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USACE / NAVFAC / AFCEC **UFGS-35 31 19.20 (November 2023)**

Preparing Activity: USACE **Superseding**
UFGS-35 31 19.20 (January 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2025
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DIVISION 35 - WATERWAY AND MARINE CONSTRUCTION

SECTION 35 31 19.20

ARTICULATING CONCRETE BLOCK REVETMENTS

11/23

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SECTION 35 31 19.20

ARTICULATING CONCRETE BLOCK REVETMENTS
11/23

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NOTE: This guide specification covers the requirements for commercially available concrete block products for revetments.

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 item(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).

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PART 1 GENERAL

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NOTE: PART 2 PRODUCTS is based on commercial items, and does not address field casting of blocks or manufacturing of non standard blocks.

This guide specifications assumes the ACB is Government designed for issues such as hydraulic stability and geotextile filters. Maximum flexibility is desirable for Contractor product selection, installation sequence, construction equipment, and block orientation.

Notes before paragraphs are provided to present assumptions in preparation of the guide specification, make suggestions for conditions that

warrant project revisions, and provide background technical information or references for further information. They should be reviewed prior to revising wording for use in project specifications.

The drawings should show appropriate details for toe key-in, anchor trenches, revetment termination, transition to riprap, anchors, geotextiles, horizontal and vertical joint thickness between ACB, joint/placement pattern of ACB's.

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1.1 MEASUREMENT AND PAYMENT

Measurement of ACB revetment for payment will be made on the basis of the face area. The pay lines of ACB revetment will be neat lines taken off the approved shop drawings; and will include embedded blocks and anchor trenches. Work includes incidental grading and preparatory work, furnishing and installing the geotextile and ACB, filling the voids, securing cable fasteners, installing soil anchors, and seeding (where specified). Engineering services and product testing are incidental, if required. Placing cast-in-place concrete joints and cutting blocks are incidental, if required. Payment will be made at the respective unit price per square meter foot listed on the Bidding Schedule. Payment will be full compensation for all material, labor and equipment to complete the work.

1.2 REFERENCES

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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 Reference Identifier (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.

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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 288 (2021) Standard Specification for Geosynthetic Specification for Highway

Applications

ASTM INTERNATIONAL (ASTM)

ASTM C42/C42M	(2020) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C138/C138M	(2024a) Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C140/C140M	(2025) Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C1262/C1262M	(2024) Standard Test Method for Evaluating the Freeze-Thaw Durability of Dry-Cast Segmental Retaining Wall Units and Related Concrete Units
ASTM D4355/D4355M	(2014) Deterioration of Geotextiles from Exposure to Light, Moisture and Heat in a Xenon-Arc Type Apparatus
ASTM D4491/D4491M	(2017) Standard Test Methods for Water Permeability of Geotextiles by Permittivity
ASTM D4533/D4533M	(2015) Standard Test Method for Trapezoid Tearing Strength of Geotextiles
ASTM D4632/D4632M	(2015a) Grab Breaking Load and Elongation of Geotextiles
ASTM D4751	(2020) Standard Test Method for Determining Apparent Opening Size of a Geotextile
ASTM D4833/D4833M	(2007; R 2020) Standard Test Method forIndex Puncture Resistance of Geomembranes and Related Products
ASTM D4873/D4873M	(2017) Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

FHWA RD-89-199	(1989) Hydraulic Stability of Articulated Concrete Block Revetment Systems During Overtopping Flow

1.3 DEFINITIONS

1.3.1 Articulating Concrete Block (ACB) Revetment System

A matrix of interconnected concrete block units for erosion protection. Units are connected by geometric interlock and/or cables, geotextiles, or geogrids, and typically include a geotextile underlayment for subsoil

retention.

1.3.2 Blocks

Articulating concrete block revetment units will be referred to as blocks.

1.3.3 Interlocking Blocks

For each pair of abutting blocks provide interlocking keys that limit lateral expansion. Provide key and keyhole with an interference fit such that the joint movement has a minimum aperture at closure, and a maximum aperture when pulled apart. The joint freeplay must allow articulation of each individual block.

1.3.4 Freeplay

Freeplay is the maximum lateral joint movement for interlocking blocks (difference between maximum and minimum aperture).

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified 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 Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters 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 or Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal

for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Block Installation; G, [_____]

Geotextile Installation; G, [_____]

SD-03 Product Data

Articulating Concrete Block; G, [_____]

Geotextile; G, [_____]

Anchors; G, [_____]

SD-04 Samples

Articulating Concrete Block

SD-06 Test Reports

Flume Test

1.5 DELIVERY, STORAGE, AND HANDLING

Check products upon delivery to assure that the proper material has been received and is undamaged. For geosynthetics, follow the guidelines presented in ASTM D4873/D4873M.

1.5.1 Blocks

Provide blocks which are sound and free of defects that would interfere with proper placement or that would impair the strength or longevity of the installation. Discard blocks with the following defects:

a. Broken appendages.
b. Chips larger than 50 mm 2 inches in any dimension.
c. Cracks wider than 0.5 mm 0.02 inches and longer than 33 percent of the nominal height.
d. Exposed skin reinforcement or rebar.
e. Displaying evidence of the Alkali-Silica Reaction (ASR) such as map cracking.
f. Discard/remove blocks exhibitting efflorescence over 25 percent of the surface if directed by the Contracting Officer.

Minor cracks, incidental to the usual method of manufacture, or chipping that results from customary methods of handling in shipping, delivery and placement will not be deemed grounds for rejection. Store blocks in a suitable location away from mud, paint, wet cement, and other contamination or disturbance.

1.5.2 Geotextiles

1.5.2.1 Labeling

Label each roll with the manufacturer's name, product identification, roll dimensions, lot number, and date manufactured.

1.5.2.2 Handling

Handle and unload geosynthetic rolls by hand, or with load carrying straps, a fork lift with a stinger bar, or an axial bar assembly. Do not drag geosynthetic rolls, lift by one end, lift by cables or chains, or drop to the ground.

1.5.2.3 Storage

Protect geotextiles 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, elevate the rolls from the ground surface and protected with an opaque waterproof cover. Deliver geotextiles to the site in a dry and undamaged condition.

1.6 SCHEDULING

To limit ultraviolet light exposure of the geotextile, place the blocks within 7 days after placing the geotextile, and the void filler within 14 days after placing the geotextile.

PART 2 PRODUCTS

2.1 ARTICULATING CONCRETE BLOCK

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NOTE: Hand placed (interlocking) ACB typically provides a neater, more pleasing appearance in parks and public areas. Cabled ACB can have superior hydraulic stability to interlocking products, it is more difficult to remove (such as by vandalism), and it has improved constructability when placed in water.

The table of ACB requirements is comprehensive, and many of the properties are interrelated. Including all listed properties will be specification overkill for most projects. Renumber notes where properties are deleted.

The critical shear stress is preferred by the industry over critical velocity because the critical shear is relatively constant for a product. Critical velocity varies depending on flow characteristics (such as depth and turbulence); so that the critical velocity in the flume test is not comparable to the required critical velocity in the field.

The surface void area ratio, DCF, and curvature radius can be used to specify products best suited to placement on curved surfaces, and turf establishment. Some blocks are available with open cells or solid cores. Most products marketed specifically for ACB revetments are within reasonable limits for general use.

Modifying the requirements for a performance specification may be considered for small low hazard projects or negotiated contracts, and may be preferred by some manufacturers. However, performance requirements for firm fixed price (low bid) contracts is not recommended for ACB's because of the price level jumps between product sizes, and because there is no control in how bidders incorporate risk for a low frequency design event.

Interface friction for soil/fabric and fabric/blocks should be considered by the designer. Because typical design values for soil/fabric are available in geosynthetic design guides, and because the Contractor generally has no control over the soil, the soil/fabric interface friction angle is not addressed in the specification (although for certain critical applications, this may need to be added to verify design assumptions). Interface friction for fabric/blocks is addressed in the specification because it is affected by geotextile and block combinations, it can affect installation, and because the interface friction for fabric/block is highly variable dependent on manufacturing characteristics of both products.

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Submit descriptive technical data on the blocks, cables, cable fittings, soil anchors, and geotextile. Include all material properties specified under paragraph PRODUCTS. Submit catalog cuts, technical data sheets, or test data showing that the products meet the specifications. Also include a copy of any standard manufacturer's warranties for the products. See below under "geotextile" for more requirements. Meet the following criteria:

TABLE 1. ACB Requirements		
Criteria	Required Value	Test Method
Matrix Assembly: [Interlocking Blocks] [Cabled System]		
Thickness, minimum	[100 mm][4 inches]	N/A
Net Weight/Area, minimum	1.4 kN/m230 psf	Note a.
Critical Shear Stress, minimum	[170 N/m2][3.5 psf]	FHWA RD-89-199
Critical Velocity, minimum	5 m/sec15 ft/sec	FHWA RD-89-199
Curvature Radius, maximum	1 m3 feet	Note b.
Surface Void Area Ratio	25 - 40 percent	Note c.
Drainage Correction Factor (DCF)	20 - 35 percent	Note d.

TABLE 1. ACB Requirements		
Criteria	Required Value	Test Method
Block/Geotextile Interface Friction Angle	[35 degrees, minimum]	Note e.
a. Determine the weight of the mattress per unit area with the nominal joint spacing, in a non-submerged condition.		
b. The curvature radius must be indicative of the ability of the assembled mattress to conform to one dimensional subgrade curves without binding, such as for anchor trenches and swales. The curvature radius must be demonstrated, if requested by the Contracting Officer.		
c. The surface void area ratio must be determined at the visible (with filled voids) surface of the blocks, with the joints spaced in a neutral position (50 percent), and express as a percentage of the gross mat area. The void area must include area between the blocks and open cells within the block.		
d. The drainage correction factor must the minimum void area ratio (usually taken at the base of the blocks), with the joints spaced in a neutral position (50 percent freeplay in each direction), and must be expressed as a percentage of the gross mat area.		
e. The concrete surface must be sufficiently rough to prevent sliding of the blocks on the geotextile. The interface friction must be matched with the selected block and geotextile combination, and must be included with the ACB and Geotextile Data submittal. Demonstrate the block/geotextile interface friction angle, if requested by the Contracting Officer.		

2.1.1 Hydraulic Stability

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NOTE: The velocity and shear stress conditions derived from this test are critical state conditions, and do not represent allowable design values. The surface tolerances for block placement are generally better in the test than field conditions.

FHWA RD-89-199 is a research document, not a standard test method. ASTM committee D18.25.04 has a draft standard based on a flume test, similar to FHWA RD-89-199. The flume test is very expensive: testing expenses can be on the order of $30,000.

FHWA RD-89-199 included a 20 mm 3/4 inch Enkamat fabric below the blocks for the purpose of installing instrumentation to research block behavior. The Enkamat provided a very effective drainage layer that is not integral to the test method. A drainage layer provides a very

significant improvement in the ACB stability in the flume test. Regardless of the flume test conditions, the designer should consider including a granular drainage layer in areas with high turbulence flow.

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2.1.1.1 Flume Test

Submit a report of testing for the ACB in conformance with FHWA RD-89-199. Usage of a drainage layer as prescribed in FHWA RD-89-199 is not required. Clearly state if the critical shear stress associated with the stability threshold of the ACB system was derived from laboratory testing that included a sub-block drainage layer as a component of the tested system. Test the ACB product in a flume chamber satisfying the requirements of FHWA RD-89-199. If the product was tested with a drainage layer, the installed product must incorporate a similar drainage layer with adequate filtration design for the site soils. Base the flume test on conservative assumptions for field placement of the blocks (such as block orientation, and joint spacing within construction tolerances). Indicate the critical shear stress (and critical velocity) in the test report. Submit the Flume Test results at the same time as the ACB and Geotextile Data.

2.1.1.2 Extrapolation of Hydraulic Stability

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NOTE: Preliminary research has indicated that extrapolation is conservative when extrapolating to thicker blocks, and unconservative when extrapolating to thinner blocks.

The paragraph has no description for similiar footprint, interlocking mechanism, and industry standards. Recommend that additional requirments be for those description be inserted based on actual field conditions.

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Extrapolation of critical shear stress for untested blocks within a similar family of ACB are subject to limitations. Use extrapolation only for blocks having a similar footprint area and interlock mechanism, but with variable thickness or net weight/area. Accept extrapolation only if the following conditions are met:

a. The extrapolation is in strict accordance with hydraulic similitude methods commonly accepted by the industry, and includes quantitative treatment for a block overturning failure mode.

b. The tested block is the smaller product size in both thickness and net weight/area, and extrapolation does not extend the critical velocity more than 3 meters per second 10 feet per second from the tested product size.

2.1.2 Matrix Assembly - Interlocking Blocks

Interlocking blocks are assumed to function without the use of cables or similar restraints. Place void filler to inhibit lateral movement and block pullout, cover the geotextile, and increase hydraulic stability.

2.1.3 Matrix Assembly - Cabled Systems

Interconnect cable tied concrete block by flexible cables running through the blocks. Penetrate each block by a cable that allows articulation of the blocks, but restrains removal of individual blocks. Place void filler to inhibit lateral movement, cover the geotextile, and increase hydraulic stability.[ ][Fabricate articulating concrete block, cables, and fittings into transportable mattresses at the manufacturer's plant.]

2.1.4 Structural requirements

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NOTE: Freeze-thaw Testing - The specifier should edit this paragraph based on the project's location. The default values correspond to the default values in ASTM C1372, Segmental Concrete Retaining Wall Units. The freeze thaw requirements for retaining wall blocks are referenced since they are similar products, ACB blocks can be produced by similar manufacturing methods, and retaining walls have been the subject of more freeze thaw durability research. The number of seasonal freeze thaw cycles for typical ACB's is likely less than for retaining walls. Chloride from deicing salts or sea water increases saturation of the concrete, and thus has a very pronounced affect on freeze thaw degradation.New procedures has been developed and should be investigated and specify to measure the rate of freeze thaw degradation from chloride. The amount of degradation that is unacceptable should be stated.

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Provide wet cast articulating concrete block using concrete as specified herein, or dry-cast by a vibratory block forming machine. Manufacture the blocks to the following requirements:

2.1.4.1 Compressive Strength

Provide a minimum compressive strength of 28 MPa 4000 psi for an average of 3 units, and 24 MPa 3500 psi for an individual unit. Determine compressive strength by ASTM C42/C42M for wet cast blocks, or by ASTM C140/C140M for dry cast blocks.

2.1.4.2 Water Absorption for Dry Cast Units

Provide a maximum water absorption for dry cast units of 145 kg/m^3 9 pcf for an average of 3 units, and 195 kg/m^3 12 pcf for an individual unit. Determine water absorption by ASTM C140/C140M.

[2.1.4.3 Saturated Surface-Dry Density

Provide a minimum saturated surface-dry density of [140] [_____] for average of 3 units, and [140] [_____] for an individual unit.

][2.1.4.4 Air Entraining

Air entrain wet cast concrete to contain between 4 and 7 percent total air

determined in accordance with ASTM C138/C138M.

][2.1.4.5 Freeze-Thaw Durability

For freeze-thaw durability tested in accordance with ASTM C1262/C1262M, specimens must comply with either of the following: (1) the weight loss of each of 5 specimens after 100 cycles must not exceed 1 percent; or (2) the weight loss of each of 5 specimens after 150 cycles must not exceed 1.5 percent.

]2.2 GEOTEXTILE

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NOTE: The AASHTO M 288 table provides survivability requirements. Class 1 is recommended for harsh or severe installation conditions where there is a potential for vehicular traffic, or where irregular sections may require removal and replacement of mattresses to achieve proper alignment. Class 2 is allowed where no vehicle traffic will occur on the installation, and where mattress placement is in regular, even reaches. Reference Protection of Work paragraph in Part 3.

Some manufactures require minimum geotextile properties for warranty coverage. Most manufacturers have recommended geotextiles, but these should be verified for compatibility with the subgrade soils.

Filters should not impede seepage. Clogging resistance is critical for uplift stability. Site specific design should be performed if any of the following problematic soil conditions are encountered: highly erodible soils such as non-cohesive silts, gap graded soils, or laminated sand/silt.

Some references for geotextile design include:
1. Koerner, "Designing with Geosynthetics", Prentice Hall.
2. FHWA, "Geosynthetic Design and Construction Guidelines."
3. Geosynthetics '95, "Geotextile Permeability Criteria for Revetments", pp. 217-230.

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 Geotechnical Fabrics Report magazine publishes an annual specifiers guide that is ideal for this purpose.

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Submit two samples of the proposed block at the same time as the ACB and Geotextile Data submittal. Provide samples that are typical of the size, texture, color, and finish. If the Contracting Officer is familiar with the product, this submittal may be waived. Geotextile used as filters below the ACB must be a [woven] [non-woven] fabric. The geotextile must meet the material properties specified in AASHTO M 288 for Class [2] strength property requirements and for permanent erosion control. Base filter requirements in AASHTO M 288 on in-situ soil with [less than 15 percent] [15 percent to 50 percent] [greater than 50 percent] passing the 0.075 mm sieve opening.Geotextile used as a filter below the ACB must be a [woven] [non-woven] fabric, meeting the requirements specified in Table 2. The property values (except for AOS) represent minimum average roll values (MARV) in the weakest principal direction.

TABLE 2. GEOTEXTILE PHYSICAL PROPERTIES

PROPERTY	TEST REQUIREMENT	TEST METHOD
Grab Tensile, N lbs.	[700 160 nonwoven]	ASTM D4632/D4632M
	[1100 250 woven]	
Tear Strength, N lbs.	[250 55 nonwoven]	ASTM D4533/D4533M
	[400 90 woven]	
Puncture Strength, N lbs.	[250 55 nonwoven]	ASTM D4833/D4833M
	[400 90 woven]	
Permittivity, 1/sec	[0.5]	ASTM D4491/D4491M
Apparent Opening Size, µm U.S. Sieve	[150 - 212][70 - 100]	ASTM D4751
Ultraviolet Stability	[50 percent]	ASTM D4355/D4355M

2.3 CABLE

2.3.1 Installation Requirements for Cable

Use cable for preassembled mattresses that is sufficiently sized and fastened for the size/weight of the assembled mattresses such that the assembled mattresses can be placed in compliance with OSHA standards. The manufacturer is responsible for determining the minimum cable strength compatible with the mattress size for safe handling. Base cable strength on a minimum factor of safety of 5, and include appropriate reduction factors for mechanically crimped cable, and other fasteners. If applicable, include the use of a spreader bar for placing the mattresses in loading conditions.

2.3.2 Fasteners Other than Cable

Any systems which rely on geotextiles (or other fabric integral with the mattress) to maintain block-to-block interconnection must meet the applicable portions of this specification for cables. Geosynthetics

strength must include appropriate factors of safety, with particular attention given to the grab points.

2.3.3 Design Requirements for Cable

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NOTE: The designer may need to research survivability of cables in the environment where the ACB will be placed. The installation requirements for cable strength usually govern, unless anchors are used.
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Use ropes manufactured from polyester, stainless steel wire, or galvanized steel wire for ACB's that rely on cables to maintain block to block interconnection. Provide cable with a minimum breaking strength of [_____] pounds. Construct polyester rope of high tenacity, large elastic modulus, continuous filament polyester fibers; and consisting of a core construction comprised of parallel fibers contained within an outer jacket or cover.

2.3.4 Anchors

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NOTE: Anchors require a cabled system. Anchors should be used with caution. Control of mattress uplift may only be successful for short term, low frequency, overload. ACB mattresses that are locally uplifted, with or without anchors, may show significant subgrade distortion, which could be a precursor to failure. Anchors spaced throughout the revetment also require special details to maintain integrity of the geotextile filter.

Because anchors are not required for typical installations, this paragraph may commonly be deleted. Where anchors are used for specialized applications, add requirements for anchor materials, minimum property requirements, and design characteristics.

Drawings must detail location and spacing of anchors.
****

Submit calculations for the anchor pullout capacity. Tabulated manufacturer's data is acceptable, provided the embedment soils are proven applicable to the project site. Select anchors with an ultimate vertical pullout resistance for the project site soil conditions of at least [_____] pounds. Provide anchors that are capable of being attached directly to the ACB mat in a manner which will achieve little or no slack in the cable system or gaps in the ACB mattress. Attach anchors to the mat in such a manner that they will not be affected by tampering or vandalism. Anchors must have the capability of being load-tested to the specified pull-out capacity.

2.4 VOID FILLER

2.4.1 Aggregate

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NOTE: Aggregate is used below the normal water level, or where turf can not be established. Department of Transportation specifications for road base aggregate have been used, such as ASTM D1241, Gradation B.
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Provide aggregate for filling the voids in the block meeting the requirements of [_____].

2.4.2 Topsoil and Seed

Provide topsoil for filling the voids in the block and seed for turf establishment meeting the requirements of Section 32 92 19 SEEDING.

PART 3 EXECUTION

3.1 SUBGRADE PREPARATION

Place the ACB revetment on undisturbed native soils, or acceptably placed and compacted fill. Do not place the ACB on surfaces that contain mud, frost, organic soils, embankment that has not met compaction requirements, or where the Contracting Officer determines that unsatisfactory material remains in or under the subgrade.

3.1.1 Clearing

Completely remove all vegetation as specified in Section [31 00 00 EARTHWORK] [31 11 00 CLEARING AND GRUBBING]. Completely remove root balls and stump. Remove remaining roots from trees and brush to a depth of 0.3 meters 1 foot below the subgrade surface. Rake and remove loose roots and twigs, turf clods, stones larger than 13 mm 1/2 inch diameter, and other debris from the final surface. Correct rills and gullies from erosion.

3.1.2 Bank Grading

Finish grading to a smooth surface, typical of that obtainable with a dozer and blade. A rough surface typically obtained with a backhoe or dragline will not be acceptable. When ACB placement in water is shown on the drawings, the slope stability and grading requirements must be determined by a qualified geotecnical engineer.[When natural shorelines require grading in preparation for ACB installation, observe the bank stratification and document in daily Contractor Quality Control reports. Use grading practices that avoid spreading fine grained soils over more pervious soils, particularly near the toe of slopes. If inadequate material is available to comply with this requirement, notify the Contracting Officer.].

3.1.3 Compaction and Subgrade Finishing

[Compact fill soils to the specified density in Section 31 00 00 EARTHWORK.] Compact incidental grading (where embankment is not otherwise specified) by heavy equipment or by tamping with a bucket to a density characteristic of the surrounding soils. Compact the final surfaces

accessible by compaction equipment with a smooth drum roller or vibratory plate tamper until there is no further evidence of consolidation. Where slopes limit operation of compaction equipment, the final surface conditions must be determined by a qualified geotechnical engineer. Correct localized loose or soft zones.

3.1.4 Grade Tolerances

Provide grading tolerance within 50 mm 2 inches from the prescribed elevations, with no abrupt variations that would cause unacceptable projections of individual blocks.

3.1.5 Subgrade Surface Tolerances

Maintain the subgrade in a smooth condition between installation of the geotextile and the blocks. Rake windrows, stones, clods of cohesive soil, and irregularities smooth. Correct ruts, rills and gullies resulting from traffic, precipitation runoff, groundwater seepage, prior to installation of blocks.

3.2 GEOTEXTILE INSTALLATION

3.2.1 General

See "block installation" paragraph for drawing requirements. Lay the geotextile flat and smooth so that it is in direct contact with the subgrade. Provide geotextile that is free of tension, folds, and wrinkles. Minimize the number of seams and overlaps by selective orientation of geotextile panels, within the limitations of maintaining a consistent pattern. Place geotextile in accordance with the requirements of paragraph GEOTEXTILE. Place immediately prior to block installation, if necessary to limit damage to the geotextile from equipment or repeated pedestrian traffic and limit disturbance of the subgrade from precipitation or runoff.

3.2.2 Geotextile Seams

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NOTE: Sewn, welded or glued seams are desirable for shoreline protection (or where flow reversal occurs). Substitute the following for sewn seams:

Seams must be continuously sewn at the locations shown on the drawings. The minimum distance from the geotextile edge to the stitch line nearest to that edge must be 75 mm 3 inches. Seam strength must meet the minimum requirements specified in AASHTO M288 for a class 2 geotextile. Take quality assurance samples at the request of the Contracting Officer. Tie off the thread at the end of each seam run to prevent unraveling. Seams must be on the top side of the geotextile to allow inspection. Sew skipped stitches or discontinuities with an extra line of stitching with a minimum of 450 mm 18 inches of overlap.

Pins/staples may not be desirable where filtration is critical.

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Overlap seams a minimum of 450 mm 18 inches or according to manufacturers recommendations, whichever is the most stringent requirement. Provide shingled seams on slopes and butt end seams so that runoff and channel flow passes over the fabric. Secure geotextile panels before block placement by adequate sandbags, spare blocks, or pins/staples.

3.3 BLOCK INSTALLATION

Place all blocks in accordance with the manufacturer's recommendations and the Contractor's approved shop drawings. Submit drawings showing details of the ACB and Geotextile Installation, including the block layout patterns in relation to the feature alignment, anticipated locations of cast-in-place concrete joints, mattress junction details, soil anchors, and proposed installation methods for void filling materials.

3.3.1 Placement of Pre-Assembled Mattresses

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NOTE: The spreader bar may be deleted where tolerances are a minor concern. The spreader bar may have associated cost when placing one end of the mattress in water, due to work in disconnecting the rigging on the wet end.
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[Place pre-assembled ACB mattresses with mattresses attached to a spreader bar to aid in lifting, aligning and placing the mattresses.]Place mattresses directly into position, with a maximum space or gap between mattresses of 75 mm 3 inches in excess of the nominal joint spacing of blocks within the mattress. Lift and reset mattresses out of alignment. Do not push or pull mattresses laterally after they are in contact with the geotextile. Do not accept overlapping of mats and blocks that project vertically more than 25 mm 1 inch beyond the adjacent blocks are not permitted. [As adjacent mats are placed, secure them to each other by fastening the protruding horizontal and vertical cable connections and end cable loops together along each side of the mats.]

3.3.2 Hand Placement of Interlocking Blocks

Space hand placed blocks to maximize the ACB ability to articulate. Use adequate alignment control, such as string lines, to keep the block pattern in alignment and the joint spacing consistent and uniform. Initially, no more than two working block rows must progress simultaneously in the direction of placement. Additional working rows may be added after experience shows that true lines are maintained. Choose a convenient location as the starting position for ACB placement for control of the block pattern alignment. Sumbit the starting position for placement of the ACB to the Contracting Officer for approval.

3.3.2.1 Target Joint Spacing

Install interlocking blocks with a uniform aperture in the interlocking connections. Neutrally space the target joint spacing with equal free-play for the joint to open and close.

3.3.2.2 Correction of Joint Spacing

If the block pattern becomes skewed to an extent that blocks bind, joints

close, or blocks stickup, then remove and replace the placed ACB that is determined to be out of tolerance. Where the nonconformance of the joint spacing is due to project features, such as warped slopes or anchor trenches, then field locate cast-in-place concrete joints in concurrence with the Contracting Officer.

3.3.2.3 Maintenance of Joint Spacing

If the block pattern becomes skewed to an extent that the joint freeplay is not acceptable to the Contracting Officer, then field locate cast-in-place concrete joints as directed by the Contracting Officer.

3.3.2.4 Block Layout Pattern Dependent on Project Features

If the block pattern is shown to be maintained parallel and perpendicular to selected project features, such as the crest/toe of levee/channel slopes, then implement field location of cast-in-place concrete joints as needed, and as directed by the Contracting Officer.

3.3.3 Tolerances

3.3.3.1 Vertical Tolerance

Maximum acceptable block projections (vertical offset from adjacent blocks) for "installation in the dry" must not exceed 0.5 inches for interlocking blocks, 25 mm 1.0 inch for cabled systems. Typical block projections must be less than half the maximum projections.

3.3.3.2 Horizontal Tolerance

Less than half the maximum projections.

3.4 ANCHORS

Carefully position anchors for attachment to the ACB. Align rigid shafts with the ACB cables. Flexible anchors (cables, ropes, and tie offs) must be linear between the ACB fastener and the restraining device before tensioning. Seal gaps and penetrations in the geotextile to allow for penetration of the anchor [in accordance with the drawing details].

3.5 CONCRETE JOINTS

3.5.1 General Requirements

Minimize use of cast in place concrete joints to the extent practicable. All concrete joints not shown on the shop drawings must be reviewed and approved by the Contracting Officer prior to field placement. Joints that require concrete include:

a. Joints between cable tied mattresses where the joint is 75 mm 3 inches wider than the nominal joint.

a. Joints where block interlock is discontinuous.

b. Abutments where the ACB meets headwalls, pipe penetrations, or sidewalks.

c. Any areas where there are partial blocks (to avoid small blocks with reduced hydraulic stability).

Field placed concrete must have a specified strength that is 1000 psi greater than the specified strength of the ACB concrete miture. The durability properties as the be proportioned for similar strength and durability properties of the ACB concrete must meet applicable portions of Section [03 30 00 CAST-IN-PLACE CONCRETE] [03 30 53 MISCELLANEOUS CAST-IN-PLACE CONCRETE]. Complete all cable ties and anchoring prior to placing concrete.

3.5.2 Abutments

The ACB must abut pipe outlets, retaining walls, flood walls, head walls, sidewalks, and other abutments in a neat appearance. Unless a specific detail is indicated on the drawings, fill voids with partial blocks and fill the gap with cast-in-place concrete. Place the concrete flush with the surface of the blocks, and float finish. Strike control joints both vertically and horizontally in locations where gap fills exceed the width or height of a single ACB. Fill control joints with a polyurethane base sealant to be approved by the Contracting Officer prior to usage.

3.6 VOID FILLER AND SEEDING

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NOTE: Topsoil will consolidate in the voids. Overfilling above the top of block is common to increase the topsoil fill level, but may increase sedimentation during turf establishment.

Broadcast seeding of ACB is difficult because it is difficult to rake the seed in. Hydroseeding of ACB is difficult because of channelization of runoff and susceptibility of the void filler to desiccation. In areas where establishment of quality turf is important, it has been successful to blend a rich mixture of seed (about 10 times the normal application rate, or about 0.5 to 1 kg/cubic m 1 to 2 pounds per cubic yard into the topsoil prior to placing. Hanging geogrids and retaining wall geogrids, now exist to facilitate vegetation, which may be useful in establishing vegetation. Watering during establishment is more critical than typical turf due to the heat absorption of the concrete blocks and capillary break of the geotextile.

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Fill the voids of the articulating concrete block mats with topsoil, except fill voids below the normal water level with aggregate void filler. Complete all cable ties and anchoring prior to filling voids. Complete seeding and maintenance in accordance with Section 32 92 19 SEEDING.

3.7 PROTECTION OF WORK

Protect work against damage from subsequent operations. Remove and replace displaced or broken blocks to conform to all requirements of this section. Do not incorporate damaged material. Do not allow equipment on the ACB that could crack, cause abrasion, or otherwise damage the blocks. Do not operate vehicles directly on geotextile, except that rubber tired vehicles may operate directly on short reaches of geotextile that meets or

exceeds AASHTO M 288 survivability requirements for Class 1 geotextile, if there is no rutting, if the vehicle access is necessary to accomplish the work, and if the Contracting Officer observes the operation and approves. Do not operate vehicles on the ACB until (during or after) placement of void filler. Restrict vehicle traffic on the ACB to light weight rubber tired vehicles, and where intermittent access is necessary to accomplish the work. Do not establish routine haul routes on the ACB. These allowances do not waive the Contractor's obligation to maintain the installation until acceptance, and verify that vehicle access does not crack, or in any way damage, the ACB.

3.8 QUALITY CONTROL TESTING

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NOTE: The manufacturer should have completed similar testing for it's own QC. The following testing is suggested as an acceptance check on a schedule typical for QA. The suggested frequency is on the order of 0.5 percent of construction cost.

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Perform the following testing independent of the manufacturing process, by an agency other than the manufacturer. Sample and test the ACB blocks for compressive strength, water absorption and unit weight. The sample frequency must be 3 specimens for each 2500 m^2 3000 SY. Test methods are consistent with those specified in PART 2 PRODUCTS.

-- End of Section --