflict shall be resolved per the requirements in Paragraph 1.03.A of this Section.

F. Soil Shear Parameters. The Retaining Wall Design Engineer shall prepare the construction shop drawings based upon soil shear strength parameters from the available project data and the recommendations of the project Geotechnical Engineer as specified in Paragraph 1.06.A.4 of this Section. If insufficient data exists to develop the retaining wall design, the Retaining Wall Design Engineer shall communicate the specific deficiency of the project information or data to the Owner in writing.

G. Allowable bearing pressure requirements for each retaining wall shall be clearly shown on the construction shop drawings.
H. Global Stability. Overall (global) stability shall be evaluated in accordance with the principals of limit equilibrium analysis as set forth in FHWA GEC 011 – Volume I as referenced in Paragraph 1.03.C.1.d. The minimum factors of safety shall be as follows:

- Normal Service – Critical (Static) 1.5
- Normal Service – Noncritical (Static) 1.3
- Rapid Drawdown (if applicable) 1.1

I. Seismic Stability. When applicable per the AASHTO LRFD Specifications as referenced in Paragraph 1.03.C.1.a of this Section, seismic loading shall be evaluated in accordance with AASHTO LRFD or NCMA methodology as referenced in Paragraph 1.03.C.1 of this Section.

1.07 QUALITY ASSURANCE

A. Retaining Wall Installation Contractor Qualifications. In order to demonstrate basic competence in the construction of precast modular block MSE walls, the Retaining Wall Installation Contractor shall document compliance with the following:

1. Experience.
   a. Completion of at least ten (10) projects using precast modular block MSE wall system within the past three (3) years, and
   b. Construction of at least 50,000 square feet (4,650 square meters) of precast modular block MSE wall system within the past three (3) years.

2. Retaining Wall Installation Contractor experience documentation for each qualifying project shall include:
   a. Project name and location
   b. Date (month and year) of construction completion
   c. Contact information of Owner or General Contractor
   d. Type (trade name) of precast modular block system built
   e. Maximum height of the MSE wall constructed
   f. Face area of the wall constructed

B. Retaining Wall Design Engineer Qualifications and Statement of Experience. The Retaining Wall Design Engineer shall submit a written statement affirming that he or she has the following minimum qualifications and experience.

1. The Retaining Wall Design Engineer shall be a licensed professional engineer to practice in the jurisdiction of the project location.

2. The Retaining Wall Design Engineer shall be independently capable of performing all internal and external stability analyses, including those for seismic loading, compound stability, rapid draw-down and deep-seated, global modes of failure.

3. The Retaining Wall Design Engineer shall affirm that he or she has personally supervised the design of the retaining walls for the project, that the design considers all the requirements listed in Paragraphs 1.06.C through 1.06.I, and that he or she accepts responsibility as the design engineer of record for the retaining walls constructed on the project.

4. The Retaining Wall Design Engineer shall affirm that he or she has personally designed or supervised the design in excess of 100,000 face square feet (9,000 face square meters) of modular block retaining walls within the past three (3) years.

C. The Owner reserves the right to reject the design services of any engineer or engineering firm who, in the sole opinion of the Owner, does not possess the requisite experience or qualifications.

1.08 QUALITY CONTROL

A. The Owner’s Representative shall review all submittals for materials, design, Retaining Wall Design Engineer qualifications and the Retaining Wall Installation Contractor qualifications.
B. The Owner shall retain the services of an Inspection Engineer who is experienced with the construction of precast modular block MSE wall structures to perform inspection and testing. The cost of inspection and testing shall be the responsibility of the Owner. Inspection shall be periodically performed throughout the construction of the retaining walls.

C. The Inspection Engineer shall perform the following duties:
   1. Inspect the construction of the precast modular block structure for conformance with construction shop drawings and the requirements of this specification.
   2. Verify that soil or aggregate fill placed and compacted in the reinforced, retained and foundation zones of the retaining walls conforms to Paragraphs 2.04 and 2.05 of this Section and exhibits the shear strength parameters used in the design.
   3. Verify that the shear strength of the in-situ soil conforms to that used in the design.
   4. Inspect, test, and document soil compaction in accordance with these specifications:
      a. Dry unit weight and percent compaction
      b. Allowable moisture content
      c. Actual moisture content
      d. Pass/fail assessment
      e. Test location – wall station number
      f. Test elevation
      g. Distance of test location behind the wall face
   5. Verify that all excavated slopes in the vicinity of the retaining wall are bench-cut per the OSHA guidelines or as directed by the project Geotechnical Engineer.
   6. Notify the General Contractor and Retaining Wall Installation Contractor of any deficiencies in the retaining wall construction and provide the Retaining Wall Installation Contractor a reasonable opportunity to correct the deficiency.
   7. Notify the Owner, General Contractor, and Retaining Wall Installation Contractor of any construction deficiencies that have not been corrected timely.
   8. Document all inspection and testing results.
   9. Test compacted density and moisture content of the retained backfill at the following frequency:
      a. At least once every 1,000 square feet (90 square meters) (in plan) per 9-inch (230 mm) vertical lift, and
      b. At least once per every 18 inches (460 mm) of vertical wall construction.

D. The Owner’s engagement of the Inspection Engineer does not relieve the Retaining Wall Installation Contractor of responsibility to construct the proposed retaining wall in accordance with the approved construction shop drawings and these specifications.

E. The Retaining Wall Installation Contractor shall inspect the on-site grades and excavations prior to construction and notify the Retaining Wall Design Engineer and General Contractor if on-site conditions differ from the elevations and grading conditions depicted in the contract documents or retaining wall construction shop drawings.

1.09 DELIVERY, STORAGE AND HANDLING

A. The Retaining Wall Installation Contractor shall inspect the materials upon delivery to ensure that the proper type, grade and color of materials have been delivered.

B. The Retaining Wall Installation Contractor shall store and handle all materials in accordance with the manufacturers’ recommendations as specified herein and in a manner that prevents deterioration or damage due to moisture, temperature changes, contaminants, corrosion, breaking, chipping, UV exposure or other causes. Damaged materials shall not be incorporated into the work.

C. Geosynthetics
   1. All geosynthetic materials shall be handled in accordance with ASTM D4873. The materials should be stored off the ground and protected from precipitation, sunlight, dirt and physical damage.
D. Precast Modular Blocks
1. Precast modular blocks shall be stored in an area with positive drainage away from the blocks. Be careful to protect the block from mud and excessive chipping and breakage. Precast modular blocks shall not be stacked more than three (3) units high in the storage area.

E. Drainage Aggregate and Backfill Stockpiles
1. Drainage aggregate or backfill material shall not be piled over unstable slopes or areas of the project site with buried utilities.
2. Drainage aggregate and/or structure backfill material shall not be staged where it may become mixed with or contaminated by dissimilar material or fine-grained soils such as clay or silt.

PART 2 – MATERIALS

2.01 PRECAST MODULAR BLOCK RETAINING WALL UNITS

A. All units shall be wet-cast precast modular retaining wall units conforming to ASTM C1776.

B. All units for the project shall be obtained from the same manufacturer. The manufacturer shall be licensed and authorized to produce the retaining wall units by the precast modular block system patent holder/licensor and shall document compliance with the published quality control standards of the proprietary precast modular block system licensor for the previous three (3) years or the total time the manufacturer has been licensed, whichever is less.

C. Concrete used in the production of the precast modular block units shall be first-purpose, fresh concrete. It shall not consist of returned, reconstituted, surplus or waste concrete. It shall be an original production mix meeting the requirements of ASTM C94 and exhibit the following:
   1. Minimum 28-day compressive strength of 4,000 psi (27.6 MPa).
   2. Shall be free of water soluble chlorides and chloride based accelerator admixtures.
   3. 6% +/- 1½% air-entrainment in conformance ASTM C94.
   4. Maximum slump of 5 inches +/- 1½ inches (125 mm +/- 40 mm) per ASTM C143 for conventional concrete mix designs.

D. Each concrete block shall be cast in a single continuous pour without cold joints. With the exception of half-block units, corner units and other special application units, the precast modular block units shall conform to the nominal dimensions listed in the table below and be produced to the dimensional tolerances shown.

<table>
<thead>
<tr>
<th>Block Type</th>
<th>Dimension</th>
<th>Nominal Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>28” (710 mm) Block</td>
<td>Height</td>
<td>18” (457 mm)</td>
<td>+/- 3/16&quot; (5 mm)</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>46-1/8” (1172 mm)</td>
<td>+/- 1/2” (13 mm)</td>
</tr>
<tr>
<td></td>
<td>Width*</td>
<td>28” (710 mm)</td>
<td>+/- 1/2” (13 mm)</td>
</tr>
<tr>
<td>41” (1030 mm) Block</td>
<td>Height</td>
<td>18” (457 mm)</td>
<td>+/- 3/16&quot; (5 mm)</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>46-1/8” (1172 mm)</td>
<td>+/- 1/2” (13 mm)</td>
</tr>
<tr>
<td></td>
<td>Width*</td>
<td>40-1/2” (1030 mm)</td>
<td>+/- 1/2” (13 mm)</td>
</tr>
</tbody>
</table>

* Block tolerance measurements shall exclude variable face texture

E. Individual block units shall have a nominal height of 18 inches (457 mm).

F. With the exception of top units, corner units and other special application units, the precast modular block units shall have two (2), circular dome shear knobs that are 10 inches (254 mm), 7.5 inches (190 mm), or 6.75 inches (171 mm) in diameter and 4 inches (102 mm) or 2 inches (51 mm) in
height. The shear knobs shall fully index into a continuous semi-cylindrical shear channel in the bottom of the block course above.

G. The peak interlock shear between any two (2) vertically stacked precast modular block units with 10 inch (254 mm) diameter shear knobs, measured in accordance with ASTM D6916, shall exceed 6,500 lb/ft (95 kN/m) at a minimum normal load of 500 lb/ft (7 kN/m) as well as an ultimate peak interface shear capacity in excess of 11,000 lb/ft (160 kN/m). The peak interlock shear between any two (2) vertically stacked precast modular block units with 7.5 inch (190 mm) or 6.75 inch (171 mm) diameter shear knobs, measured in accordance with ASTM D6916, shall exceed 1,850 lb/ft (27 kN/m) at a minimum normal load of 500 lb/ft (7 kN/m) as well as an ultimate peak interface shear capacity in excess of 10,000 lb/ft (146 kN/m). Test specimen blocks tested under ASTM D6916 shall be actual full-scale production blocks of known compressive strength. The interface shear capacity reported shall be corrected for a 4,000 psi (27.6 MPa) concrete compressive strength. Regardless of precast modular block configuration, interface shear testing shall be completed without the inclusion of unit core fill aggregate.

H. The 28" (710 mm) and 41" (1030 mm) precast modular block units shall be cast with a 13" (330 mm) wide, continuous vertical core slot that will permit the insertion of a 12" (305 mm) inch wide strip of geogrid reinforcement to pass completely through the block. When installed in this manner, the geogrid reinforcement shall form a non-normal load dependent, positive connection between the block unit and the reinforcement strip. The use of steel for the purposes of creating the geogrid to block connection is not acceptable.

I. Without field cutting or special modification, the precast modular block units shall be capable of achieving a minimum radius of 14 ft 6 in (4.42 m).

J. The precast modular block units shall be manufactured with an integrally cast shear knobs that establishes a standard horizontal set-back for subsequent block courses. The precast modular block system shall be available in the three (3) standard horizontal set-back facing batter options listed below:

<table>
<thead>
<tr>
<th>Horizontal Set-Back/Blk. Course</th>
<th>Max. Facing Batter</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot; (10 mm)</td>
<td>1.2°</td>
</tr>
<tr>
<td>1-5/8&quot; (41 mm)</td>
<td>5.2°</td>
</tr>
<tr>
<td>9-3/8&quot; (238 mm)</td>
<td>27.5°</td>
</tr>
</tbody>
</table>

The precast modular block units shall be furnished with the required shear knobs that provide the facing batter required in the construction shop drawings.

K. The precast modular block unit face texture shall be selected by the Owner from the range of textures available from the precast modular block manufacturer. Each textured block facing unit shall be a minimum of 5.76 square feet (0.54 square meters) with a unique texture pattern that repeats with a maximum frequency of once in any 15 square feet (1.4 square meters) of wall face.

L. The block color shall be selected by the Owner from the range of colors available from the precast modular block manufacturer.

M. All precast modular block units shall be sound and free of cracks or other defects that would interfere with the proper installation of the units, impair the strength or performance of the constructed wall. PMB units to be used in exposed wall construction shall not exhibit chips or cracks in the exposed face or faces of the unit that are not otherwise permitted. Chips smaller than 1.5" (38 mm) in its largest dimension and cracks not wider than 0.012" (0.3 mm) and not longer than 25% of the nominal height of the PMB unit shall be permitted. PMB units with bug holes in the
exposed architectural face smaller than 0.75" (19 mm) in its largest dimension shall be permitted. Bug holes, water marks, and color variation on non-architectural faces are acceptable. PMB units that exhibit cracks that are continuous through any solid element of the PMB unit shall not be incorporated in the work regardless of the width or length of the crack.

N. Preapproved Manufacturers.
Manufacturers of Redi-Rock Retaining Wall Systems as licensed by Redi-Rock International, LLC,

Signature Stone
211 30th Street, Greeley, CO 80631
Telephone: (970) 539-2201
Website: www.signaturestone.net | www.redi-rock.com

O. Substitutions. Technical information demonstrating conformance with the requirements of this specification for an alternative precast modular block retaining wall system must be submitted for preapproval at least 14 calendar days prior to the bid date. Acceptable alternative PMB retaining wall systems, otherwise found to be in conformance with this specification, shall be approved in writing by the Owner 7 days prior to the bid date. The Owner’s Representative reserves the right to provide no response to submissions made out of the time requirements of this Section or to submissions of block retaining wall systems that are determined to be unacceptable to the Owner.

2.02 GEOGRID REINFORCEMENT

A. Geogrid reinforcement shall be a woven or knitted, PVC coated geogrid manufactured from high-tenacity polyester (PET) fiber with an average molecular weight greater than 25,000 (\(M_n > 25,000\)) and a maximum carboxyl end group content less than 30 (CEG < 30). The geogrid shall be furnished in prefabricated roll widths of certified tensile strength by the manufacturer. The prefabricated roll width of the geogrid shall be 12" (300 mm) +/- 1/2" (13 mm). No cutting of geogrid reinforcement down to the 12" (300 mm) roll width from a larger commercial roll width will be allowed under any circumstances.

B. The ultimate tensile strength (\(T_{ul}\)) of the geogrid reinforcement shall be measured in accordance with ASTM D6637.

C. Geogrid – Soil Friction Properties
1. Friction factor, \(F^*\), shall be in accordance with the AASHTO LRFD Bridge Design Specifications as referenced in Paragraph 1.03.C.1.a and Section 3.4.2 of FHWA GEC 011 – Volume I as referenced in Paragraph 1.03.C.1.d in this Section or equal to \(2/3 \tan \phi\), where \(\phi\) is the effective angle of internal friction of the reinforced backfill soil for a default value.
2. Linear Scale Correction Factor, \(\alpha\), shall equal 0.8.

D. Long-Term Tensile Strength (\(T_{al}\)) of the geogrid reinforcement shall be calculated in accordance with Section 3.5.2 of FHWA GEC 011 – Volume I as provided in this specification.
1. The creep reduction factor (\(RF_{CR}\)) shall be determined in accordance with Appendix D of FHWA GEC 011 – Volume II as referenced in Paragraph 1.03.C.1.e in this Section and ASTM D6992 for a minimum 75 year design life, or equal to a default value of 1.7.
2. Minimum installation damage reduction factor (\(RF_{ID}\)) shall be based upon documented full-scale tests in a soil that is comparable to the material proposed for use as reinforced backfill in accordance with ASTM D5818, or equal to a default value of 1.25.
3. Minimum durability reduction factor (\(RF_{D}\)) shall be based upon Section 3.5.2.d of FHWA GEC 011 – Volume I or equal to a default value of 1.3 for a soil pH range of 3 to 9.

E. Connection strength between the PMB retaining wall unit and the geogrid reinforcement shall be determined from short-term testing per the requirements in Appendix B.4 of FHWA GEC 011 – Volume II for a minimum 75-year design life.
F. The minimum value of $T_{ai}$ for geogrid used in design of a reinforced precast modular block retaining wall shall be 2,000 lb/ft (29 kN/m) or greater.

G. The minimum length of geogrid reinforcement measured from the back of the PMB unit shall be the greater of the following:
   1. 0.7 times the wall design height, $H$.
   2. 5 feet (1.52 m).
   3. The length required by design to meet internal stability requirements, soil bearing pressure requirements and constructability requirements.

H. Constructability Requirements. Geogrid reinforcement length shall be measured from the back of the PMB unit and shall be consistent for the entire height of a given retaining wall section.

I. Geogrid shall be positively connected to every PMB unit. Design coverage ratio, $R_c$, as calculated in accordance with AASHTO LRFD Bridge Design Specifications Figure 11.10.6.4.1-2 shall not exceed 0.50, and 0.25 for the top and bottom layers of geogrid.

J. Preapproved Geogrid Reinforcement Products.
   1. Miragrid XT Geogrids as manufactured by TenCate Geosynthetics of Pendergrass, Georgia USA and distributed by Manufacturers of the Redi-Rock Retaining Wall System.

K. Substitutions. No substitutions of geogrid reinforcement products shall be allowed.

2.03 GEOTEXTILE

A. Nonwoven geotextile fabric shall be placed as indicated on the retaining wall construction shop drawings. The nonwoven geotextile fabric shall meet the requirements Class 3 construction survivability in accordance with AASHTO M 288.

B. Preapproved Nonwoven Geotextile Products
   1. TenCate Mirafi 140N
   2. Strata StrataTex ST-142
   3. Hanes TerraTex N04.5
   4. Propex Geotex 451

2.04 DRAINAGE AGGREGATE AND UNIT CORE FILL

A. Drainage aggregate and unit core fill shall be a durable crushed stone conforming to No. 57 size per ASTM C33 with the following particle-size distribution requirements per ASTM D422:

<table>
<thead>
<tr>
<th>U.S. Standard Sieve Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-½” (38 mm)</td>
<td>100</td>
</tr>
<tr>
<td>1” (25 mm)</td>
<td>95 - 100</td>
</tr>
<tr>
<td>⅜” (13 mm)</td>
<td>25 - 60</td>
</tr>
<tr>
<td>No. 4 (4.76 mm)</td>
<td>0 - 10</td>
</tr>
<tr>
<td>No. 8 (2.38 mm)</td>
<td>0 - 5</td>
</tr>
</tbody>
</table>

2.05 REINFORCED BACKFILL

A. Material used as reinforced backfill material in the reinforced zone shall be a granular fill material meeting the requirements per Section 703.08(a) of CDOT Standard Specifications as referenced in Paragraph 103.C.1.g in this Section, USCS soil types GW, GP, SW or SP per ASTM D2487, or alternatively by AASHTO Group Classification A-1-a or A-3 per AASHTO M 145. The backfill shall
exhibit a minimum peak effective internal angle of friction, $\phi = 34$ degrees and meet the following particle-size distribution requirements per ASTM D422.

<table>
<thead>
<tr>
<th>U.S. Standard Sieve Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4” (19 mm)</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.76 mm)</td>
<td>30 - 100</td>
</tr>
<tr>
<td>No. 50 (0.30 mm)</td>
<td>10 - 60</td>
</tr>
<tr>
<td>No. 200 (0.07 mm)</td>
<td>0 - 20</td>
</tr>
</tbody>
</table>

B. The reinforced backfill material shall be free of sod, peat, roots or other organic or deleterious matter including, but not limited to, ice, snow or frozen soils. Materials passing the No. 40 (0.42 mm) sieve shall have a liquid limit not exceeding 35 and plasticity index of 6 or less per ASTM D4318. Organic content in the backfill material shall be less than 1% per AASHTO T-267 and the pH of the backfill material shall be between 5 and 8.

C. Soundness. The reinforced backfill material shall exhibit a magnesium sulfate soundness loss of less than 30% after four (4) cycles, or sodium sulfate soundness loss of less than 15% after five (5) cycles as measured in accordance with AASHTO T-104.

D. Reinforced backfill shall not be comprised of crushed or recycled concrete, recycled asphalt, bottom ash, shale or any other material that may degrade, creep or experience a loss in shear strength or a change in pH over time.

2.06 LEVELING PAD

A. The precast modular block units shall be placed on a leveling pad constructed from crushed stone or unreinforced concrete. The leveling pad shall be constructed to the dimensions and limits shown on the retaining wall design shop drawings prepared by the Retaining Wall Design Engineer.

B. Crushed stone used for construction of a granular leveling pad shall meet the requirements of the drainage aggregate and unit core fill in Paragraph 2.04 or a preapproved alternate material.

C. Concrete used for construction of an unreinforced concrete leveling pad shall satisfy the criteria for AASHTO Class B concrete. The concrete should be cured a minimum of 12 hours prior to placement of the precast modular block units and exhibit a minimum 28-day compressive strength of 2,500 psi (17.2 MPa).

2.07 DRAINAGE

A. Drainage Pipe
   1. Drainage pipe shall be a 4” (100 mm) diameter, 3-hole perforated, HDPE pipe with a minimum pipe stiffness of 22 psi (152 kPa) per ASTM D2412, or a 4” (100 mm) diameter, 3-hole perforated, Schedule 40 PVC pipe.
   2. The drainage pipe shall be manufactured in accordance with ASTM F2648 for HDPE pipe and fittings, or ASTM D3034 for PVC pipe and fittings.

PART 3 – EXECUTION

3.01 GENERAL

A. All work shall be performed in accordance with OSHA safety standards, state and local building codes and manufacturer’s requirements.
B. The General Contractor is responsible for the location and protection of all existing underground utilities. Any new utilities proposed for installation in the vicinity of the retaining wall, shall be installed concurrent with retaining wall construction. The General Contractor shall coordinate the work of subcontractors affected by this requirement.

C. New utilities installed below the retaining wall shall be backfilled and compacted to a minimum of 98% of the maximum standard Proctor dry density per ASTM D698 or a minimum 95% of the maximum modified Proctor dry density per ASTM D1557.

D. The General Contractor is responsible to ensure that safe excavations and embankments are maintained throughout the course of the project.

E. All work shall be inspected by the Inspection Engineer as directed by the Owner.

3.02 EXAMINATION

A. Prior to construction, the General Contractor, Grading Contractor, Retaining Wall Installation Contractor and Inspection Engineer shall examine the areas in which the retaining wall will be constructed to evaluate compliance with the requirements for installation tolerances, worker safety and any site conditions affecting performance of the completed structure. Installation shall proceed only after unsatisfactory conditions have been corrected.

3.03 PREPARATION

A. Fill Soil.
   1. The Inspection Engineer shall verify that reinforced backfill placed in the reinforced zone satisfies the criteria of this Section.
   2. The Inspection Engineer shall verify that any fill soil placed in the foundation and retained zones of the retaining wall satisfies the specification of the Retaining Wall Design Engineer as shown on the construction shop drawings.

B. Excavation.
   1. The Grading Contractor shall excavate to the lines and grades required for construction of the precast modular block retaining wall as shown on the construction shop drawings. The Grading Contractor shall minimize over-excavation. Excavation support, if required, shall be the responsibility of the Grading Contractor.
   2. Over-excavated soil shall be replaced with compacted fill in conformance with the specifications of the Retaining Wall Design Engineer and the project specifications.
   3. Embankment excavations shall be cut in accordance with OSHA guidelines or as directed by the project Geotechnical Engineer and inspected by the Inspection Engineer for compliance.

C. Foundation Preparation.
   1. Prior to construction of the precast modular block retaining wall, the leveling pad and reinforced zone areas and undercut zone (if applicable) shall be cleared and grubbed. All topsoil, brush, frozen soil and organic material shall be removed. Additional foundation soils found to be unsatisfactory beyond the specified undercut limits shall be undercut and replaced with approved fill as directed by the project Geotechnical Engineer. The Inspection Engineer shall verify that the undercut limits are consistent with the requirements of the project Geotechnical Engineer and that all tested soil fill material is properly compacted according to the project specifications. The Inspection Engineer shall document the undercut and replacement.
   2. Following excavation for the leveling pad and reinforced zone areas and undercut zone (if applicable), the Inspection Engineer shall evaluate the in-situ soil in the foundation zone.
      a. The Inspection Engineer shall verify that the shear strength of the in-situ soil used in the Retaining Wall Design is appropriate. The Inspection Engineer shall immediately stop
work and notify the Owner if the in-situ shear strength is found to be lower than the retaining wall design assumptions.

b. The Inspection Engineer shall verify that the foundation soil exhibits sufficient ultimate bearing capacity to satisfy the requirements indicated on the retaining wall construction shop drawings per Paragraph 1.06.G of this Section.

D. Leveling Pad.
1. The leveling pad shall be constructed to provide a level, hard surface on which to place the first course of precast modular block units. The leveling pad shall be placed in the dimensions shown on the retaining wall construction shop drawings and extend to the limits indicated.
2. Crushed Stone Leveling Pad. Crushed stone shall be placed in uniform maximum lifts of 6” (150 mm). The crushed stone shall be compacted by a minimum of 3 passes of a vibratory plate compactor capable of exerting 2,000 lb (8.9 kN) of centrifugal force and to the satisfaction of the Inspection Engineer.
3. Concrete Leveling Pad. The Retaining Wall Installation Contractor shall erect proper forms or use bank pour method as required to ensure the accurate placement of the concrete leveling pad according to the retaining wall construction shop drawings.

3.04 PRECAST MODULAR BLOCK WALL SYSTEM INSTALLATION

A. The precast modular block structure shall be constructed in accordance with the construction shop drawings, these specifications and the recommendations of the retaining wall system component manufacturers. Where conflicts exist between the manufacturer’s recommendations and these specifications, these specifications shall prevail.

B. Drainage components. Drainage pipe, geotextile and drainage aggregate shall be installed as shown on the construction shop drawings. Drainage pipe shall be routed to daylight or at least 12” (300 mm) in front of the face of block. Temporary termination of drainage discharge pipe shall be left exposed, clearly marked with a stake or post, properly protected from damage, and indicated to the General Contractor and the Grading Contractor.

C. Precast Modular Block Installation
1. The first course of block units shall be placed with the front face edges tightly abutted together on adjacent blocks, on the prepared leveling pad at the locations and elevations shown on the construction shop drawings. The Retaining Wall Installation Contractor shall take special care to ensure that the bottom course of block units are in full contact with the leveling pad, are set level and true and are properly aligned according to the locations shown on the construction shop drawings with correct offset for wall face batter.
2. Nonwoven geotextile fabric shall be placed in the V-shaped joints between adjacent blocks if required on the retaining wall construction shop drawings. Drainage aggregate shall be placed in the V-shaped joints between adjacent blocks, and extend to a minimum distance of 12” (300 mm) behind the block units.
3. Drainage aggregate shall be placed in 9 inch maximum lifts and compacted by a minimum of three (3) passes of a vibratory plate compactor capable exerting a minimum of 2,000 lb (8.9 kN) of centrifugal force.
4. Unit core fill shall be placed in the precast modular block unit vertical core slot. The unit core fill shall completely fill the slot to the level of the top of the block unit. The top of the block unit shall be broom-cleaned prior to placement of subsequent block courses. No additional courses of precast modular blocks may be stacked before the unit core fill is installed in the blocks on the course below.
5. Nonwoven geotextile fabric shall be placed between the drainage aggregate and the reinforced backfill if required on the retaining wall construction shop drawings. Nonwoven geotextile fabric shall be placed to cover the top of the drainage aggregate prior to the placement of wall backfill or low-permeability fill above. Nonwoven geotextile fabric placed on top of drainage aggregate shall be covered with backfill soil immediately following the placement.
6. Backfill shall be placed in front of the bottom blocks prior to placement of subsequent block courses or as soon as construction allows.
7. Subsequent courses of block units shall be installed with a running bond (half block horizontal course-to-course offset). With the exception of 90 degree corner units, the shear channel of the upper block shall be fully engaged with the shear knobs of the block course below. The upper block course shall be pushed forward to fully engage the interface shear key between the blocks and to ensure consistent face batter and wall alignment. Geogrid, drainage aggregate, unit core fill, geotextile and properly compacted wall backfill shall be complete and in-place for each course of block units before the next course of blocks is stacked.
8. The elevation of retained backfill shall be maintained at the same elevation of the reinforced backfill throughout the construction of the retaining wall.
9. If included as part of the precast modular block wall design, cap units shall be secured with an adhesive in accordance with the precast modular block manufacturer’s recommendation.

D. Geogrid Reinforcement Installation
1. Geogrid reinforcement shall be installed at the locations and elevations shown on the construction shop drawings on level fill compacted to the requirements of this specification.
2. Continuous 12” (300 mm) wide strips of geogrid reinforcement shall be passed completely through the vertical core slot of the precast modular block unit and extended to the embedment length shown on the construction shop drawings. The strips shall be staked or anchored as necessary to maintain a taut condition.
3. Reinforcement length (L) of the geogrid reinforcement is measured from the back of the precast modular block unit. The cut length (Lc) is two times the reinforcement length plus additional length through the block facing unit. The cut length is calculated as follows:
   \[ L_c = 2 \times L + 3 \text{ ft} \quad \text{(2} \times L + 0.9 \text{ m)} \quad 28” \ (710 \text{ mm}) \text{ block unit} \\
   L_c = 2 \times L + 5 \text{ ft} \quad \text{(2} \times L + 1.5 \text{ m)} \quad 41” \ (1030 \text{ mm}) \text{ block unit} \\
4. The geogrid strip shall be continuous throughout its entire length and may not be spliced. The geogrid shall be furnished in nominal, prefabricated roll width of 12” (300 mm) ± ½” (13 mm). No field modification of the geogrid roll width shall be permitted.
5. Neither rubber tire nor track vehicles may operate directly on the geogrid. Construction vehicle traffic in the reinforced zone shall be limited to speeds of less than 5 mph (8 km/hr) once a minimum of 9 inches (230 mm) of compacted fill has been placed over the geogrid reinforcement. Sudden braking and turning of construction vehicles in the reinforced zone shall be avoided.

E. Construction Tolerance. Allowable construction tolerance of the retaining wall shall be as follows:
1. Deviation from the design batter and horizontal alignment, when measured along a 10’ (3 m) straight wall section, shall not exceed 3/4” (19 mm).
2. Deviation from the overall design batter shall not exceed 1/2” (13 mm) per 10’ (3 m) of wall height.
3. The maximum allowable offset (horizontal bulge) of the face in any precast modular block joint shall be 1/2” (13 mm).
4. The base of the precast modular block wall excavation shall be within 2” (50 mm) of the staked elevations, unless otherwise approved by the Inspection Engineer.
5. Differential vertical settlement of the face shall not exceed 1’ (300 mm) along any 200’ (61 m) of wall length.
6. The maximum allowable vertical displacement of the face in any precast modular block joint shall be 1/2” (13 mm).
7. The wall face shall be placed within 2” (50 mm) of the horizontal location staked.

3.05 REINFORCED AND RETAINED BACKFILL PLACEMENT

A. Backfill material placed behind the drainage aggregate shall be compacted as follows:
1. Minimum 98% of the maximum standard Proctor dry density at ± 2% optimum moisture content per ASTM D698,
2. Minimum 95% of the maximum modified Proctor dry density at ± 2% optimum moisture content per ASTM D1557, or
3. Minimum 85% relative density per ASTM D4254.

B. Compactive effort within 3’ (0.9 m) of the back of the precast modular blocks should be accomplished with walk-behind compactors compacted in thinner lifts to achieve the same moisture and density requirements. Heavy equipment should not be operated within 3’ (0.9 m) of the back of the precast modular blocks.

C. Backfill material shall be installed in lifts that do not exceed a compacted thickness of 9” (230 mm).

D. At the end of each work day, the Retaining Wall Installation Contractor shall grade and compact the surface of the last lift of the wall backfill to a 3% ± 1% slope away from the precast modular block wall face.

E. The General Contractor shall direct the Grading Contractor to protect the precast modular block wall structure against surface water runoff at all times through the use of berms, diversion ditches, silt fence, temporary drains and/or any other necessary measures to prevent soil staining of the wall face, scour of the retaining wall foundation or erosion of the reinforced and retained backfill.

3.06 OBSTRUCTIONS IN THE REINFORCED AND RETAINED ZONES

A. The Retaining Wall Installation Contractor shall make all required allowances for obstructions behind and through the wall face in accordance with the approved construction shop drawings.

B. Should unplanned obstructions become apparent for which the approved construction shop drawings do not account, the affected portion of the wall shall not be constructed until the Retaining Wall Design Engineer can appropriately address the required procedures for construction of the wall section in question.

3.07 COMPLETION

A. For walls supporting unpaved areas, a minimum of 6” (150 mm) of compacted, low-permeability fill shall be placed over the wall backfill zone of the precast modular block retaining wall. The adjacent retained soil shall be graded to prevent ponding of water behind the completed retaining wall.

B. The General Contractor shall coordinate the finish grading above and below the walls with the Grading Contractor and the Landscape Contractor. For retaining wall with crest slopes of 5H to 1V or steeper, silt fence shall be installed along the wall crest immediately following construction. The silt fence shall be located 3’ to 4’ (0.9 m to 1.2 m) behind the uppermost precast modular block units. The crest slope above the wall shall be immediately erosion protected and/or seeded to establish vegetation. The General Contractor shall ensure that the seeded slope receives adequate irrigation and erosion protection to support germination and growth.

C. The General Contractor shall coordinate the extension of the temporarily terminated drainage discharge pipes as indicated in Paragraph 3.04.B of this Section to proper discharge or daylight points with the Utility Contractor or Landscape Contractor. The extension of drainage discharge pipes shall be installed at a continuous positive slope to discharge points.

D. The General Contractor shall confirm that the as-built precast modular block wall geometries conform to the requirements of this Section. The General Contractor shall notify the Owner of any deviations.

END OF SECTION 32 32 16