
USACE / NAVFAC / AFCEA UFGS-02832 (September 2004)

Preparing Activity: USACE (CW) Superseding
UFGS-02832 (September 2003)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 22 December 2004

Latest change indicated by CHG tags

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SECTION 02832

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09/04

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SECTION 02832

SEGMENTAL CONCRETE BLOCK RETAINING WALL 09/04

NOTE: This guide specification covers the requirements for segmental concrete block retaining walls, using geosynthetic soil reinforcement.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

This guide specification includes tailoring options for Contractor design, Government design, and hybrid design. Selection or deselection of a tailoring option will include or exclude that option in the section, but editing the resulting section to fit the project is still required.

The following is guidance in selecting 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 through 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.

PART 1 GENERAL

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 REFERENCES

NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

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	(2002) Corrugated Polyethylene Drainage Pipe
AASHTO M 288	(2000) Geotextile Specifications for Highway Applications

ASTM INTERNATIONAL (ASTM)

ASTM C 1262	(1998e1) Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units
ASTM C 136	(2004) Sieve Analysis of Fine and Coarse Aggregates
ASTM C 1372	(2004e1) Segmental Retaining Wall Units
ASTM C 140	(2003) Sampling and Testing Concrete Masonry Units and Related Units
ASTM C 920	(2002) Elastomeric Joint Sealants
ASTM D 1241	(2000) Materials for Soil-Aggregate Subbase, Base, and Surface Courses
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 2487	(2000) Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 2488	(2000) Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 2922	(2004) Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
ASTM D 4355	(2002) Deterioration of Geotextiles from Exposure to Light, Moisture and Heat in a

Xenon-Arc Type Apparatus

ASTM D 448	(2003a) Sizes of Aggregate for Road and Bridge Construction
ASTM D 4491	(1999a) Water Permeability of Geotextiles by Permittivity
ASTM D 4595	(1986; R 2001) Tensile Properties of Geotextiles by the Wide-Width Strip Method
ASTM D 4632	(1991; R 2003) Grab Breaking Load and Elongation of Geotextiles
ASTM D 4751	(1999a) Determining Apparent Opening Size of a Geotextile
ASTM D 4873	(2002) Identification, Storage, and Handling of Geosynthetic Rolls and Samples
ASTM D 5321	(2002) Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
ASTM D 6638	(2001) Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
ASTM D 698	(2000a ¹) 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
GSI GRI GT6	(1992) Geotextile Pullout

NATIONAL CONCRETE MASONRY ASSOCIATION (NCMA)

NCMA TR127	(1997) Design Manual for Segmental Retaining Walls
NCMA TR160	(1998) Seismic Design Manual for Segmental Retaining Walls

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

FHWA NHI-00-043	(2004) Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines (ISDDC)
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1.2 DEFINITIONS

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

- a. Blocks. Segmental concrete retaining wall units will be referred to as blocks.
- b. Drainage Aggregate. Granular soil or aggregate which is placed within, between, and/or immediately behind segmental concrete units.
- c. Fill. Soil or aggregate placed in, behind, or below the wall will be referred to as fill.
- d. Reinforced Fill. Soil which is placed and compacted within the neat line volume of reinforcement as outlined on the plans.
- e. Retained Fill. Soil which is placed and compacted behind the reinforced fill.
- f. Reinforcement. Reinforcement shall consist of a geogrid or a geotextile product manufactured for use as reinforcing. Reinforcement shall not include steel products.
- g. 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

1.3 SUBMITTALS

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" 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 projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy 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.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Shop Drawings[; G][; G, [_____]]

Fabrication and installation drawings. The shop drawings shall include 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.

SD-03 Product Data

Components and Equipment

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.

Supplier Qualifications Manufacturer's Representative

Documentation showing that the installer and supplier meet the qualifications listed.

Soil Testing[; G][; G, [_____]]
Reinforcement Testing[; G][; G, [_____]]

Testing data specific to the blocks and reinforcement to be supplied.

a. The shear strength between blocks shall be established in accordance with NCMA TR127.

b. The connection strength between the blocks and the reinforcement shall be established in accordance with ASTM D 6638.

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 D 5321.

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 GSI GRI GT6.

Calculations[; G][; G, [____]]

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 D 4595. The calculation shall itemize each reduction factor and include backup data to justify each reduction factor.

Design calculations, including computer output data and program documentation. The calculations shall include all items described under PARAGRAPH: SEGMENTAL RETAINING WALL DESIGN.

SD-04 Samples

Segmental Concrete Units[; G][; G, [____]]

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

Reinforcement[; G][; G, [____]]

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.

Samples of each type of reinforcement. The samples shall be labeled and have a minimum size 200 by 250 mm 8 by 10 inches. Geogrid shall include at least 2 apertures (3 junctions) in each direction.

SD-07 Certificates

Reinforcement[; G][; G, [_____]]

Affidavit certifying that the reinforcement meets the project specifications. The affidavit shall 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 shall attach a statement certifying that the affidavit addressed to the wholesale company is representative of the material supplied.] The documents shall include a statement confirming that all purchased resin used to produce reinforcement is virgin resin. The mill certificate shall include the tensile strength tested in accordance with ASTM D 4595.

1.4 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.

1.5 SEGMENTAL RETAINING WALL DESIGN

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.

1.5.1 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.

The Contractor shall complete all stability analyses in accordance with either the NCMA TR127, 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.]

1.5.2 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 TR127 or FHWA NHI-00-043. Calculations shall include analysis of all failure modes listed in the NCMA TR127. Design calculations shall include a clear outline of material properties and assumptions.[The Contractor shall use the following soil parameters and water elevation for stability analysis, and shall select additional soil parameters as required to complete the analysis.]

Moist Unit Weight of reinforced fill, [_____] kN/m³ pcf
Saturated Unit Weight of reinforced fill, [_____] kN/m³ pcf

Internal Friction Angle of reinforced fill, [30] degrees
Cohesion of reinforced fill, [0] kPa psf
Water Elevation in reinforced fill, [_____] meters feet

1.5.2.1 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.

1.5.2.2 Seismic Design Requirements

NOTE: The pseudo static analysis method is only
applicable up to $A \leq 0.4$ 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).

[The Contractor shall complete the seismic stability analysis in accordance with NCMA TR160 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 [____].]

1.5.2.3 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.

1.5.3 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. 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).

1.6 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.

The Contractor shall 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. The standard products shall have been in satisfactory commercial or industrial use for 2 years before bid opening. 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].

1.7 SUPPLIER QUALIFICATIONS

NOTE: The suggested text is recognized to be somewhat vague. It limits situations where 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.

[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.]

1.8 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.

The Contractor shall have 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].

1.9 DELIVERY, STORAGE AND HANDLING

The Contractor shall check products upon delivery to assure that the proper material has been received and is undamaged. For geosynthetics, the guidelines presented in ASTM D 4873 shall be followed.

1.9.1 Segmental Concrete Units and Wall Caps

The Contractor shall protect blocks from damage and exposure to cement, paint, excessive mud, and like materials. The Contractor shall check materials upon delivery to assure that the block dimensions are within the tolerances specified.

1.9.2 Geosynthetic Labeling

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

1.9.3 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.

1.9.4 Geosynthetic Storage

Geosynthetics shall be protected 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 SEGMENTAL CONCRETE UNITS

2.1.1 Architectural requirements

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.

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. 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).

- a. Face color - [Tan/Grey/Brown/Natural Limestone].
- b. Face Texture - [split face typical of broken mortar/brick face].
- c. Face Appearance - [straight, single-surface face/sculptured with 3-surface beveled face/rounded, smooth-curved face].
- d. Batter - Blocks shall be engaged 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].
- e. Block Size - a minimum of 0.06 square meters 2/3 square feet of face area, and minimum 150 mm 6 inch height.
- f. Bond configuration - No bond configuration is required for straight face blocks. Beveled or sculptured face blocks shall be designed to stack with a half-bond (joints located at midpoint of vertically adjacent blocks). The block edges shall be finished so that vertical joints are flush.

2.1.2 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 C 1372, 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 shall be manufactured to the requirements of ASTM C 1372, except for the following modifications:

- a. Minimum 28-day compressive strength of 31 MPa 4500 psi, based on net area in accordance with ASTM C 140.
- b. A maximum moisture absorption rate of 145 kg/m^3 9 pcf, in accordance with ASTM C 140.
- 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 C 1262, 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 TR127 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]

2.1.3 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.

2.2 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 D 4603, "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."

2.2.1 Geogrid Reinforcement

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.

2.2.2 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 D 4833), 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.

2.2.3 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 shown on the contract drawings shall meet the property requirements listed in Table 1. Reinforcement strength requirements represent minimum average roll values in the machine direction. The reinforcement shown on the contract drawings shall meet the property requirements listed in Table 1. Additional reinforcement shown in the approved shop drawing submittal shall meet the long term design strength requirements used in the design and shall meet other properties listed in Table 1. Reinforcement strength requirements represent minimum average roll values in the machine direction.

TABLE 1. REINFORCEMENT PROPERTIES

PROPERTY	REQUIREMENT	TEST DESIGNATION
Long Term Design Strength	[_____] kN/m lb/inch	NCMA TR127, Method A
Permittivity (geotextiles)	[0.5] per second	ASTM D 4491
UV Resistance	70 percent after 500 hours	ASTM D 4355
Coefficient of Interaction for Pullout	[.85]	GSI GRI GT6
Coefficient for Direct Shear	[_____] degrees	ASTM D 5321

2.2.3.1 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.

2.2.3.2 Connection Strength

The connection strength between the blocks and reinforcement determined in accordance with ASTM D 6638 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

2.3 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/m² 8 oz/sy.

TABLE 2. GEOTEXTILE PHYSICAL PROPERTIES

PROPERTY	TEST REQUIREMENT	TEST METHOD
Grab Tensile, N	[700 nonwoven] [1100 woven]	ASTM D 4632
Apparent Opening Size (µm)	[150 - 212]	ASTM D 4751
Permittivity, sec-1	[0.5]	ASTM D 4491

TABLE 2. GEOTEXTILE PHYSICAL PROPERTIES

PROPERTY	TEST REQUIREMENT	TEST METHOD
Grab Tensile, lbs.	[160 nonwoven] [250 woven]	ASTM D 4632
Apparent Opening Size (U.S. Sieve)	[70 - 100]	ASTM D 4751
Permittivity, sec-1	[0.5]	ASTM D 4491

2.4 SOILS AND AGGREGATES

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.

All material placed as fill shall consist of material classified by ASTM D 2487 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. The Contractor shall 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.

- a. Drainage Aggregate shall meet the requirements of [ASTM D 448, size No.7].
- b. Aggregate Base material for the wall leveling pads shall meet the requirements of [ASTM D 1241, gradation C].
- c. Reinforced Fill. Soil placed in the reinforced fill zone shall consist of [granular material with less than [5][15] percent passing the 75 µm No. 200 sieve].
- c. Retained Fill. Soil placed in the retained fill zone shall [meet the minimum requirements above].

2.5 MASONRY ADHESIVE

The masonry adhesive shall meet the following requirements:

- a. ASTM C 920, Type S, Grade NS, Class 25
- b. expected 30 year life
- c. meet the recommendations of the block manufacturer

2.6 DRAINAGE PIPE

The drainage pipe shall be corrugated polyethylene pipe meeting requirements of AASHTO M 252.

PART 3 EXECUTION

3.1 CLASSIFICATION OF SOIL MATERIALS

Classification of soil materials shall be performed by the Contractor in accordance with ASTM D 2488. 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 D 2487. 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

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.

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. The blocks shall be placed with the edges in tight contact. [No gap shall be allowed for wall batter and curvature.] The vertical joints shall be maintained with a minimum 100 mm 4 inch overlap on the underlying block. Coping required to keep block alignment shall be done with a full depth saw cut. No splitting shall be allowed.
- d. Stacking of blocks prior to filling any lower course of block with drainage aggregate will not be allowed.
- e. Cap units [and the top two course of blocks] shall be joined using masonry adhesive. Care shall be taken to keep adhesive from coming into contact with the face of wall units.

3.5 REINFORCEMENT INSTALLATION

- a. Before placing reinforcement, the subgrade or subsequent lift of fill shall be compacted and graded level with the top of the blocks. The surface shall be smooth and free of windrows, sheepsfoot impressions, and rocks.
- b. Reinforcement shall be placed 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. Reinforcement strips shall be placed immediately next to adjacent strips to provide 100 percent coverage.
- c. The reinforcement shall be installed in tension. The reinforcement shall be pulled taut and anchored with staples or stakes prior to placing the overlying lift of fill. The tension shall be uniform along the length of the wall and consistent between layers.
- d. All reinforcement shall be 100% covered by soil so that reinforcement panels do not contact in overlaps. Where the wall bends, a veneer of fill shall be placed to a nominal thickness of 75 mm 3 inches to separate overlapping reinforcement.

3.6 FILL PLACEMENT

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.

- 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, the Contractor shall 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 D 698. The

maximum density is hereafter abbreviated as the "Standard Proctor" value.

3.7.2 Moisture Control

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.

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

3.8.1 General

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 01451A CONTRACTOR 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. Nuclear density testing equipment shall be used in general accordance with ASTM D 2922.

3.8.2 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.

3.8.3 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.

3.8.4 Testing Schedule

Moisture-Density Relations (ASTM D 698)

One test for each material variation[, not less than [____] tests total].

In-Place Densities (ASTM D 1556 or ASTM D 2922)

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.

Sieve Analysis, (ASTM C 136)

(1) Drainage Aggregate, [1 test for each source].

3.9 REINFORCEMENT TESTING

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 GSI GRI GG5 or GSI GRI GT6 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).

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.

TABLE 3. REINFORCEMENT TESTING

PROPERTY	TEST DESIGNATION	FREQUENCY
Wide Width Strip Tensile Strength	ASTM D 4595	[_____]

ASTM D 4595 shall be modified for geogrids considering recommendations in GSI GRI GG6; and the tensile strength shall be expressed on a unit length basis by substituting $n \cdot a$ for W_s , where:

W_s = 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

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.

a. Horizontal: The top of wall shall be within [_____] [75 mm] [3 inches] of the plan location.

b. Vertical: The top of wall elevations shall be within [_____] [30 mm] [0.1 feet] above to [_____] [30 mm] [0.1 feet] below the prescribed top of wall elevations shown on the drawings.

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

d. Block Defects: The blocks will be accepted on the basis of tolerances specified in ASTM C 1372.

e. Block Gaps: Gaps between adjacent blocks shall not exceed 3 mm
1/8 inches.

3.12 PROTECTION OF WORK

Work shall be protected against damage from subsequent operations. Disturbed or displaced blocks shall be removed and replaced to conform to all requirements of this section. Damaged material shall not be incorporated into the wall. Upon completion of wall erection, the Contractor shall clean the wall face to remove any loose soil deposits or stains.

-- End of Section --