SECTION 32 32 16
PRECAST MODULAR BLOCK RETAINING WALL

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 (PMB) gravity retaining wall with or without geosynthetic reinforcement. It should be noted that precast concrete modular block and PMB are used interchangeably throughout this document and will be referenced as the abbreviation PMB going forward. PMB retaining wall blocks under this section shall be cast utilizing a wet-cast concrete mixture and exhibit a final handling weight in excess of 475 lb (215 kg) per unit.

B. Scope of Work: The work shall consist of furnishing materials, labor, equipment, and supervision for the construction of a (PMB) 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 and Division 31, Division 32 and Division 33 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 for the purposes of site access shall be the responsibility of the General Contractor. Removal of unsuitable soils and replacement with select fill shall be done as directed and approved in writing by the Owner or Owner’s representative and shall be paid under separate pay items.

B. Measurement and Payment.
   1. The unit of measurement for furnishing the PMB 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 any coping or cap units. The final measured quantity shall include supply of all material components and the installation of the PMB retaining wall system.
   2. The final accepted quantities of the PMB retaining wall system will be compensated per the vertical face area as described above. The quantities of the PMB 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:
   1. Precast Modular Block (PMB) Unit – machine placed, wet cast concrete modular block retaining wall facing unit.
   2. Geotextile – a 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 facing 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 fill material.
   4. Drainage Aggregate – clean, crushed stone placed within and immediately behind the PMB units to facilitate drainage and reduce compaction requirements immediately adjacent to and behind the PMB units.
   5. Unit Core Fill – clean, crushed stone placed within the hollow vertical core of a PMB unit. Typically, the same material used for drainage aggregate as defined above.
   6. Foundation Zone – soil zone immediately beneath the leveling pad.
   7. Retained Zone – soil zone immediately behind the drainage aggregate and wall infill for wall sections designed as modular gravity structures.
   8. 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. The reinforced zone exists only for retaining wall sections that utilize geosynthetic soil reinforcement for stability.
   9. Reinforced Fill – structural fill placed within the reinforced zone.
   10. Leveling Pad – hard, flat surface upon which the bottom course of PMBs is placed. The leveling pad may be constructed with crushed stone or cast-in-place concrete. A leveling pad is not a structural footing.
   11. Wall Infill – the fill material placed and compacted between the drainage aggregate and the excavated soil face in retaining wall sections designed as modular gravity structures.

C. Reference Standards
   1. Design
      a. Design Manual for Segmental Retaining Walls, National Concrete Masonry Association, 3rd Edition, 2010.
      b. Precast Modular Block Design Manual Volume I: Gravity Walls, Aster Brands, 2022.
      c. AASHTO LRFD Bridge Design Specifications, 8th and 9th Edition.
      d. Minimum Design Loads for Buildings and Other Structures – ASCE/SEI 7-16.
      e. International Building Code, 2024 Edition.
      f. FHWA-NHI-10-024 Volume I and GEC 11 Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.
      g. FHWA-NHI-10-025 Volume II and GEC 11 Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.
   2. Precast Modular Block Units
      a. ACI 201 – Guide to Durable Concrete
      b. ACI 318 – Building Code Requirements for Structural Concrete
      c. ASTM C33 – Standard Specification for Concrete Aggregates
      d. ASTM C39 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
      e. ASTM C94 – Standard Specification for Ready-Mixed Concrete.
      f. ASTM C136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

g. ASTM C143 – Standard Test Method for Slump of Hydraulic-Cement Concrete.
h. ASTM C150 – Standard Specification for Portland Cement
i. ASTM C231 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
j. ASTM C260 – Standard Specification for Air-Entraining Admixtures for Concrete.
k. ASTM C494 – Standard Specification for Chemical Admixtures for Concrete.
l. ASTM C595 – Standard Specification for Blended Hydraulic Cements.
m. ASTM C618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
n. ASTM C666 – Standard Test Method for Concrete Resistance to Rapid Freezing and Thawing.
o. ASTM C845 – Standard Specification for Expansive Hydraulic Cement.
p. ASTM C920 – Standard Specification for Elastomeric Joint Sealants.
q. ASTM C989 – Standard Specification for Slag Cement for Use in Concrete and Mortars.
r. ASTM C1116 – Standard Specification for Fiber-Reinforced Concrete.
s. ASTM C1157 – Standard Performance Specification for Hydraulic Cement.
t. ASTM C1218 – Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.
u. ASTM C1240 – Standard Specification for Silica Fume Used in Cementitious Mixtures.
v. ASTM C1611 – Standard Test Method for Slump Flow of Self-Consolidating Concrete.
w. ASTM C1776 – Standard Specification for Wet-Cast Precast Modular Retaining Wall Units.
x. ASTM D6638 – Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks).
y. ASTM D6916 – Standard Test Method for Determining Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks).

3. Geosynthetics
   a. AASHTO M 288 – Geotextile Specification for Highway Applications.
   b. ASTM D3786 – Standard Test Method for Bursting Strength of Textile Fabrics Diaphragm Bursting Strength Tester Method.
   c. ASTM D4354 – Standard Practice for Sampling of Geosynthetics for Testing.
   d. ASTM D4355 – Standard Test Method for Deterioration of Geotextiles
   e. ASTM D4491 – Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
   f. ASTM D4533 – Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
   g. ASTM D4595 – Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.
   h. ASTM D4632 – Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
   i. ASTM D4751 – Standard Test Method for Determining Apparent Opening Size of a Geotextile.
   j. ASTM D4759 – Standard Practice for Determining Specification Conformance of Geosynthetics.
   k. ASTM D4833 – Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.
   l. ASTM D4873 – Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
   m. ASTM D5262 – Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics.
   n. ASTM D5321 – Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.

o. ASTM D5818 – Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics.
p. ASTM D6241 – Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.
q. ASTM D6637 – Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method.
r. ASTM D6706 – Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil.
s. ASTM D6992 – Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method.

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.
   c. AASHTO T 267 – Standard Method of Test for Determination of Organic Content in Soils by Loss of Ignition.
   d. ASTM C33 – Standard Specification for Concrete Aggregates.
   e. ASTM D448 – Standard Classification for Sizes of Aggregates for Road and Bridge Construction.
   f. ASTM D698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort. (12,400 ft-lbf/ft^3 (600 kN-m/m^3)).
   g. ASTM D1241 – Standard Specification for Materials for Soil-Aggregate Subbase, Base and Surface Courses.
   h. ASTM D1556 – Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.
   i. ASTM D1557 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)).
   j. ASTM D2487 – Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
   k. ASTM D2488 – Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
   l. ASTM D3080 – Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions.
   m. ASTM D4254 – Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.
   n. ASTM D4318 – Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
   o. ASTM D4767- Test Method for Consolidated-Undrained Triaxial Compression Test for Cohesive Soils.
   p. ASTM D4972 – Standard Test Method for pH of Soils.
   q. ASTM D6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.
   r. ASTM D6938 – Standard Test Method for In-Place Density and Water Content of Soil and Aggregate by Nuclear Methods (Shallow Depth).
   s. ASTM G51 – Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing.
   t. ASTM G57 – Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method.

5. Drainage Pipe

a. ASTM D3034 – Standard Specification for Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
b. ASTM F2648 – Standard Specification for 2 in to 60 in [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 General Contractor, the Retaining Wall Design Engineer (RWDE), the Retaining Wall Installation Contractor (RWIC), the Earthwork/Grading Contractor, and the Qualified 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 RWDE shall be provided the opportunity to explain all aspects of the retaining wall construction drawings.
   b. The RWDE shall communicate the required bearing capacity of the soil below the retaining wall structure and the shear strength of in-situ soils assumed in the retaining wall design to the Inspection Engineer.
   c. The RWDE shall explain the required shear strength of fill soil in the reinforced, retained, and foundation zones of the retaining wall to the Inspection Engineer.
   d. The RWDE shall explain any measures required for coordination of the installation of utilities or other obstructions in the retained fill zones of the retaining wall.
   e. The RWIC shall explain all excavation needs, site access and material staging area requirements to the General Contractor and Earthwork/Grading Contractor.

B. The General Contractor may choose to self-perform any or all the work, and the Earthwork and Grading Contractor may or may not also be the RWIC. Also, the project Civil Engineer or the project Geotechnical Engineer may or may not also be the RWDE.

1.05 SUBMITTALS

A. Product Data. At least 14 days prior to construction, the General Contractor shall submit 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. PMB System brochure.
   2. PMB concrete test results specified in Part 2.01, Paragraph 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. Geosynthetic Soil Reinforcement (if required by the retaining wall design). The contractor shall provide certified manufacturer test reports for the geosynthetic soil reinforcement 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 RWIC, per Part 1.07, Paragraph A of this section.

C. Retaining Wall Design Calculations and Construction Shop Drawings. Prior to construction, the General Contractor shall furnish construction shop drawings and the supporting structural calculations report to the Owner for review and approval. Unless specifically requested by the Owner, the submittal may be in electronic format. 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 RWDE as specified in Part 1.07, Paragraph B of this section.
   3. Certificate of Insurance of the RWDE as specified in Part 1.06, Paragraph B of this section.

1.06 CONSTRUCTION SHOP DRAWING PREPARATION

A. The RWDE shall coordinate 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 RWDE 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 file of the civil site plans listed in (1).
   3. Report of geotechnical investigation and all addenda and supplemental reports.
   4. Recommendations of the project Geotechnical Engineer regarding 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.
   5. Information pertaining to the magnitude, location, and nature of surcharge loadings acting on or near the proposed wall.

B. The RWDE shall provide the Owner with a certificate of professional liability insurance verifying the minimum coverage limits are adequate for the size and scale of the retaining wall design for the project.

C. Design of the PMB 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 RWDE shall note any exceptions to the requirements of this section by listing them at the bottom right corner of the first page of the construction shop drawings.

E. Approval or rejection of the exceptions taken by the Retaining Wall Engineer will be made in writing as directed by the Owner.

F. The RWDE shall determine the appropriate standard(s) to be utilized, and to which the PMB design shall be based upon, except as noted herein. Refer to Part 1.03, Paragraph C, Part 1. Some project Owners may also specify which standard shall be used.

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

H. Soil Shear Parameters. The RWDE 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. If insufficient data exists to develop the retaining wall design, the RWDE shall communicate the specific deficiency of the project information or data to the Owner in writing.

I. Allowable bearing pressure requirements for each retaining wall shall be clearly shown on the construction drawings.

J. Global Stability. Overall (global) stability shall be evaluated in accordance with the principles of limit equilibrium analysis as set forth in the approved standards, as determined by the RWDE, as referenced in Section 1.06, Part F. The minimum recommended factors of safety shall be as follows, or as otherwise selected as appropriate by the RWDE:

Normal Service (static)	1.3 to 1.5*
Seismic	1.1
Rapid Drawdown (if applicable)	1.2

*High uncertainty/variability, wall supporting critical or sensitive facilities: 1.5
Low uncertainty/variability, wall not supporting critical or sensitive facilities: 1.3

K. Seismic Stability. Seismic loading shall be evaluated in accordance with AASHTO Load and Resistance Factor Design (LRFD) methodology or NCMA Allowable Stress Design (ASD) methodology as determined by the RWDE as referenced in Section 1.06, Part F.

1.07 QUALITY ASSURANCE

A. RWIC Qualifications. In order to demonstrate basic competence in the construction of PMB walls, the RWIC shall document compliance with the following:
   1. Experience.
      a. The contractor shall demonstrate competency and experience in constructing retaining walls and provide the Owner with experience documentation as explained in item 2 below.
   2. RWIC 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 PMB system used.
      e. Maximum height of the wall constructed.
      f. Face area of the wall constructed.
   3. In lieu of the requirements set forth in items 1 and 2 above, the RWIC must submit documentation demonstrating competency in PMB retaining wall construction through a training program that is deemed acceptable by the Owner.

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

1. The RWDE shall be licensed to practice in the jurisdiction of the project location.
2. The RWDE 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. The project geotechnical engineer may provide global stability analysis.
3. The RWDE shall affirm in writing 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 paragraph 1.06 and that he or she accepts responsibility as the design engineer of record for the retaining walls constructed on the project.
4. The RWDE shall affirm in writing that he or she has designed a minimum of approximately 3,000 face ft^2 (280 face m^2) of modular block earth retaining walls within the previous five (5) years.
5. In lieu of these specific requirements, the engineer may submit alternate documentation demonstrating competency in PMB retaining wall design.

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, RWDE qualifications and the RWIC qualifications.

B. The Owner's Representative shall retain the services of an Inspection Engineer who is experienced with the construction of PMB retaining wall structures to perform inspection and testing. The cost of inspection shall be the responsibility of the Owner. Inspection shall be continuous throughout the construction of the retaining walls.

C. The Inspection Engineer shall perform the following duties:
1. Inspect the construction of the PMB 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 retained and foundation zones of the retaining wall conforms with Paragraph 3.05 of this section and exhibits the shear strength and bearing capacity parameters specified by the RWDE.
3. Verify that the shear strength of the in-situ soil assumed by the RWDE is appropriate.
4. Inspect and document soil compaction in accordance with these specifications:
    a. Required dry unit weight.
    b. Actual dry unit weight.
    c. Allowable moisture content.
    d. Actual moisture content.
    e. Pass/fail assessment.
    f. Test location – wall station number.
    g. Test elevation.
    h. Distance of test location behind the wall face.
5. Verify that all excavated slopes in the vicinity of the retaining wall are in accordance with the local safety code standards and as directed by the Geotechnical Engineer.
6. Notify the RWIC of any deficiencies in the retaining wall construction and provide the RWIC a reasonable opportunity to correct the deficiency.

7. Notify the General Contractor, Owner and RWDE of any construction deficiencies that have not been corrected in a timely fashion.
8. Document all inspection results.
9. Test compacted density and moisture content of the retained backfill with the following frequency:
    a. At least once every 500 ft^3 (45 m^2) (in plan) per vertical lift, and
    b. At least once per every 18 in (460 mm) of vertical wall construction.

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

E. The RWIC shall inspect the on-site grades and excavations prior to construction and notify the RWDE and General Contractor if on-site conditions differ from the design loading assumptions, elevations, grading, soil conditions, and groundwater elevations depicted in the retaining wall construction shop drawings.

1.09 DELIVERY, STORAGE, AND HANDLING

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

B. The RWIC shall store and handle all materials in accordance with the manufacturer's 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, soil, and physical damage.

D. Precast Modular Blocks
1. PMBs 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. PMBs shall not be stacked more than six (6) units high in the storage area.

E. Drainage Aggregate and Backfill Stockpiles
1. Drainage aggregate or backfill material shall not be stocked on unstable slopes or areas of the project site with buried utilities.
2. Drainage aggregate material shall not be stocked where it may become mixed with or contaminated by poor draining 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 PMB 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 PMB system patent holder/licensor and shall document compliance with the published quality control standards of the proprietary PMB 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 PMB 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 properties as shown in the following table:

Concrete Mix Properties

Freeze Thaw Exposure Class[1]	Minimum 28-Day Compressive Strength[2]	Maximum Water Cement Ratio	Nominal Maximum Aggregate Size	Aggregate Class Designation[3]	Air Content[4]
Moderate	4,000 psi (27.6 MPa)	0.45	1 in (25 mm)	3M	4.5% +/- 1.5%
Severe	4,000 psi (27.6 MPa)	0.45	1 in (25 mm)	3S	6.0% +/- 1.5%
Very Severe	4,500 psi (30.0 MPa)	0.40	1 in (25 mm)	4S	6.0% +/- 1.5%
Maximum Water-Soluble Chloride Ion (Cl^-) Content in Concrete, Percent by Weight of Cement[5,6]					0.15
Maximum Chloride as Cl^- Concentration in Mixing Water, Parts Per Million					1000
Maximum Percentage of Total Cementitious Materials By Weight [7,9] (Very Severe Exposure Class Only):					
Fly Ash or Other Pozzolans Conforming to ASTM C618					25
Slag Conforming to ASTM C989					50
Silica Fume Conforming to ASTM C1240					10
Total of Fly Ash or Other Pozzolans, Slag, and Silica Fume[8]					50
Total of Fly Ash or Other Pozzolans and Silica Fume[8]					35
Alkali-Aggregate Reactivity Mitigation per ACI 201					
Slump (Conventional Concrete) per ASTM C143[10]			5 in +/- 1½ in (125 mm +/- 40 mm)		
Slump Flow (Self-Consolidating Concrete) per ASTM C1611			18 in – 32 in (450 mm – 800 mm)		

[1]Exposure class is as described in ACI 318. "Moderate" describes concrete that is exposed to freezing and thawing cycles and occasional exposure to moisture. "Severe" describes concrete that is exposed to freezing and thawing cycles and in continuous contact with moisture. "Very Severe" describes concrete that is exposed to freezing and thawing cycles and in continuous contact with moisture and exposed to deicing chemicals. Exposure class should be specified by owner/purchaser prior to order placement.

[2]Test method ASTM C39.

[3]Defined in ASTM C33 Table 3 *Limits for Deleterious Substances and Physical Property Requirements of Coarse Aggregates for Concrete*.

[4]Test method ASTM C231.

[5]Test method ASTM C1218 at age between 28 and 42 days.

[6]Where used in high sulfate environments or where alkali-silica reactivity is an issue, water soluble chloride shall be limited to no more than trace amounts (from impurities in concrete-making components, not intended constituents.)

[7]The total cementitious material also includes ASTM C150, C595, C845, C1157 cement. The maximum percentages shall include:

(a) Fly ash or other pozzolans in type IP, blended cement, ASTM C595, or ASTM C1157.

(b) Slag used in the manufacture of an IS blended cement, ASTM C595, or ASTM C1157.

(c) Silica fume, ASTM C1240, present in a blended cement.

[8]Fly ash or other pozzolans and silica fume shall constitute no more than 25% and 10%, respectively, of the total weight of the cementitious materials.

[9]Prescriptive limits shown may be waived for concrete mixes that demonstrate excellent freeze/thaw durability in a detailed and current testing program.

[10]Slump may be increased by a high-range water-reducing admixture.

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 PMB units shall conform to the nominal dimensions listed in the table below and be produced to the dimensional tolerances shown.

Block Type	Dimension	Nominal Value	Tolerance
Retaining Block	Height	9 in (229 mm)	+/- 3/16 in (5 mm)
	Length	46-1/8 in (1172 mm)	+/- 1/2 in (13 mm)
	Width*	24 in (610 mm)	+/- 1/2 in (13 mm)

* Block tolerance measurements shall exclude variable face texture

E. Individual block units shall have a nominal height of 9 in (229 mm).

F. With the exception of corner units and other special application units, the PMB units shall have two (2), oval dome shear knobs that are 10 in (254 mm) in width by 5 in (127 mm) in length and 2 in (51 mm) in height. The shear knobs shall fully index into a continuous trapezoidal shear channel in the bottom of the block course above. The peak interface shear between any two (2) vertically stacked PMB units, with 10 in (254 mm) by 5 in (127 mm) shear knobs without geogrid inclusion, measured in accordance with ASTM D6916 shall exceed 2,900 lb/ft (42.3 kN/m) at a minimum normal load of 500 lb/ft (7.3 kN/m) as well as an ultimate peak interface shear capacity in excess of 4,200 lb/ft (61.3 kN/m). The peak interface shear between any two (2) vertically stacked PMB units, with 10 in (254 mm) by 5 in (127 mm) shear knobs with geogrid inclusion, measured in accordance with ASTM D6916 shall exceed 2,300 lb/ft (33.6 kN/m) at a minimum normal load of 500 lb/ft (7.3 kN/m) as well as an ultimate peak interface shear capacity in excess of 4,000 lb/ft (58.4 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.

G. In certain configurations and/or combinations of blocks, some minor on-site trimming/partial removal of some of the shear knobs may be necessary to allow for proper alignment.

H. The 24 in (610 mm) PMB units are cast with a 13 in (330 mm) wide, continuous vertical core slot completely through the block.

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

J. The PMB units shall be manufactured with integrally cast shear knobs that establish a standard horizontal set-back for subsequent block courses. The PMB system shall be available in the standard horizontal set-back facing batter options listed below:

Horizontal Set-Back/Blk. Course	Max. Facing Batter
13/16 in (21 mm)	5.2˚

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

K. The PMB unit face texture shall be selected by the Owner from the available range of textures available from the PMB manufacturer. Each textured block facing unit shall be a minimum of 2.88 ft^2 (0.27 m^2) with a unique texture pattern that repeats with a maximum frequency of once in any 9 ft^2 (0.84 m^2) of wall face.

L. The block color shall be selected by the Owner from the available range of colors available from the PMB manufacturer. Concrete blocks can also be stained after installation based upon Owner's selection of concrete stain colors.

M. All PMB units shall be sound and free of cracks or other defects that would interfere with the proper installation of the unit, and/or 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 in (38 mm) in its largest dimension and cracks not wider than 0.012 in (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 in (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 Novum Wall ® Retaining Wall Systems as licensed by Redi-Rock International, LLC, 3890 Charlevoix Avenue, Suite 310, Petoskey, MI 49770 USA; telephone (866) 222-8400; website: www.redi-rock.com.

O. Substitutions. Technical information demonstrating conformance with the requirements of this specification for an alternative PMB 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 outside of the time requirements of this section or to submissions of block retaining wall systems that are determined to be unacceptable to the Owner.

P. Value Engineering Alternatives. The Owner may evaluate and accept systems that meet the requirements of this specification after the bid date that provide a minimum cost savings of 20% to the Owner. Construction expediency will not be considered as a contributing portion of the cost savings total.

2.02 GEOGRID REINFORCEMENT

A. Geogrid reinforcement shall be a woven or knitted PVC coated geogrid manufactured from high-tenacity PET polyester fiber with an average molecular weight greater than 25,000 (M_n > 25,0000) and a carboxyl end group less than 30 (CEG < 30). The geogrid shall be furnished in prefabricated roll widths of certified tensile strength by the manufacturer.

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

C. Geogrid – Soil Reinforcement Interaction Performance
1. Coefficient of Interaction for Pullout, C_i, shall equal 0.8
2. Coefficient of Direct Sliding, C_{ds}, shall equal 0.8.

D. Long-Term Design Strength ($LTDS_l$) of the geogrid reinforcement shall be calculated in accordance with Section 2.5.2.21 of NCMA Design Manual for Segmental Retaining Walls, 3rd Edition, 5th Printing and as provided in this specification.
   1. The creep reduction factor (RF_{CR}) shall be determined per Table 5-4 in the AASHTO NTPEP Report REGO-2016-01-063 for a minimum 75 year design life.
   2. Minimum installation damage reduction factor (RF_{ID}) shall be 1.05. The value of 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.
   3. Minimum durability reduction factor (RF_D) shall be 1.10 for a soil pH range of 3 to 9.

E. Connection between the PMB retaining wall unit and the geogrid reinforcement shall be determined from short-term testing per the requirements of ASTM D6638.

F. The minimum value of T_{al} 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 shall be the greater of the following:
   1. 0.6 times the wall design height, H.
   2. 4 feet (1.2 m).
   3. The length required by design to meet internal and external stability requirements, soil bearing pressure requirements and constructability requirements.

H. Constructability Requirements. Geogrid design embedment length shall be measured from the form line of the precast modular block facing unit.

I. Geogrid shall be placed in between precast modular block units to create a friction connection. Design coverage ratio, Rc, shall equal 1.0 for 100% geogrid reinforcement coverage on any specific geogrid reinforcement layer.

J. Preapproved Geogrid Reinforcement Products.
   1. Miragrid XT Geogrids as manufactured by Solmax.

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. Additionally, it is recommended the nonwoven geotextile fabric be placed in the v-shaped joint between adjacent block units on the same course. The nonwoven geotextile fabric shall meet the requirements Class 3 construction survivability in accordance with AASHTO M 288.

B. Preapproved Nonwoven Geotextile Products
   1. Mirafi 140N.
   2. Propex Geotex 451.
   3. Skaps GT-142.
   4. Thrace-Linq 140EX.
   5. Carthage Mills FX-40HS.
   6. Stratatex ST 142.

2.04 DRAINAGE AGGREGATE AND WALL INFILL

A. Drainage aggregate (and wall infill for retaining walls designed as modular gravity structures) shall be a durable crushed stone conforming to No. 57 size per ASTM C33 with the following particle-size distribution requirements per ASTM D6913:

U.S. Standard Sieve Size	% Passing
1-½ in (38 mm)	100
1 in (25 mm)	95-100
½ in (13 mm)	25-60
No. 4 (4.76 mm)	0-10
No. 8 (2.38 mm)	0-5

2.05 LEVELING PAD

A. The PMB 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 drawings prepared by the RWDE.

B. Crushed stone used for construction of a granular leveling pad shall meet the requirements of the drainage aggregate and wall infill in Section 2.03 or a preapproved alternate material.

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

2.06 DRAINAGE

A. Drainage Pipe
   1. Drainage collection pipe shall be a 4 in (100 mm) diameter, 3-hole perforated, HDPE pipe with a minimum pipe stiffness of 22 psi (152 kPa) per ASTM D2412.
   2. The drainage pipe shall be manufactured in accordance with ASTM D1248 for HDPE pipe and fittings.

B. Preapproved Drainage Pipe Products
   1. ADS 3000 Triple Wall pipe as manufactured by Advanced Drainage Systems.

PART 3 – EXECUTION

3.01 GENERAL

A. All work shall be performed in accordance with OSHA, State, and local 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% maximum dry density per ASTM D698 standard proctor.

D. The General Contractor is responsible for ensuring 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, RWIC 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 retained backfill material placed within a horizontal distance of one (1.0) times the wall height behind the wall blocks satisfies the criteria of this section.
   2. The Inspection Engineer shall verify that any fill soil installed in the foundation and retained soil zones of the retaining wall satisfies the specification of the RWDE as shown on the construction drawings.

B. Excavation.
   1. The Grading Contractor shall excavate to the lines and grades required for construction of the PMB retaining wall as shown on the construction 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 RWDE and “Division 31, Section 31 20 00 – Earthmoving” of the project specifications.
   3. Embankment excavations shall be bench cut as directed by the project Geotechnical Engineer and inspected by the Inspection Engineer for compliance.

C. Foundation Preparation.
   1. Prior to construction of the PMB retaining wall, the leveling pad area 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 ensure that the undercut limits are consistent with the requirements of the project Geotechnical Engineer and that all soil fill material is properly compacted in accordance with project specifications. The Inspection Engineer shall document the volume of undercut and replacement, if required.

2. Following excavation for the leveling pad and undercut zone (if applicable), the Inspection Engineer shall evaluate the in-situ soil in the foundation and retained soil zones.
    a. The Inspection Engineer shall verify that the shear strength of the in-situ soil assumed by the RWDE is appropriate. The Inspection Engineer shall immediately stop work and notify the Owner if the in-situ shear strength is found to be inconsistent with 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 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 PMB units. The leveling pad shall be placed in the dimensions shown on the retaining wall construction drawings and extend to the limits indicated.
2. Crushed Stone Leveling Pad. Crushed stone shall be placed in uniform maximum lifts of 6 in (150 mm). The crushed stone shall be compacted by a minimum of 3 passes of a vibratory compactor capable of exerting 2,000 lb (8.9 kN) of centrifugal force and to the satisfaction of the Inspection Engineer.
3. Unreinforced Concrete Leveling Pad. The concrete shall be placed in the same dimensions as those required for the crushed stone leveling pad. The RWIC shall erect proper forms as required to ensure the accurate placement of the concrete leveling pad according to the retaining wall construction drawings.

3.04 PRECAST MODULAR BLOCK WALL SYSTEM INSTALLATION

A. The PMB structure shall be constructed in accordance with the construction 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.
1. Pipe, geotextile, and drainage aggregate shall be installed as shown on the construction shop drawings.

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 drawings. The RWIC 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 drawings.
2. Backfill shall be placed in front of the bottom course of blocks prior to placement of subsequent block courses. The recommended nonwoven geotextile fabric shall be placed in the V-shaped joints between adjacent blocks. Drainage aggregate shall be placed in the V-shaped joints between adjacent blocks and extend to a minimum distance of 12 in (300 mm) behind the block unit.
3. Drainage aggregate shall be placed in 9 in maximum lifts (as specified by the RWDE) 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, or by other suitable compaction methods.

4. Unit core fill shall be placed in the PMB unit vertical core slot. The 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 swept-cleaned prior to placement of subsequent block courses. No additional courses of PMBs 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 retained soil (gravity wall design) or between the drainage aggregate and the reinforced fill (reinforced wall design) as required on the retaining wall construction drawings.
6. Subsequent courses of block units shall be installed with a running bond (approximate half block horizontal course-to-course offset). With the exception of specialty blocks, 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 knob between the blocks and to ensure consistent face batter and wall alignment. For reinforced walls, the geogrid reinforcement will be placed over the shear knobs, so full engagement may not be possible and the upper block course shall be pushed as far forward as possible without deteriorating the geogrid. Geogrid, drainage aggregate, unit core fill, geotextile and properly compacted backfill shall be complete and in-place for each course of block units before the next course of blocks is stacked.
7. The elevation of retained soil fill shall not be less than 2 block courses (18 in (457 mm)) below the elevation of the retained backfill throughout the construction of the retaining wall.
8. If included as part of the PMB wall design, cap units shall be secured with an appropriate construction adhesive.
9. Geogrid reinforcement (if required by the retaining wall design) shall be installed at the locations and elevations shown on the construction drawings on level fill compacted to the requirements of this specification.
10. Continuous geogrid reinforcement shall be installed with the strength direction (roll or machine direction) perpendicular to the wall face between the precast modular block units and extended to the embedment length shown on the construction plans. The geogrid shall be staked or anchored as necessary to maintain a taut condition.
11. Reinforcement length (L) of the geogrid reinforcement is measured from the form line of the precast modular block unit.
12. The geogrid reinforcement shall be continuous throughout its entire length and may not be spliced.
13. Backfill on top of the geogrid from back of the PMB to the back of the reinforced soil zone to maintain a taut condition upon completion of geogrid installation.
14. 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.

D. Construction Tolerance. Allowable construction tolerance of the retaining wall shall be as follows:
1. Deviation from the horizontal alignment of the wall face shall not exceed a 1/200 ratio when measured along straight wall section and shall not exceed 2 in (50 mm) from staked location.
2. The maximum allowable offset (horizontal bulge) of the face in any precast modular block joint shall be 1/2 in (13 mm).
3. The base of the precast modular block wall excavation shall be within 2 in (50 mm) of the staked elevations, unless otherwise approved by the Inspection Engineer.
4. Differential vertical settlement of the face shall not exceed a 1/100 ratio of wall length and shall not exceed 3 in (75 mm).

5. The maximum allowable vertical displacement of the face in any precast modular block joint shall be 1/2 in (13 mm).
6. Deviation from the overall design batter shall not exceed 1° from vertical.
7. Refer to local project requirements for additional allowable construction tolerances.

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3.05 WALL INFILL AND BACKFILL PLACEMENT

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

B. Compaction within 3 ft (0.9 m) of the back of the PMBs should be accomplished with walk-behind compactors. Compaction in this zone shall be within 95% of maximum dry density as measured in accordance with ASTM D1557 modified proctor or 80% relative density per ASTM D 4254. Heavy equipment should not be operated within 3 ft (0.9 m) of the back of the PMBs.

C. Backfill material shall be installed in lifts that do not exceed a thickness of 9 in (230 mm), as specified by RWDE.

D. At the end of each workday, the RWIC shall grade the surface of the last lift of the granular wall infill to a 3% ± 1% slope away from the PMB wall face and compact it.

E. The General Contractor shall direct the Grading Contractor to protect the PMB 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 backfill or wall infill.

3.06 OBSTRUCTIONS IN THE INFILL ZONE

A. The RWIC 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 RWDE 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 12 in (300 mm) of compacted, low-permeability fill shall be placed over the granular wall infill zone of the PMB retaining wall structure. The adjacent retained soil shall be graded to prevent ponding of water behind the completed retaining wall.

B. For retaining walls with crest slopes of 5H:1V or steeper, appropriate soil erosion/sedimentation control measures shall be installed along the wall crest immediately following construction and grading of the crest slope. The crest slope above the wall shall be immediately seeded and protected 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 confirm that the as-built PMB 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