UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2015
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DIVISION 32 - EXTERIOR IMPROVEMENTS

SECTION 32 32 23

SEGMENTAL CONCRETE BLOCK RETAINING WALL

04/08

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USACE / NAVFAC / AFCEC / NASA | **UFGS-32 32 23 (April 2008) Change 1 - 08/14**

Preparing Activity: USACE | **Superseding UFGS-32 32 23 (October 2007)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION 32 32 23

SEGMENTAL CONCRETE BLOCK RETAINING WALL
04/08

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NOTE: This guide specification covers the requirements for segmental concrete block retaining walls, using geosynthetic soil reinforcement. This section was originally developed for USACE Civil Works projects.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

PART 1 GENERAL

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NOTE: The following is guidance in selecting the proposed tailoring options:

(1) Contractor Design. Many suppliers have designers that specialize in design of SRW's. Allowing the Contractor to design the system provides the most competitive bidding process. The Contractor has the capacity to select materials for the most efficient design. This is the most favorable design method for typical applications.

(2) Government Design. Non-typical applications

may be best designed before solicitation. Such projects would include applications where the design conditions are beyond the capabilities of commercial software available from SRW suppliers, or applications where the Contractor could not be expected to bid without performing stability calculations during the bidding process. Examples may include bin walls, or structures with unusual loading applications, such as coastal structures, blast resistant structures, or structures in seismic zone 4.

(3) Hybrid Design. Much of the civil works Corps of Engineers projects involve conditions where the global stability requires analysis, but the internal, external and compound stability are routine. Such conditions are common on water front structures. Contractor analysis of global stability is not biddable since the analysis may indicate structure definition that could not be assumed during bid. While this could be handled though a modification to the contract, there is a risk that it will be overlooked. Also, experience has shown that it is difficult to specify the degree of work involved in the design analysis (the reason architect-engineer services are negotiated in accordance with the Federal Acquisition Regulation, Part 36). The hybrid design incorporates the advantages of the Contractor designed wall for internal, external and compound stability, while eliminating the conflict of interest in requiring Contractor design of global stability. Changes made to the wall during preparation of shop drawings, such as free standing height, footing embedment, or location could affect the global stability. If the hybrid design method is used, the submittal process should assure that the wall designer reviews the shop drawing submittals, regardless of a Contractor design check for global stability.

NOTE: This section does not address requirements for dewatering, shoring, or earthwork below foundation level.

Geometric requirements such as wall height, length, and construction limits should be shown on the drawings.

Notes before paragraphs are provided to present assumptions in preparation of the guide specification, make suggestions for conditions that warrant revisions, and provide background technical information or references for further information. They should be consulted prior to revising wording for project specifications.

****

1.1 MEASUREMENT AND PAYMENT

Measurement of segmental retaining wall for payment will be made on the

basis of the face area in the vertical plane of segmental concrete units. The pay lines of the structure will be neat lines taken off the approved shop drawings; and will extend from the block-leveling pad interface to the top of wall, excluding any fencing or barrier. Payment will be made at the respective unit price per square meter (SM) foot (SF) listed on the Bidding Schedule. Payment will be full compensation for engineering services, excavation and preparatory work, and furnishing all material, labor and equipment to complete the work.

1.2 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 252	(2009) Standard Specification for Corrugated Polyethylene Drainage Pipe
AASHTO M 288	(2006; R 2011) Standard Specification for Geotextile Specification for Highway Applications

ASTM INTERNATIONAL (ASTM)

ASTM C1262	(2010) Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units
ASTM C136	(2006) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C1372	(2014) Standard Specification for Dry-Cast Segmental Retaining Wall Units

ASTM C140/C140M	(2014a) Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C920	(2014a) Standard Specification for Elastomeric Joint Sealants
ASTM C94/C94M	(2014b) Standard Specification for Ready-Mixed Concrete
ASTM D1241	(2007) Materials for Soil-Aggregate Subbase, Base, and Surface Courses
ASTM D1556	(2007) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D2487	(2011) Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D2488	(2009a) Description and Identification of Soils (Visual-Manual Procedure)
ASTM D4355/D4355M	(2014) Deterioration of Geotextiles from Exposure to Light, Moisture and Heat in a Xenon-Arc Type Apparatus
ASTM D448	(2012) Sizes of Aggregate for Road and Bridge Construction
ASTM D4491	(1999a; R 2014; E 2014) Water Permeability of Geotextiles by Permittivity
ASTM D4595	(2011) Tensile Properties of Geotextiles by the Wide-Width Strip Method
ASTM D4632/D4632M	(2008; R 2013; E 2013; E 2014) Grab Breaking Load and Elongation of Geotextiles
ASTM D4751	(2012) Determining Apparent Opening Size of a Geotextile
ASTM D4873	(2002; R 2009) Identification, Storage, and Handling of Geosynthetic Rolls and Samples
ASTM D5321/D5321M	(2014) Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
ASTM D6638	(2011) Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
ASTM D6706	(2001; R 2013) Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil

ASTM D6938	(2010) Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D698	(2012; E 2014) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.))

GEOSYNTHETIC INSTITUTE (GSI)

GSI GRI GG6	(1996) Grip Types for Use in Wide Width Testing of Geotextiles and Geogrids

NATIONAL CONCRETE MASONRY ASSOCIATION (NCMA)

NCMA TR127B	(2010) Design Manual for Segmental Retaining Walls

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

FHWA NHI-00-043	(2000) Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines (ISDDC)

1.3 DEFINITIONS

****
NOTE: This guide specification only applies to geosynthetic (extensible) reinforcement. There are differences in design and construction applicable to steel soil (inextensible) reinforcement.
****

1.3.1 Blocks

Segmental concrete retaining wall units will be referred to as blocks.

1.3.2 Drainage Aggregate

Granular soil or aggregate which is placed within, between, and/or immediately behind segmental concrete units.

1.3.3 Fill

Soil or aggregate placed in, behind, or below the wall will be referred to as fill.

1.3.4 Reinforced Fill

Soil which is placed and compacted within the neat line volume of reinforcement as outlined on the plans.

1.3.5 Retained Fill

Soil which is placed and compacted behind the reinforced fill.

1.3.6 Reinforcement

Reinforcement shall consist of a geogrid or a geotextile product manufactured for use as reinforcing. Reinforcement shall not include steel products.

1.3.7 Long Term Design Strength

The long term design strength (LTDS) is:

$$LTDS = T_{ult} / (RF_D * RF_{ID} * RF_{CR})$$

where:

T_{ult} is the ultimate strength
RF_D is the reduction factor for chemical and biological durability
RF_{ID} is the reduction factor for installation damage
RF_{CR} is the reduction factor for creep

1.4 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

An "S" following a submittal item indicates that the submittal is required for the Sustainability Notebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Shop Drawings; G[, [_____]]

SD-03 Product Data

Components and Equipment
Supplier Qualifications
Manufacturer's Representative
Soil Testing; G[, [_____]]
Reinforcement Testing; G[, [_____]]
Calculations; G[, [_____]]

SD-04 Samples

Segmental Concrete Units; G[, [_____]]
Reinforcement; G[, [_____]]

SD-07 Certificates

Reinforcement

1.5 QUALITY ASSURANCE

1.5.1 Contractor Qualifications

****

NOTE: The qualifications should be modified for the project's degree of difficulty. Enforceable project requirements are limited to the number of completed projects, or years experience.

****

Furnish Components and equipment that are standard products of a manufacturer regularly engaged in the manufacturing of products that are of a similar material, design and workmanship. Submit descriptive technical data on the blocks, wall caps, masonry adhesive, reinforcement, geotextile filter materials and equipment to be used. The submittal shall include all material properties specified under PART 2 PRODUCTS. The submittal shall also include a copy of any standard manufacturer's warranties for the products. The standard products shall have been in satisfactory commercial or industrial use for 2 years before award of this contract. The job foreman or the company directly responsible for the wall installation shall have [completed a minimum of 10 segmental concrete retaining wall projects] [at least 2 years experience].

1.5.2 Supplier Qualifications

****

NOTE: The suggested text is recognized to be somewhat vague. It limits situations were a never-before-used product is proposed, or where a product is proposed for use outside the limitations (such as batter) listed in the manufacturer's literature. The qualifications should be modified for the project's degree of difficulty (e.g. walls over 10 m height). Caution to avoid unreasonable qualifications should be exercised if modifying.

****

Submit documentation showing that the installer and supplier meet the qualifications listed. [Suppliers of segmental retaining wall system components shall have demonstrated experience in the supply of similar size and types of segmental retaining walls on previous projects.]

1.5.3 Manufacturer's Representative

****

NOTE: The geosynthetic manufacturers representatives generally have assumed involvement in construction; but that is not necessarily true in all localities. The number of site visits expected by the manufacturer's representative should be quantified if known.

****

Provide a qualified and experienced representative from the block or reinforcement manufacturer available on an as-needed basis during the wall construction. The representative shall visit the site for consultation [at least once during construction] [as requested by the Contracting Officer].

1.6 DELIVERY, STORAGE, AND HANDLING

Check products upon delivery to assure that the proper material has been received and is undamaged. For geosynthetics, the guidelines presented in ASTM D4873 shall be followed.

1.6.1 Segmental Concrete Units and Wall Caps

Protect blocks from damage and exposure to cement, paint, excessive mud, and like materials. Check materials upon delivery to assure that the block dimensions are within the tolerances specified.

1.6.2 Geosynthetic Labeling

Each roll shall be labeled with the manufacturer's name, product identification, roll dimensions, lot number, and date manufactured.

1.6.3 Geosynthetic Handling

Geosynthetic rolls shall be handled and unloaded by hand, or with load carrying straps, a fork lift with a stinger bar, or an axial bar assembly. Geosynthetic rolls shall not be dragged, lifted by one end, lifted by cables or chains, or dropped to the ground.

1.6.4 Geosynthetic Storage

Protect geosynthetics from cement, paint, excessive mud, chemicals, sparks

and flames, temperatures in excess of 70 degrees C 160 degrees F, and any other environmental condition that may degrade the physical properties. If stored outdoors, the rolls shall be elevated from the ground surface. Geosynthetics, except for extruded grids, shall be protected with an opaque waterproof cover. Geosynthetics shall be delivered to the site in a dry and undamaged condition. Geotextiles shall not be exposed to direct sunlight for more than 7 days.

PART 2 PRODUCTS

2.1 SYSTEM REQUIREMENTS

This work element includes engineering services in addition to the construction requirements. The Contractor is responsible for engineering services that include design of the wall in accordance with the National Concrete Masonry Association design method, and providing shop drawings indicating all features of the complete design. This work element includes engineering in addition to the construction requirements. The NCMA design method for segmental retaining walls considers potential failure modes categorized by external, internal, local, compound, and global stability. The Government has considered the global stability and has provided the minimum design requirements on the drawings. The Contractor is responsible for engineering services that include analysis of the wall for all modes of stability, and providing shop drawings indicating all features of the complete design.

2.1.1 Design Requirements

****

NOTE: The NCMA and FHWA design methods are nearly identical. They differ primarily in the treatment of the vertical component of active earth pressure and the connection strength. The current (1998) FHWA design results in a conservative connection strength that only a small number of products meet. The FHWA design method is less commonly used, except in transportation related projects. The FHWA design method may be required for works within highway right-of-way.

****

Complete all stability analyses in accordance with either the NCMA TR127B, or the Federal Highway Administration/AASHTO method detailed in FHWA NHI-00-043. Only one method shall be followed for the complete design, including reinforcement design strength, layout, stability calculations, and seismic effects. The segmental retaining wall system shall be designed under the direction of, and be signed by, a professional engineer.[The engineer shall visit the job at least once during the construction.]

2.1.2 Design Parameters

****

NOTE: The soil properties listed are given for the purpose of establishing a common basis for bidding. Verify that the contract documents provide sufficient information for interpretation of soil conditions below the wall, behind the wall, and at Government furnished borrow locations. Listing soil

properties in the specification is optional. An alternative is to provide testing results.

The soil properties listed commonly have a significant influence on the reinforcement design, but are not all inclusive. The parameters suggested as defaults are limited to those commonly included in standard design tables, since that will probably be representative of a Contractors analysis during bidding. More control over the product can be obtained by specifying soil properties for retained fill, soil properties for foundation soils, and changes in water levels through the retained fill, reinforced fill, and drains. Indicate surcharge loads (live or dead) and location on drawings.

Government selected soil properties will give more control in procuring a prudent design for competitively bid projects. The Government usually has access to all the geologic information that will be available to the Contractor during construction, and often has invested more time in consideration of the data than the Contractor can afford during the bidding process. However, there is a disadvantage to listing the soil properties if the Contractor has the option to change conditions and void the assumptions. The soil properties should not be listed if the borrow source is uncertain.

****

Calculations shall include determination of long term design strength of reinforcement specific to this project in accordance with the NCMA TR127B or FHWA NHI-00-043. Submit calculations of the long term design strength for the reinforcement in accordance with the NCMA or FHWA design method. The ultimate strength or index strength shall be based on the minimum average roll value tensile strength of the product using the wide width strength test in ASTM D4595. Submit Design calculations, including computer output data and program documentation. The calculations shall include all items described under PARAGRAPH: SEGMENTAL RETAINING WALL DESIGN. The calculation shall itemize each reduction factor and include backup data to justify each reduction factor. Calculations shall include analysis of all failure modes listed in the NCMA TR127B. Design calculations shall include a clear outline of material properties and assumptions.[Use the following soil parameters and water elevation for stability analysis, and select additional soil parameters as required to complete the analysis.]

Moist Unit Weight of reinforced fill	[_____] kN/m^3 pcf
Saturated Unit Weight of reinforced fill	[_____] kN/m^3 pcf
Internal Friction Angle of reinforced fill	[30][_____] degrees
Cohesion of reinforced fill	[0][_____] kPa psf

Water Elevation in reinforced fill	[_____] meters feet

2.1.2.1 External Stability Design Requirements

****

NOTE: The minimum base width is an empirical constraint. The minimum base width of 0.7H is the same as FHWA requirements, but slightly exceeding the NCMA requirement of 0.6H.

****

As a minimum requirement, the length of the reinforcing at the base of the wall shall not be less than 0.7 times the total height of the blocks.

[2.1.2.2 Seismic Design Requirements

****

NOTE: The pseudo static analysis method is only applicable up to A < 0.4 in the NCMA manual, and up to A < 0.29 in the FHWA method. The wall should be Government designed if A exceeds the recommendations of the design method, or if a dynamic analysis is considered necessary. The NCMA Seismic Design Manual references AASHTO and the Canadian Foundation Engineering Manual for sources of the A value. ER 1110-2-1806 (31 July 1995) also contains similar data obtained from the National Earthquake Hazard Reduction Program (NEHRP).

****

Complete the seismic stability analysis in accordance with NCMA TR127B or FHWA NHI-00-043. The pseudo-acceleration value with a 10 percent probability of exceedance in 50 years (referred to as the A value by NCMA and FHWA) shall be assumed as [_____].

]2.1.2.3 Global Stability Design Requirements

The long term design strength of the lowest [_____] reinforcement layer[s] shall equal or exceed the requirements listed in Table 1. Reinforcement lengths shall be no less than the lengths shown on the drawings.

2.1.3 Layout

Shop drawings shall reflect all information needed to fabricate and erect the walls including the leveling pad elevations; the shape and dimensions of wall elements; the number, size, type, and details of the soil reinforcing system and anchorage; and identification of areas requiring coping. Submit Fabrication and installation drawings. Include with the shop drawings all items described under paragraph SEGMENTAL RETAINING WALL DESIGN.If approved by the Contracting Officer, shop drawings may consist of marked up contract drawings showing exact dimensions for the blocks supplied, required coping, and other minor revisions. The design and layout of the internal reinforcement shall be subject to the following:

a. All features indicated in the contract documents shall be incorporated in the final design and construction.

b. The leveling pad elevations may vary, but shall be no higher than the embedment depth profile shown.

c. Each reinforcement level shall run as continuous as practical throughout the profile. If a geotextile filter is present, the reinforcement shall be laid out so that interference with the geotextile is minimized.

d. Any reinforcement not placed with the machine direction as the design reinforcement direction shall be identified on the shop drawings.

e. Reinforcement attached to the wall facing shall not combine geogrid and geotextile, nor products from different manufacturers, within one wall. The number of reinforcement products shall be limited to avoid confusion in placement. For walls under 3.5 meters 12 feet high, all reinforcement shall be the same grade and strength (i.e. design with one reinforcement strength).

2.2 SEGMENTAL CONCRETE UNITS

Submit two samples of each proposed block. Each sample shall be typical of the size, texture, color, and finish.

2.2.1 Architectural requirements

2.2.1.1 Face color

****
NOTES: The block color or tint can sometimes change noticeably between production runs. If the block color is inconsistent, the wall may show an irregular visible line or pattern where blocks from different production runs merge. If this is important to the architect, it can be specified that all blocks within a wall must come from the same production run. Normally, this is an unnecessary restriction.
****

[Tan/Grey/Brown/Natural Limestone][_____]

2.2.1.2 Face Texture

[split face typical of broken mortar/brick face][_____]

2.2.1.3 Face Appearance

****
NOTE: Use of blocks with a sculptured face (uneven, beveled, or rounded) usually requires maintaining a half-bond (stacking the vertical joint at the midpoint of the underlying block) for architectural reasons.
****

[Straight, single-surface face/sculptured with 3-surface beveled face/rounded, smooth-curved face][_____]

2.2.1.4 Batter

****

NOTE: Wall batter on curves changes the wall (arc) length between courses. Straight face blocks may be laid without maintaining half-bond and are better suited for curved walls. Steep wall batter reduces interference due to unconstant arc length on curves.

The NCMA design manual is only applicable to wall batter between 0 and 15 degrees (about 1H:4V).

****

Engagae blocks to the block below by use of keys, lips, pins, clips, or other reliable mechanism to provide a consistent wall batter [between 1H:6V and 1H:16V][_____].

2.2.1.5 Block Size

A minimum of 0.06 square meters 2/3 square feet of face area, and minimum 150 mm 6 inch height

2.2.1.6 Bond Configuration

No bond configuration is required for straight face blocks. Design beveled or sculptured face blocks to stack with a half-bond (joints located at midpoint of vertically adjacent blocks). Finish the block edges so that vertical joints are flush.

2.2.2 Structural requirements

****

NOTES: Durability - AASHTO has proposed specifications for blocks that include: minimum compressive strength = 28 MPa (4000 psi) and absorption not exceeding 5 percent (Ref. 1997 Interim Revisions to the Standard Specifications for Highway Bridges). Additional options to increase resistance to chloride attack along roads includes a sloped cap block, surface sealing the completed wall, and higher compressive strength.

Freeze-thaw Testing - The first choice is the default requirement in ASTM C1372, but is not required by the ASTM test (1997) unless testing is required by the specifier. The second choice for 3 percent saline solution is used by the Minnesota Department of Transportation. The specifier should edit this based on the project's location since other states may have different requirements.

The block weight per unit face area is listed as an index statistic to limit pore area and face thickness. Blocks with thin faces and large pore spaces can be damaged by traffic or debris hitting the wall and are less durable. The face thickness and/or pore area can be specified, but the weight per face area is more readily available.

****

The blocks must be manufactured to the requirements of ASTM C1372 or ASTM C94/C94M, except for the following modifications:

a. Minimum 28-day compressive strength of 31 MPa 4000 psi, based on net area in accordance with ASTM C140/C140M.

b. A maximum moisture absorption rate of 145 kg/m^3 9 pcf, in accordance with ASTM C140/C140M.

c. The minimum oven dry density of concrete shall be 2000 kg/m^3 125 pcf.

d. The blocks shall provide a minimum of 400 kg/square meter 80 psf of wall face area (determined without void filling).

e. For freeze-thaw durability tested in accordance with ASTM C1262, specimens shall comply with either of the following: (1) the weight loss of each of 5 specimens after 100 cycles shall not exceed 1 percent; or (2) the weight loss of each of 5 specimens after 150 cycles shall not exceed 1.5 percent. [when tested in a 3 percent saline solution: (1) the weight loss of each of 5 specimens after 40 cycles shall not exceed 1 percent; or (2) the weight loss of 4 out of 5 specimens after 50 cycles shall not exceed 1.5 percent.]

f. The shear strength between blocks determined in accordance with NCMA TR127B shall have shear strength meeting the following minimum requirements:

Minimum Peak Shear Capacity = [_____] kN/m lbs/ft
Friction Angle for Peak Shear Capacity = [_____] degrees
[Minimum Service State Shear Capacity = [_____] kN/m lbs/ft
Friction Angle for Service State Shear Capacity = [_____] degrees]

2.2.3 Wall Caps

Segmental concrete block units shall be placed as caps on top of all segmental concrete retaining walls. The cap blocks shall have a color and texture on exposed faces to match that of the other blocks and meet the requirements for the other blocks except that the minimum height shall be 75 mm 3 inches. Each cap block shall have abutting edges saw cut or formed to provide tight, flush abutting joints with no gaps in the joints when placed end to end in the alignment shown on the drawings.

2.3 REINFORCEMENT

****

NOTE: Polyester is susceptible to hydrolysis in alkaline conditions. A high molecular weight and low carboxyl end group number limit the hydrolysis. Normally, a mill certificate or certification of these properties is adequate. The molecular weight of polyester geosynthetics is determined from GSI GRI GG6, "Determination of the Number Average Molecular Weight of Polyethylene Terephthalate (PET) yarns Based on a Relative Viscosity Value", and ASTM D4603, "Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer." The carboxyl end group number is determined from GSI GRI GG7, "Carboxyl End

Group Content of Polyethylene Terephthalate (PET) Yarns."

****

2.3.1 Geogrid Reinforcement

****

NOTE: The geogrid sample is intended to be for visual demonstration prior to product delivery. Quality assurance testing, if performed, should be obtained from material actually delivered to the job. If testing is to be performed for pre qualification, the minimum sample size should be 1 meter (36 inches) in length and the full roll width. Although 1 square meter (yard) will provide enough material for testing, the full roll width should be sampled since it provides a better selection of specimen locations, it clearly shows the machine and cross directions, and the difference in waste and shipping costs is negligible.

****

Geogrid shall be a geosynthetic manufactured for reinforcement applications. The geogrid shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil, aggregate, or other fill materials. The geogrid structure shall be dimensionally stable and able to retain its geometry under manufacture, transport and installation. The geogrid shall be manufactured with 100 percent virgin resin consisting of polyethylene, polypropylene, or polyester, and with a maximum of 5 percent in-plant regrind material. Polyester resin shall have a minimum molecular weight of 25,000 and a carboxyl end group number less than 30. Polyethylene and polypropylene shall be stabilized with long term antioxidants.

2.3.2 Geotextile Reinforcement

****

NOTE: Survivability - The AASHTO M 288 requirements are minimum requirements and will not normally control in the product selection. The AASHTO reference can be avoided by listing the grab, tear, burst, and puncture strengths. These properties are listed in AASHTO M 288. The puncture strength (ASTM D4833/D4833M), the trapezoidal tear strength (ASTM D4533) and the mullen burst strength (ASTM D3786) are recognized as important geotextile properties. For the intended application, the commonly specified values for puncture, burst and tear seldom control the product selection.

****

Geotextile shall be a pervious sheet of polymeric material and shall consist of long-chain synthetic polymers composed of at least 95 percent by weight polyethylene, polypropylene, or polyesters. The geotextile shall be manufactured with 100 percent virgin resin, and with a maximum of 5 percent in-plant regrind material. Geotextile shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including the selvages. Polyester resin shall have a minimum

molecular weight of 20,000 and a carboxyl end group number less than 50. Polyethylene and polypropylene shall be stabilized with long term antioxidants. For survivability during installation, and in addition to installation damage used in calculating the long term design strength, the geotextile shall meet the minimum requirements in AASHTO M 288 Class 1, and shall have a minimum mass per unit area of 270 g/m^2 8 oz/sy.

2.3.3 Reinforcement Properties

****

NOTES: Permittivity - Reinforcement geotextiles should not puddle or impede infiltration or seepage. AASHTO M 288 provides some default guidance.

Geosynthetic Selection - The Federal Acquisition Regulations require full and open competition. Usually justification is not necessary if 3 products meet the specifications. In combining various material requirements, it is easy to specify a geosynthetic product that does not exist. Design utilizing geosynthetics should include a listing with the calculations that verify the specified products are commercially available. The Geosynthetics Fabrics Report magazine publishes an annual specifiers guide that is ideal for this purpose.

****

The reinforcement shown in the approved shop drawing submittal shall meet the long term design strength requirements used in the design, and shall meet the properties listed in Table 1. Reinforcement strength requirements represent minimum average roll values in the machine direction.
The reinforcement indicated must meet the property requirements listed in Table 1. Reinforcement strength requirements represent minimum average roll values in the machine direction.
The reinforcement indicated must meet the property requirements listed in Table 1. Additional reinforcement shown in the approved shop drawing submittal must meet the long term design strength requirements used in the design and shall meet other properties listed in Table 1. Submit affidavit certifying that the reinforcement meets the project specifications. The affidavit must be signed by an official authorized to certify on behalf of the manufacturer and shall be accompanied by a mill certificate that verifies physical properties were tested during manufacturing and lists the manufacturer's quality control testing. [If the affidavit is dated after award of the contract and/or is not specific to the project, the supplier must attach a statement certifying that the affidavit addressed to the wholesale company is representative of the material supplied.] Include in the documents a statement confirming that all purchased resin used to produce reinforcement is virgin resin. Include in the mill certificate the tensile strength tested in accordance with ASTM D4595. Reinforcement strength requirements represent minimum average roll values in the machine direction.

TABLE 1. REINFORCEMENT PROPERTIES		
PROPERTY	REQUIREMENT	TEST DESIGNATION
Permittivity (geotextiles)	[0.5][_____] per second	ASTM D4491
UV Resistance	70 percent after 500 HOURS	ASTM D4355/D4355M
Long Term Design	[_____] kN/m lb/inch	NCMA TR127B, Method A
Coefficient of Interaction for Pullout	[.85][_____]	ASTM D6706
Coefficient for Direct Shear	[_____] degrees	ASTM D5321/D5321M

2.3.3.1 Long Term Design Strength

The long term design strength shall be based on reduction factors for installation damage and durability that are applicable to the fill that will be used. Minimum reduction factors for durability include: 1.1 for polyethylene and polypropylene geosynthetics, 1.15 for coated polyester geogrids, and 1.6 for polyester geotextiles. The creep reduction factor must be consistent with the test procedure used for determining the ultimate strength.

2.3.3.2 Connection Strength

The connection strength between the blocks and reinforcement determined in accordance with ASTM D6638 shall have connection strength meeting the following minimum requirements:

Minimum Peak Connection Strength = [_____] kN/m lbs/ft
Friction Angle for Peak Connection Strength = [_____] degrees
Minimum Service State Connection Strength = [_____] kN/m lbs/ft
Friction Angle for Service State Connection Strength = [_____] degrees

2.4 GEOTEXTILE FILTER

Geotextiles used as filters shall meet the requirements specified in Table 2. The property values (except for AOS) represent minimum average roll values (MARV) in the weakest principal direction. For survivability during installation, the geotextile shall meet the minimum requirements in AASHTO M 288 Class 2, and shall have a minimum mass per unit area of 270 g/m ^{2} 8 oz/sy.

TABLE 2. GEOTEXTILE PHYSICAL PROPERTIES		
PROPERTY	TEST REQUIREMENT	TEST METHOD
Grab Tensile, N lbs.	[700 160 nonwoven] [1100 250 woven]	ASTM D4632/D4632M

TABLE 2. GEOTEXTILE PHYSICAL PROPERTIES		
PROPERTY	TEST REQUIREMENT	TEST METHOD
Apparent Opening Size (µm) (U.S. Sieve)	150 - 212 70 - 100	ASTM D4751
Permittivity, sec-1	0.5	ASTM D4491

2.5 SOILS AND AGGREGATES

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NOTE: Drainage Aggregate and Aggregate Base - The designer may substitute a gradation readily available in the locality, such as state standard specifications for road construction.

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All material placed as fill shall consist of material classified by ASTM D2487 as GW, GP, GC, GM, SP, SM, SC, CL, ML, or SW. The material shall be free of ice; snow; frozen earth; trash; debris; sod; roots; organic matter; contamination from hazardous, toxic or radiological substances; or stones larger than 3 inches in any dimension. Each material shall be obtained entirely from one borrow source, unless the Contracting Officer determines that quality control is adequate and the alternate source produces material that is similar in gradation, texture, and interaction with the reinforcement. Supply any testing required by the Contracting Officer to evaluate alternate sources. All materials shall be of a character and quality satisfactory for the purpose intended.

2.5.1 Drainage Aggregate

Meet the requirements of ASTM D448, size No.7.

2.5.2 Aggregate Base Material

For the wall leveling pads meet the requirements of ASTM D1241, gradation C.

2.5.3 Reinforced Fill

Soil placed in the reinforced fill zone must consist of granular material with less than [5][15] percent passing the 75 µm No. 200 sieve.

2.5.4 Retained Fill

Soil placed in the retained fill zone must meet the minimum requirements above.

2.6 MASONRY ADHESIVE

The masonry adhesive shall meet the following requirements:

a. ASTM C920, Type S, Grade NS, Class 25

b. Recommendations of the block manufacturer

2.7 DRAINAGE PIPE

Provide corrugated polyethylene pipe drainage pipe meeting requirements of AASHTO M 252.

PART 3 EXECUTION

3.1 CLASSIFICATION OF SOIL MATERIALS

Perform classification of soil materials in accordance with ASTM D2488. The Contracting Officer reserves the right to revise the Contractor classifications. In the case of disagreement, the Contracting Officer's classification will govern unless the soils are classified in accordance with ASTM D2487. All testing completed by the Contractor in conjunction with soil material classification will be considered incidental to the contract work.

3.2 EARTHWORK

The leveling pad and reinforced fill zone shall bear on undisturbed native soils, or acceptably placed and compacted fill. In the event that it is necessary to remove material to a depth greater than specified or to place fill below the leveling pad not otherwise provided for in the contract, the Contracting Officer shall be notified prior to work and an adjustment in the contract price will be considered in accordance with the contract. Additional work not authorized by the Contracting Officer shall be at the Contractor's expense.

3.2.1 Excavation

Foundation soil shall be excavated as required for leveling pad dimensions and reinforcement placement shown on the construction drawings. Material for backfilling shall be stockpiled in a neat and orderly manner at a sufficient distance from the banks of the excavation to avoid overloading and to prevent slides or caving. Excavation and fill shall be performed in a manner and sequence that will provide proper drainage at all times. The Contractor is responsible for disposal of surplus material, waste material, and material that does not meet specifications, including any soil which is disturbed by the Contractor's operations or softened due to exposure to the elements and water.

3.2.2 Stockpiles

Stockpiles of all material to be incorporated into the work shall be kept in a neat and well drained condition, giving due consideration to drainage at all times. The ground surface at stockpile locations shall be cleared, grubbed, and sealed. Topsoil shall be stockpiled separately from suitable backfill material. Stockpiles of aggregates and granular soils shall be protected from contamination which may destroy the quality and fitness of the stockpiled material. If the Contractor fails to protect the stockpiles, and any material becomes frozen, saturated, intermixed with other materials, or otherwise out of specification or unsatisfactory for the use intended, such material shall be removed and replaced with new material from approved sources at no additional cost to the Government.

3.3 LEVELING PAD

3.3.1 Aggregate Base Leveling Pad

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NOTE: Notification of the Contracting Officer - It is beyond the scope of a specification to provide remedies to all possible problems. If the specification indicates the Contracting Officer shall be notified, it is assumed qualified assistance will be utilized to assess the situation when necessary.

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The subgrade below the leveling pad shall be compacted with at least 3 passes with a vibratory plate compactor with an operating weight not less than 200 kg 450 pounds. The aggregate base material shall be placed in lifts not exceeding 150 mm 6 inches and compacted with at least 3 passes with a vibratory plate compactor. If the subgrade or aggregate base pumps, bleeds water, or cracks during compaction, the Contracting Officer shall be notified and, if no other changes are directed, the aggregate shall be replaced with a concrete leveling pad.

3.3.2 Concrete Leveling Pad

Tolerances in screeding shall be sufficient to place the blocks directly on the leveling pad without mortar, pointing, or leveling course between the blocks and leveling pad.

3.4 BLOCK INSTALLATION

The wall system components shall be constructed in accordance with the wall supplier's recommendations and construction manual. Damaged blocks shall not be incorporated in the retaining wall.

a. Block placement shall begin at the lowest leveling pad elevation. The blocks shall be in full contact with the leveling pad. Each course of block shall be placed sequentially for the entire wall alignment to maintain a level working platform for layout of reinforcement and placement of fill.

b. The grade and alignment of the first course shall be surveyed and the results furnished to the Contracting Officer prior to placing the second course. Survey control for alignment shall include a string line, offset from a base line, or suitable provisions that can be reproduced for quality assurance.

c. Place the blocks with the edges in tight contact. [No gap are allowed for wall batter and curvature.] Maintain the vertical joints with a minimum 100 mm 4 inch overlap on the underlying block. Do coping required to keep block alignment with a full depth saw cut. No splitting is allowed.

d. Stacking of blocks prior to filling any lower course of block with drainage aggregate will not be allowed.

e. Join cap units [and the top two course of blocks] using masonry adhesive. Take care to keep adhesive from coming into contact with the face of wall units.

3.5 REINFORCEMENT INSTALLATION

a. Before placing reinforcement, compact the subgrade or subsequent lift of fill and grade level with the top of the blocks. The surface must be smooth and free of windrows, sheepsfoot impressions, and rocks.

b. Place reinforcement at the elevations and to the extent shown on the construction drawings and the approved shop drawing submittal. Reinforcement shall be oriented with the design strength axis perpendicular to the wall face. Each segment of reinforcement shall be continuous. Spliced connections between shorter pieces of reinforcement will not be allowed. Place reinforcement strips immediately next to adjacent strips to provide 100 percent coverage.

c. Install the reinforcement in tension. Pull the reinforcement taut and anchor with staples or stakes prior to placing the overlying lift of fill. The tension must be uniform along the length of the wall and consistent between layers.

d. All reinforcement must be 100 percent covered by soil so that reinforcement panels do not contact in overlaps. Where the wall bends, place a veneer of fill to a nominal thickness of 75 mm 3 inches to separate overlapping reinforcement.

3.6 FILL PLACEMENT

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NOTE: Subparagraph "c." below - Studies have documented rubber tired heavy equipment traveling on geogrids with minimal or no damage. However, it is regarded as poor practice and usually unnecessary. Problematic conditions include coarse crushed gravel and coated geogrids. The intent of the specification is to minimize equipment on the geogrid so that it occurs only when necessary.

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a. Fill placement, including drainage aggregate, shall be completed to the top of each course of facing blocks prior to stacking the subsequent course of blocks.

b. Reinforced fill shall be placed from the wall back toward the fill area to ensure that the reinforcement remains taut. Fill shall be placed, spread, and compacted in such manner that minimizes the development of wrinkles in or movement of the reinforcement.

c. A minimum fill thickness of 150 mm 6 inches is required prior to operation of vehicles over the reinforcement. Sudden braking and sharp turning shall be avoided. Tracked equipment shall not turn within the reinforced fill zone to prevent tracks from displacing the fill and damaging the reinforcement. Construction equipment shall not be operated directly upon the reinforcement as part of the planned construction sequence. Rubber tired equipment may operate directly on the reinforcement if: the Contractor submits information documenting testing of equipment operating on a similar geogrid product on similar soils, the travel is infrequent, equipment travels slow, turning is minimized, and no damage or displacement to the reinforcement is observed.

d. Drainage aggregate shall be placed and tamped directly behind, between, and within the cells of the facing units. Compaction of the drainage aggregate shall be achieved by at least two passes on each lift with a vibratory plate compactor. Care shall be taken not to contact or chip the blocks with the compactor. Aggregate placed within the block cores and recesses shall be compacted by hand tamping and rodding.

e. At the end of each day, slope the last lift of fill away from the wall in a manner that will allow drainage and direct runoff away from the wall face.

3.7 COMPACTION

Fill shall not be placed on surfaces that contain mud, frost, organic soils, fill soils that have not met compaction requirements, or where the Contracting Officer determines that unsatisfactory material remains in or under the fill. Fill shall be spread and compacted in lifts not exceeding the height of one course of blocks.

3.7.1 Degree of Compaction

Degree of compaction required is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D698. The maximum density is hereafter abbreviated as the "Standard Proctor" value.

3.7.2 Moisture Control

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NOTE: Moisture content limits for compaction should be included in these paragraphs when necessary for obtaining strength and stability in embankments and fill, for controlling movement of expansive soils and when, in the opinion of the project geotechnical engineer, moisture control is required for the soils being used. Specify an acceptable variation from the optimum moisture if justified from experience with similar soils or where demonstrated from moisture-density tests for the borrow material during planning. Block alignment is sometimes difficult to maintain if cohesive soils are placed wet of optimum in the reinforced fill zone.

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Control of moisture in the fill shall be maintained to provide acceptable compaction. Disking and plowing will not be allowed in the reinforced fill zone. Moisture content of cohesive soils shall be adjusted at the borrow source before placement. Adding water directly to the reinforced fill zone shall only be conducted under conditions where the soil has sufficient porosity and capillarity to provide uniform moisture throughout the fill during compaction.

3.7.3 Compaction

Reinforced and retained fill shall be compacted to 95 percent of the Standard Proctor Density. Care shall be exercised in the compaction process to avoid misalignment of the facing blocks. Heavy compaction equipment (including vibratory drum rollers) shall not be used within 900 mm 3 feet from the wall face.

3.8 SOIL TESTING

All testing expenses shall be the Contractor's responsibility. Prior to sampling and testing the work, testing laboratories shall be inspected and approved in accordance with Section 01 45 00.00 1001 45 00.00 20 01 45 00.00 40 QUALITY CONTROL. The Contracting Officer reserves the right to direct the location and select the material for samples to be tested and to direct where and when moisture-density tests shall be performed. Use nuclear density testing equipment in general accordance with ASTM D6938.

3.8.1 Transmittal

The Contracting Officer shall be informed of test results daily for direction on corrective action required. Draft copies of field testing results shall be furnished to the Contracting Officer on a frequent and regular basis, as directed.

3.8.2 Corrective Action.

Tests of materials which do not meet the contract requirements (failing test) will not be counted as part of the required testing. Each such failing test must be retaken at the same location as the failing test was taken. If testing indicates material does not meet the contract requirements, the material represented by the failing test shall not be placed in the contract work or shall be recompacted or removed. The quantity of material represented by the failing test shall be determined by the Contracting Officer up to the quantity represented by the testing frequency. The Contractor may increase testing frequency in the vicinity of a failing test in order to reduce removal requirements, as approved by the Contracting Officer. Such increases in testing frequency shall be at the Contractor's expense and at no additional cost to the Government.

3.8.3 Testing Schedule

3.8.3.1 Moisture-Density Relations

ASTM D698. One test for each material variation[, not less than [_____] tests total].

3.8.3.2 In-Place Densities

ASTM D1556 or ASTM D6938. Not less than 1 test for each 0.67 vertical meters per 100 linear meters 2 vertical feet per 300 linear feet along wall face.

3.8.3.3 Sieve Analysis

ASTM C136. Drainage Aggregate, 1 test for each source.

3.9 REINFORCEMENT TESTING

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NOTES: Primary reasons for testing geosynthetics include verification of quality control by the manufacturer, detecting degradation during shipping and storage, and verifying the correct product is supplied. Verification of quality control by the manufacturer and detecting degradation during

shipping and storage is not economically justified for small jobs. Unlike reinforcing steel for concrete, geosynthetics are difficult to identify in the field, and even experience personnel can sometimes mistake the product identity of unlabeled material. Testing after delivery to verify the correct product was supplied may be advisable for critical structures. The strength is usually the most critical property to verify an acceptable product is furnished.

For cohesive fill, testing the interaction coefficient in accordance with ASTM D6706 or ASTM D6706 may be justified. The interaction coefficient effects the length required to develop stress in the reinforcement, and thus the embedment length. For granular retained fill, there is very little difference between products so testing is not justified. For cohesive soil, the interaction coefficient is only significant for the upper courses (usually the top 1 meter (3 feet)). The test is expensive, and is not normally justified (the usual alternative is to make a conservative assumption).

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All testing expenses shall be the Contractor's responsibility. Testing shall be performed by a commercial testing laboratory selected by the Contractor and approved by the Contracting Officer or performed by the Contractor if approved by the Contracting Officer. The Contracting Officer reserves the right to direct the location and select the material for samples. Testing data specific to the blocks and reinforcement to be supplied shall be as follows:

a. The shear strength between blocks shall be established in accordance with NCMA TR127B.

b. The connection strength between the blocks and the reinforcement shall be established in accordance with ASTM D6638. If the FHWA design method is used, the modifications in FHWA NHI-00-043 shall be implemented.

c. The coefficient for direct shear of the reinforcement on a soil similar in gradation and texture to the material that will be used for fill in the reinforced zone shall be established in accordance with ASTM D5321/D5321M.

d. The coefficient of interaction for pull-out resistance of the reinforcement in a soil similar in gradation and texture to the material that will be used for fill in the reinforced zone shall be established in accordance with ASTM D6706.

TABLE 3. REINFORCEMENT TESTING		
PROPERTY	TEST DESIGNATION	FREQUENCY
Wide Width Strip Tensile Strength	ASTM D4595	[_____]

Modify ASTM D4595 for geogrids considering recommendations in GSI GRI GG6; and the tensile strength shall be expressed on a unit length basis by substituting n*a for Ws, where:

Ws = specimen width, (mm inches)
n = number of ribs in the sample (must be a whole number)
a = nominal rib spacing for the product tested, (mm inches)

3.10 DRAINAGE PIPE

Drain pipe shall be placed as indicated on the drawings. Drain lines shall be laid to true grades and alignment with a continuous fall in the direction of flow. The interior of the pipe shall be kept clean from soil and debris; and open ends shall be temporarily capped as necessary.

3.11 CONSTRUCTION TOLERANCES

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NOTE: The suggested tolerances represent the standard of practice. Tighter tolerances should be specified with caution. Loosen horizontal and vertical tolerance if acceptable. Plumbness and alignment will limit bulging.

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3.11.1 Horizontal

The top of wall must be within [_____] [75 mm] [3 inches] of the plan location.

3.11.2 Vertical

The top of wall elevations must be within [_____] [30 mm] [0.1 feet] above to [_____] [30 mm] [0.1 feet] below the prescribed top of wall elevations indicated.

3.11.3 Plumbness and Alignment

The wall batter and alignment offset measured as deviation from a straight edge must be within plus or minus [_____] [30 mm per 3 meter] [1.25 inches per 10 feet] section. The batter measured from vertical must be within [2][_____] degrees of the plan dimension.

3.11.4 Block Defects

The blocks will be accepted on the basis of tolerances specified in ASTM C1372.

3.11.5 Block Gaps

Gaps between adjacent blocks must not exceed 3 mm 1/8 inches.

3.12 PROTECTION OF WORK

Protect work against damage from subsequent operations. Remove disturbed or displaced blocks and replace to conform to all requirements of this section. Do not incorporate damaged material into the wall. Upon completion of wall erection, clean the wall face to remove any loose soil deposits or stains.

-- End of Section --