

**ARMORFLEX® REVETMENT SYSTEM SPECIFICATION  
DURING WAVE ATTACK APPLICATIONS**

**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 manufacturer's performance research results and calculations in support of the cellular concrete mat system and geotextile proposed for use. All calculations must be made in accordance with PART 2.A. of this specification.

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: PRODUCTS**

**A. General**

All cellular concrete mats shall be pre-manufactured as an assembly of concrete blocks, with specific hydraulic capacities, bound into mats by the use of revetment cables. Cellular concrete mats may be assembled on-site by hand-placing individual blocks with subsequent insertion of cables.

Individual blocks in the cellular mats shall be staggered and interlocked for enhanced stability. The open cell version of the block has two (2) vertical openings of rectangular cross section with sufficient wall thickness to resist breakage during shipping and installation. The mats shall be constructed of open and/or closed cell blocks as shown on the contract drawings. Parallel strands of cable shall extend through two (2) ducts in each block in a manner which provides for longitudinal binding of the blocks within the mats. Each row of blocks shall be laterally offset by one-half 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).

The gross area of each individual block in direct contact with the protected subgrade shall be no less than one square foot. Each block shall incorporate interlocking surfaces that prevent 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 prevent 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 20 degrees between any given row or column of blocks in the uplift direction and a minimum of 45 degrees in the downward direction.

The cables shall be inserted into the mats in such a manner to 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 with sleeves approved by the Engineer.

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 (Waves):** All cellular concrete mats will only be accepted when accompanied by documented hydraulic performance characteristics, derived from tests under controlled wave conditions. Tests must have been conducted and monitored by an institution, public or private, which is experienced in performing wave attack studies on cellular concrete mats or similar hard-armor erosion protection products. The testing institution must have performed a minimum of three (3) such wave studies on hard-armor erosion protection systems.

**Performance (Waves):** The design of the cellular concrete mats shall be in accordance with the analytical model to predict stability of block revetments as it is developed for the Dutch Ministry of Transport and Public Works. The

calculation of the performance of the cellular concrete mats under wave attack is based on the positive interaction of the individual blocks. The influence of friction and block motion on the stability of the mattress must have been deduced from the results of large scale model tests performed by an institution experienced in conducting such tests. The analytical model for determining the cellular mat system stability includes the calculation of the pressure on top of the slope as a function of the wave characteristics and the water depth, the calculation of the maximum pressure difference across the cover layer as a function of the pressure on top of the slope and the characteristics of the granular filter and the cellular concrete mattress, and the calculation of the friction between adjacent blocks and the influence of the block motion on the pressure difference across the cellular concrete mattress. Parameters to be considered in design of the cellular concrete mattress system include: water depth, wave height, wave period, and slope angle.

## **B. Cellular Concrete Blocks**

### **1. Scope**

- 1.1 This specification covers concrete blocks for erosion control mats used in revetments, storm channels, etc. and 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. Physical Requirements

3.1 At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 1 below.

Table 1

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

3.2 Durability. The manufacturer shall satisfy the purchaser by proven field performance that the concrete units have adequate durability even if they are to be subjected to a freeze-thaw environment.

3.3 Sample and test units in accordance with ASTM Methods C 140, Sampling and Testing Concrete Masonry Units. All compressive strengths shall be tested by an approved independent laboratory.

### 4. Visual Inspection

4.1 All units shall be sound and free of defects that would interfere with the proper placing of the unit or impair the strength or permanence of the construction. 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.

4.2 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.

4.3 Chipping resulting in a weight loss exceeding 10% of the average weight of the blocks shall be deemed grounds for rejection.

4.4 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 at the expense of the contractor.

### 5. Sampling and Testing

5.1 The purchaser or his 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. Expense of Tests**

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

**7. Manufacturer**

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

ARMORTEC  
 9025 Centre Point Dr.  
 Suite 400  
 West Chester, OH 45069  
 Phone: (513) 645-7000  
 Fax: (513) 645-7993

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

**TABLE 2. STANDARD SIZES OF RECOMMENDED ARMORFLEX® BLOCK**

CLASS	TYPE	BLOCK WEIGHT		BLOCK SIZE			OPEN AREA %
		Lbs (kg)	Lbs./Sq.ft. (kg/m <sup>2</sup> )	Length inches (cm)	Width inches (cm)	Height inches (cm)	
60	Open	99-113 (45-51)	56-64 (484-553)	17.4 (44.2)	15.5 (39.4)	7.5 (19.1)	20

**C. Revetment Cable and Fittings**

There is an option of two (2) types of revetment cables 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% and 70% of the total weight of the cable. The revetment cable shall have the following physical characteristics:

		Polyester Cable				Elongation requirements specified are based upon stabilized cable. Stabilization refers to a process in which the cable is cycled fifty (50) times between a load corresponding to 200D and a load equal to 10%, 20% or 30% of the cable's approximate average breaking strength. Relevant elongation values are as shown in the table below. The tolerance on these values is $\pm 5\%$ .
	Nominal Cable Dia. (in.)	Approx. Ave. Strength		Weight per Length		
		(Lbs)	(kN)	(Lbs)/100ft	(kg/m)	
below	1/4	3,000	13.3	2.2	0.03	
	5/16	7,000	31.1	4.4	0.07	
new, dry	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 a good to excellent 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 ensures 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 six (6) or 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.  (in.)	Type	Approx. Ave. Strength		Weight per Length	
		(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 good resistance to mild concentrations of acids, alkalis, and solvents. Fittings such as sleeves and stops shall be aluminum, washers shall be galvanized steel.

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.

**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 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 geotextiles shall be finished to prevent the outer fiber from pulling away from the geotextiles.

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.

<b>TABLE 3. PHYSICAL REQUIREMENTS</b>		
Physical Property	Test Procedure	Minimum Value
Grab Tensile Strength (Non-aged Geotextile)	ASTM D4632	200 Lbs. (in any principal direction)
Breaking Elongation (Non-aged Geotextile)	ASTM D4632	50% max. (in any principal direction)
Burst Strength	ASTM D3786	400 psi
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, gradation, and plasticity shall be determined for every 200,000 square feet of installed geotextile, 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. The manufacturer 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, a torn or punctured section of fabric shall be repaired by placing a filter fabric patch over the damaged area prior to placing the mats. The patch shall be large enough to overlap a minimum of three (3) feet in all directions.

**F. Size of Cellular Concrete Mats**

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 which is approved by the Engineer.

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.

**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 the soil, as well as amount of compaction shall be as required by the Engineer.

Excavation and preparation for anchor trenches, side 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 area shall be inspected by the Engineer, the owner's representative, and by the manufacturer'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 (2) 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 a minimum of 4-inch thick granular drainage layer consisting of 2 to 2.5-inch angular crushed rock followed by site-specific filter fabric in such a manner as to produce a smooth plane surface in intimate contact with the concrete unit. 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 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 a soil 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 lineal 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 that there are not voids and so that compacted 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 such 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.