ARTICULATING CONCRETE BLOCK (ACB)
REVETMENT SYSTEM SPECIFICATIONS

PART 1: GENERAL

A. Scope of Work

The Contractor shall furnish all labor, materials, equipment, and incidentals required and perform all operations in connection with the installation of cellular concrete erosion control mats in accordance with the lines, grades, design and dimensions shown on the Contract Drawings and as specified herein.

B. Submittal

The Contractor shall submit to the Engineer all manufacturers' hydraulic testing and calculations in support of the proposed cellular concrete mat system and geotextile.

The Contractor shall furnish the manufacturer's certificates of compliance for cellular concrete blocks/mats, revetment cable, and any revetment cable fittings and connectors. The Contractor shall also furnish the manufacturer's specifications, literature, shop drawings for the layout of the mats, and any recommendations, if applicable, that are specifically related to the project.

Alternative materials may be considered. Such materials must be pre-approved in writing by the Engineer prior to bid date. Alternative material packages must be submitted to the Engineer a minimum of fifteen (15) days prior to bid date. Submittal packages must include, as a minimum, the following:

1. Full-scale laboratory testing performed by the submitting manufacturer and associated engineered calculations quantifying the hydraulic capacity of the proposed cellular concrete mat system in similar conditions to the specific project.

2. A list of 5 comparable projects, in terms of size and applications, in the United States, where the results of the specific alternate revetment system use can be verified after a minimum of one (5) year of service life.

PART 2: PRODUCT

A. General

All cellular concrete mats shall be prefabricated as an assembly of concrete blocks, with specific hydraulic capacities, laced with revetment cables. Cellular concrete mats may be assembled on-site by hand-placing the individual units either with or without subsequent insertion of cables.

Individual units in the system shall be staggered and interlocked for enhanced stability. The mats shall be constructed of open and/or closed cell units as shown on the contract

drawings. The open cell units have two (2) vertical openings of rectangular cross section with sufficient wall thickness to resist breakage during shipping and installation. Parallel strands of cable shall extend through two (2) cable ducts in each block allowing for longitudinal binding of the units within a mat. Each row of units shall be laterally offset by one-half of a block width from the adjacent row so that any given block is cabled to four other blocks (two in the row above and two in the row below).

Each block shall incorporate interlocking surfaces that minimize lateral displacement of the blocks within the mats when they are lifted by the longitudinal revetment cables. The interlocking surfaces must not protrude beyond the perimeter of the blocks to such an extent that they reduce the flexibility or articulation capability of the cellular mats or become damaged or broken when the mats are lifted during shipment or placement. Once the mats are in place, the interlocking surfaces shall minimize the lateral displacement of the blocks even if the cables should become damaged or removed. The mats must be able to flex a minimum of 18° between any given row or column of blocks in the uplift direction and a minimum of 45° in the downward direction.

The cables inserted into the mats shall form lifting loops at one end of the mat with the corresponding cable ends spliced together to form a lifting loop at the other end of the mat. The Engineer shall approve appropriate sleeves for use in order to splice the lifting loop. The cables shall be inserted after sufficient time has been allowed for the concrete to complete the curing process.

The cellular concrete mats shall be placed on a filter fabric as specified herein. Under no circumstances shall the filter fabric be affixed (i.e. chemically bonded to the blocks) to the mattress in a manner in which would jeopardize the functionality of the filter fabric. Specifically, the filter fabric shall be independent of the block system.

Certification (Open-Channel Flow): Cellular concrete mats will only be accepted when accompanied by documented hydraulic performance characteristics that are derived from tests under controlled flow conditions. Testing guidelines should conform to U.S. Federal Highway Administration and U.S. Bureau of Reclamation Testing Protocol as documented in “Minimizing Embankment Damage During Overtopping Flow”, Report No. FHWA-RD-88-181 and all hydraulic performance testing shall be performed in a 2H:1V flume.

Performance (Open-Channel Flow): The design of the cellular concrete mats shall be in accordance with the Factor-of-Safety design methodology as described in "Erosion and Sedimentation" by Pierre Julien, Cambridge University Press, 1995. The minimum designed safety factor shall be 1.5 by utilizing the following equation.

$$SF = ((\vartheta_2 / \vartheta_1)\, \alpha_\theta) / ((1 - \alpha_\theta^2)^{0.5} \cos\beta + \eta\, (\vartheta_2 / \vartheta_1) + (\vartheta_3\, F_d' \cos\delta + \vartheta_4\, F_l') / \vartheta_1 W_s) = 1.5$$

The analysis shall be performed based upon the stability of the mat due to gravity forces alone, neglecting conservative forces added by cabling, mechanical anchorage, contact with adjacent blocks, or other restraints not attributable to gravity based forces. The analysis must account for a 0.5-inch block projection.

In order to analyze the performance of the unit, the hydraulic information listed below is required:

TABLE 1. ACB HYDRAULIC INFORMATION

Velocity (ft/sec)	?
Shear Stress (lb/ft^2)	?
Friction or Bed Slope (ft/ft)	?.
Side Slope (_H:1V)	?
Allowable Unit Protrusion (in)	0.5 for Uniform Units & 0.0 for 0.5 inch Tapered Units

B. Cellular Concrete Blocks

1. Scope

1.1 This specification covers erosion control mats used in revetments for soil stabilization.

Note 1 - Concrete units covered by this specification are made from lightweight or normal weight aggregates, or both.

Note 2 - The values stated in U.S. customary units are to be regarded as the standard.

2. Materials

2.1 Cementitious Materials - Materials shall conform to the following applicable ASTM specifications:

2.1.1 Portland Cements - Specification C 150, for Portland Cement.

2.1.2 Blended Cements - Specification C 595, for Blended Hydraulic Cements.

2.1.3 Hydrated Lime Types - Specification C 207, for Hydrated Lime Types.

2.1.4 Pozzolans - Specification C 618, for Fly Ash and Raw or Calcined Natural Pozzolans for use in Portland Cement Concrete.

2.2 Aggregates shall conform to the following ASTM specifications, except that grading requirements shall not necessarily apply:

2.2.1 Normal Weight - Specification C 33, for Concrete Aggregates.

3. Casting

3.1 The concrete units shall be produced by a dry cast method. The dry cast units obtain strength in a shorter duration as well as an increase in the durability and overall quality of product.

4. Physical Requirements

4.1 At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 2 listed below.

TABLE 2. PHYSICAL REQUIREMENTS

Compressive Strength Net Area Min. p.s.i (mPa)		**Water Absorption Max. lb/ft^3 (kg/m^3)**	
Avg. of 3 units	Individual Unit	Avg. of 3 units	Individual Unit
4,000 (27.6)	3,500 (24.1)	10 (160)	12 (192)

4.2 When applicable, the manufacturer shall meet all requirements pertaining to a concrete unit's durability pertaining to a freeze-thaw environment.

4.3 Units shall be sampled and tested in accordance with ASTM D 6684-04, Standard Specification for Materials and Manufacture of Articulating Concrete Block (ACB) Revetment Systems.

5. Visual Inspection

5.1 All units shall be sound and free of defects that would interfere with either the proper placement of the unit or impair the performance of the system. Surface cracks incidental to the usual methods of manufacture, or surface chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection.

5.2 Cracks exceeding 0.25 inches (.635 cm) in width and/or 1.0 inch (2.54 cm) in depth shall be deemed grounds for rejection.

5.3 Chipping resulting in a weight loss exceeding 10% of the average weight of a concrete unit shall be deemed grounds for rejection.

5.4 Blocks rejected prior to delivery from the point of manufacture shall be replaced at the manufacturer's expense. Blocks rejected at the job site shall be repaired with structural grout or replaced at the expense of the contractor.

6. Sampling and Testing

6.1 The purchaser or their authorized representative shall be accorded proper access to facilities to inspect and sample the units at the place of manufacture from lots ready for delivery.

6.2 Field installation procedures shall comply with the procedures utilized during the hydraulic testing procedures of the recommended system. All system restraints and ancillary

components (such as synthetic drainage mediums) shall be employed as they were during testing. For example, if the hydraulic testing installations utilize a drainage layer then the field installation must utilize a drainage layer; an installation without the drainage layer would not be permitted.

6.3 The theoretical force-balance equation used for performance extrapolation tends for conservative performance values of thicker concrete units based on actual hydraulic testing of thinner units. When establishing performance values of thinner units based on actual hydraulic testing of thicker units, there is a tendency to overestimate the hydraulic performance values of the thinner units. Therefore, all performance extrapolation must be based on actual hydraulic testing of a thinner unit then relating the values to the thicker units in the same "family" of blocks.

6.4 Additional testing, other than that provided by the manufacturer, shall be borne by the purchaser.

Manufacturer

Cellular concrete blocks shall be ARMORFLEX® as manufactured and sold by:

ARMORTEC, A Contech Company
9025 Centre Pointe Dr., Suite 400
West Chester, OH 45269
Phone: 1-800-645-7000
Fax: 1-513-645-7993

The ARMORFLEX® cellular concrete blocks shall have the following nominal characteristics:

TABLE 2. STANDARD SIZES OF ARMORFLEX® BLOCKS

CLASS	**TYPE**	**BLOCK WEIGHT**		**BLOCK SIZE**			**OPEN AREA %**
		Lbs (kg)	**Lbs./Sq.ft. (kg/m^2)**	**Length inches (cm)**	**Width inches (cm)**	**Height inches (cm)**	
30S	Open	31-36 (14-16)	32-37 (152-176)	13.0 (33.0)	11.6 (29.5)	4.75 (12.1)	20
50S	Open	45-52 (20-24)	45-53 (220-254)	13.0 (33.0)	11.6 (29.5)	6.0 (15.2)	20
45S	Closed	39-45 (18-20)	40-45 (191-220)	13.0 (33.0)	11.6 (29.5)	4.75 (12.1)	10
55S	Closed	53-61 (24-28)	54-62 (259-298)	13.0 (33.0)	11.6 (29.5)	6.0 (15.2)	10
40	Open	62-71	35-40	17.4	15.5	4.75	20
50	Open	81-94 (37-43)	46-53 (396-460)	17.4 (44.2)	15.5 (39.4)	6.0 (15.2)	20

70	Open	120-138 (55-63)	68-78 (587-675)	17.4 (44.2)	15.5 (39.4)	9.0 (22.9)	20
45	Closed	78-89	43-50	17.4	15.5	4.75	10
55FT	Closed	94-108 (43-49)	53-61 (460-528)	17.4 (44.2)	15.5 (39.4)	6.0 (15.2)	10
75	Closed	120-138 (55-63)	68-78 (587-675)	17.4 (44.2)	15.5 (39.4)	7.5 (19.1)	10
85	Closed	145-167 (66-76)	82-95 (709-817)	17.4 (44.2)	15.5 (39.4)	9.0 (22.9)	10
40L	Open	95-111 (43-51)	35-41 (303-347)	17.4 (44.2)	23.6 (59.9)	4.75 (12.1)	20
70L	Open	181-211 (82-96)	68-78 (587-675)	17.4 (44.2)	23.6 (59.9)	9.0 (22.9)	20
45L	Closed	113-132 (51-60)	43-50 (382-435)	17.4 (44.2)	23.6 (59.9)	4.75 (12.1)	10
85L	Closed	219-254 (100-116)	82-95 (709-817)	17.4 (44.2)	23.6 (59.9)	9.0 (22.9)	10

C. Revetment Cable and Fittings

Option 1. Polyester Revetment Cable and Fittings. Revetment cable shall be constructed of high tenacity, low elongating, and continuous filament polyester fibers. Cable shall consist of a core construction comprised of parallel fibers contained within an outer jacket or cover. The weight of the parallel core shall be between 65% to 70% of the total weight of the cable. The revetment cable shall have the following physical properties:

Elongation requirements specified below are based upon stabilized new, dry cable. Stabilization refers to a process in which the cable is cycled between fifty (50) times $200D^2$ and a load corresponding to 10%, and a load equal to cable's breaking 20% or 30% of the approximate average strength. Relevant elongation values are as shown in the table below. The tolerance on these values is $\pm$ 5%.

Polyester Cable				
Nominal Cable Dia.	Approx. Ave. Strength		Weight per Length	
(in.)	(Lbs)	(kN)	(Lbs)/100ft	(kg/m)
1/4	3,000	13.3	2.2	0.03
5/16	7,000	31.1	4.4	0.07
3/8	10,000	44.5	5.5	0.08
1/2	15,000	66.7	9.7	0.14

ELASTIC ELONGATION

at Percentage of Break Strength		
10%	20%	30%
0.6	1.4	2.2

The revetment cable shall exhibit resistance to most concentrated acids, alkalis and solvents. Cable shall be impervious to rot, mildew and degradation associated with marine organisms. The materials used in the construction of the cable shall not be affected by continuous immersion in fresh or salt water.

Selection of cable and fittings shall be made in a manner that insures a safe design factor for mats being lifted from both ends, thereby forming a catenary. Consideration shall be taken for the bending of the cables around hooks or pins during lifting. Revetment cable splicing fittings shall be selected so that the resultant splice shall provide a minimum of 60% of the minimum rated cable strength. Fittings such as sleeves and stops shall be aluminum and washers shall be galvanized steel unless otherwise shown on the Contract Drawings.

Option 2. Galvanized Steel Revetment Cable and Fittings. Revetment cable shall be constructed of preformed galvanized aircraft cable. The cables shall be made from individual wires and strands that have been formed during the manufacture into the shape they have in finished cable.

Cable shall consist of a core construction comprised of seven (7) wires wrapped within seven (7) or nineteen (19) wire strands. The revetment cable shall have the following physical properties:

Galvanized Cable					
Nominal Cable Dia.	Type	Approx. Ave. Strength		Weight per Length	
(in.)		(Lbs)	(kN)	(Lbs)/100ft	(kg/m)
1/8	7x7	1,700	7.5	2.8	0.04
3/16	7x7	3,700	16.4	6.2	0.09
1/4	7x7	6,100	27.1	10.6	0.16
5/16	7x19	9,800	43.6	17.3	0.26
3/8	7x19	14,400	64.1	24.3	0.36

The revetment cable shall exhibit resistance to mild concentrations of acids, alkalis, and solvents. Fittings such as sleeves and stops shall be aluminum, and the washers shall be galvanized steel. Furthermore, depending on material availability, the cable type (7x7 or 7x19) can be interchanged while always ensuring the required factor of safety for the cable.

Selection of cable and fittings shall be made in a manner that insures a safe design factor for mats being lifted from both ends, thereby forming a catenary. Consideration shall be taken for the bending of the cables around hooks or pins during lifting. Revetment cable splicing fittings shall be selected so that the resultant splice shall provide a minimum of 75% of the minimum rated cable strength.

D. Anchors

Where permanent anchoring is required, e.g. hanging mats on steep slopes without toe construction, the cables (polyester or steel) shall be attached to the anchoring system as indicated on the Contract Drawings. The design and layout of the anchored system shall be design by a separate entity other than Armortec.

E. Filter Fabric

The geotextile filter shall meet the minimum physical requirements listed in Table No. 3 of these Specifications. Consultation with the manufacturer is recommended.

The geotextile must be permitted to function properly by allowing relief of hydrostatic pressure; therefore fine soil particles shall not be allowed to clog the filter fabric.

The geotextile fiber shall consist of a long-chain synthetic polymer composed of at least 85 percent by weight of propylene, ethylene, ester, or amide, and shall contain stabilizers and/or inhibitors added to the base plastic, if necessary, to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The edges of the geotextile shall be finished to prevent the outer fiber from pulling away from the geotextile.

The Contractor shall furnish the Engineer, in duplicate, manufacturer's certified test results showing actual test values obtained when the physical properties are tested for compliance with the specifications.

During all periods of shipment and storage, the filter fabric shall be protected from direct sunlight, ultraviolet rays and temperatures greater than 140 degrees Fahrenheit. To the extent possible, the fabric shall be maintained wrapped in its protective covering. The geotextile shall not be exposed to sunlight, ultraviolet rays until the installation process begins.

TABLE 3. PHYSICAL REQUIREMENTS

Physical Property	Test Procedure	Minimum Value
Grab Tensile Strength (Unaged Geotextile)	ASTM D4632	200 Lbs. (in any principal direction)
Breaking Elongation (Unaged Geotextile)	ASTM D4632	50% max. (in any principal direction)
Burst Strength	ASTM D3786	400 p.s.i
Puncture Strength	ASTM D4833	115 lbs.
A.O.S., U.S. Std. Sieve	ASTM D4751	see Design Manual
% Open Area	CWO-22125-86	See Design Manual

Permittivity	ASTM D4491	See Design Manual

Final acceptance of the filtration geotextile by the Engineer shall be dependent upon the geotextile performance when tested in accordance with ASTM D5101, Standard Test Method for Measuring the Soil-Geotextile System Clogging by the Gradient Ratio test or the Hydraulic Conductivity Ratio test. Soil characteristics such as grain size distribution and plasticity shall be determined for every 200,000 square feet of geotextile installed or for each source of borrow material used during construction. Significant differences in soil characteristics shall require further performance testing by either the Gradient Ratio or the Hydraulic Conductivity Ratio tests at the discretion of the Engineer. The locations for which the material to be tested is extracted shall be approved by the Engineer. The Contractor shall provide the site-specific soil and modified proctor curves for the site-soil, at his own expense, to the manufacturer. Also, the contractor shall be responsible for the performance of the test by a certified independent laboratory experienced in performing such test. The test shall be performed under the actual field soil conditions or as otherwise required by the Engineer.

At the time of installation, the filter fabric shall be rejected if it has been removed from its protective cover for over 72 hours or has defects, tears, punctures, flow deterioration, or damage incurred during manufacture, transportation or storage. With the acceptance of the Engineer, placing a filter fabric patch over the damaged area prior to placing the mats shall repair a torn or punctured section of fabric. The patch shall be large enough to overlap a minimum of three (3) feet in all directions.

In the event pre-assembled panels of fabric are required, the panels of filter fabric shall be sewn together at the manufacturer or another approved location.

F. Size of Cellular Concrete Mats

General. The cellular concrete blocks, cables and fittings shall be fabricated at the manufacturer or another approved location into mats with a width of up to eight (8) feet and a length up to forty (40) feet, which is approved by the Engineer.

Mat Length: The cellular concrete mats shall have the ability for fabrication in various lengths, widths, and in combinations of length and/or widths. Special mats are a combination of two opposing dimensions either in the longitudinal or transverse direction of the mats. The special mats are available in various dimensions that allow for a custom fit to a site-specific project.

PART 3: FOUNDATION PREPARATION, GEOTEXTILE AND MAT PLACEMENT

A. Foundation Preparation

General. Areas on which filter fabric and cellular concrete blocks are to be placed shall be constructed to the lines and grades shown on the Contract Drawings and to the tolerances specified in the Contract Documents, and approved by the Engineer.

Grading. The slope shall be graded to a smooth plane surface to ensure that intimate

contact is achieved between the slope face and the geotextile (filter fabric), and between the geotextile and the entire bottom surface of the cellular concrete blocks. All slope deformities, roots, grade stakes, and stones which project normal to the local slope face must be re-graded or removed. No holes, "pockmarks", slope board teeth marks, footprints, or other voids greater than 1.0 inch in depth normal to the local slope face shall be permitted. No grooves or depressions greater than 0.5 inches in depth normal to the local slope face with a dimension exceeding 1.0 foot in any direction shall be permitted. Where such areas are evident, they shall be brought to grade by placing compacted homogeneous material. The slope and slope face shall be uniformly compacted, and the depth of layers, homogeneity of soil, and amount of compaction shall be as required by the Engineer.
Excavation and preparation for anchor trenches, flanking trenches, and toe trenches or aprons shall be done in accordance to the lines, grades and dimensions shown in the Contract Drawings. The anchor trench hinge-point at the top of the slope shall be uniformly graded so that no dips or bumps greater than 0.5 inches over or under the local grade occur. The width of the anchor trench hinge-point shall also be graded uniformly to assure intimate contact between all cellular concrete blocks and the underlying grade at the hinge-point.

Inspection. Immediately prior to placing the filter fabric and cellular concrete blocks, the prepared subgrade shall be inspected by the Engineer as well as the owner's representative. No fabric or blocks shall be placed thereon until that area has been approved by each of these parties.

B. Placement of Geotextile Filter Fabric

General. Filter Fabric, or filtration geotextile, as specified elsewhere, shall be placed within the limits shown on the Contract Drawings.
Placement. The filtration geotextile shall be placed directly on the prepared area, in intimate contact with the subgrade, and free of folds or wrinkles. The geotextile shall not be walked on or disturbed when the result is a loss of intimate contact between the cellular concrete block and the geotextile or between the geotextile and the subgrade. The geotextile filter fabric shall be placed so that the upstream strip of fabric overlaps the downstream strip. The longitudinal and transverse joints shall be overlapped at least two (3) feet. The geotextile shall extend at least one foot beyond the top and bottom revetment termination points. If cellular concrete blocks are assembled and placed as large mattresses, the top lap edge of the geotextile should not occur in the same location as a space between cellular concrete mats unless the space is concrete filled.

C. Placement of Cellular Concrete Blocks/Mats

General. Cellular concrete block/mats, as specified in Part 2:A of these Specifications, shall be constructed within the specified lines and grades shown on the Contract Drawings.

Placement. The cellular concrete blocks shall be placed on the filter fabric in such a manner as to produce a smooth plane surface in intimate contact with the filter fabric. No individual block within the plane of placed cellular concrete blocks shall protrude more than one-half inch or as otherwise specified by the Engineer. To ensure that the cellular concrete blocks are flush and develop intimate contact with the subgrade, the blocks shall

be "seated" with a roller or other means as approved by the Engineer.

If assembled and placed as large mattresses, the cellular concrete mats shall be attached to a spreader bar or other approved device to aid in the lifting and placing of the mats in their proper position by the use of a crane or other approved equipment. The equipment used should have adequate capacity to place the mats without bumping, dragging, tearing or otherwise damaging the underlying fabric. The mats shall be placed side-by-side and/or end-to-end, so that the mats abut each other. Mat seams or openings between mats greater than two (2) inches shall be filled with 4000 p.s.i. non-shrink grout. Whether placed by hand or in large mattresses, distinct changes in grade that results in a discontinuous revetment surface in the direction of flow shall require a grout seam at the grade change location so as to produce a continuous surface.

Anchor trenches and side trenches shall be backfilled and compacted flush with the top of the blocks. The integrity of the trench backfill must be maintained so as to ensure a surface that is flush with the top surface of the cellular concrete blocks for its entire service life. Toe trenches shall be backfilled as shown on the Contract Drawings. Backfilling and compaction of trenches shall be completed in a timely fashion. No more than 500 linear feet of placed cellular concrete blocks with non-completed anchor and/or toe trenches shall be permitted at any time.

Finishing. The cells or openings in the cellular concrete blocks shall be backfilled and compacted immediately with suitable material to assure there are no voids and so that material extends from the filter fabric to one-inch above the surface of the cellular concrete block. Backfilling and compaction shall be completed in a timely manner so that no more than 500 feet of exposed mats exist at any time.

Consultation. The manufacturer of the cellular concrete blocks/mats shall provide design and construction advice during the design and initial installation phases of the project when required.