

SECTION 02277

ARTICULATED CONCRETE MAT

1. PART 1 GENERAL

1.1 SECTION INCLUDES

- A. Articulated Concrete Mat.

1.2 RELATED SECTIONS

- A. Section 02279 – Filter Fabric.

1.3 SUBMITTALS

- A. Submit under provisions of Section 01300 - Submittals.
- B. Submit shop drawings and product data for all items to be installed and/or constructed within this Section.
- C. Submit manufacturer's instructions for all product data.
- D. Submit manufacturer's certificate, which shall show actual test values obtained for the physical properties as tested for compliance with the specifications, for all product data.

1.4 UNIT PRICE - MEASUREMENT AND PAYMENT

A. Articulated Concrete Mat:

- 1. Basis of Measurement: At the unit bid price per square yard as stated in the proposal.
- 2. Basis of Payment: Includes material, delivery, equipment, labor, and installation according to drawings, backfill, filterer fabric, stone fill, topsoil fill, aggregate fill where indicated, submittal of concrete mix design, submittal of product information, bedding material, cable, anchors, excavation, compaction, and complete installation as indicated in the specifications and plans. Contractor must submit concrete testing results for blocks. Specific items required include compression strength, percent of air (4 to 6 percent), and unit weight.

2. PART 2 PRODUCTS

2.1 GENERAL

- A. All cellular concrete mats shall be premanufactured as an assembly of concrete blocks, with specific hydraulic capacities, bound into mats by the use of revetment cables.

- B. Individual blocks in the cellular mats shall be staggered, beveled, interlocked, and tapered for enhanced stability. The open cell version of the blocks has 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 plans. Parallel strands of cable shall extend through 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). One individual block shall be surrounded by 6 total blocks.
- C. 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 25 degrees between any given row or column of blocks in the uplift direction and a minimum of 45 degrees in the downward direction.
- D. 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.
- E. Overtopping Certification: All cellular concrete mats shall only be accepted when accompanied by documented hydraulic performance characteristics, 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. However, given the severe hydraulic conditions experienced in overtopping events, the articulated concrete block system must have been tested under supercritical, high-velocity flows. Specifically, the tested blocks must have been able to pass a 4-foot overtopping test where terminal velocity (no less than 23 ft/s) and normal depths (uniform flow) were achieved on a 2H:1V embankment slope. In addition, system restraints (such as mechanical anchors) and ancillary components (such as a synthetic drainage medium) used in the full-scale testing program must be incorporated in field installations in an identical manner.

- F. Overtopping Performance: The design of the cellular concrete mats shall be in accordance with the Factor-of-Safety design methodology as described in "Sediment Transport Technology" by D. B. Simons and F. Senturk, Water Resources Publication, 1977. This methodology assumes that the limits of stability in terms of critical shear stress and velocity have been determined through controlled testing. The analysis shall be performed based upon the stability of the mat due to gravity forces alone, neglecting forces which may be due to cabling, mechanical anchorage, contact with adjacent blocks, or other restraint not attributable to gravity based forces. The cellular concrete mats shall be designed to a minimum safety factor of 1.5. In order to replicate actual field conditions, the stability analysis must either account for a 0.5-inch block projection height or utilize a 0.5 inch tapered block top in the direction of flow. The individual blocks comprising the mat shall have an open area of not more than 20 percent. Extrapolation of tested shear stress values to the performance of thicker units may be considered only for units within the same "family" of blocks having the same geometric dimensions (length and width) and interlock of the tested units.

2.2 CELLULAR CONCRETE BLOCKS

- A. Scope:
1. This specification covers concrete blocks for erosion control mats used in dam overtopping or embankment overtopping situations.
 - a. Note 1 - Concrete units covered by this specification are made from lightweight or normal weight aggregates, or both.
 - b. Note 2 - The values stated in U.S. customary units are to be regarded as the standard.
- B. Materials:
1. Cementitious Materials - Materials shall conform to the following applicable ASTM specifications:
 - a. Portland Cements - Specification C 150, for Portland Cement.
 - b. Blended Cements - Specification C 595, for Blended Hydraulic Cements.
 - c. Hydrated Lime Types - Specification C 207, for Hydrated Lime Types.
 - d. Pozzolans - Specification C 618, for Fly Ash and Raw or Calcined Natural Pozzolans for use in Portland Cement Concrete.
 2. Aggregates shall conform to the following ASTM specifications, except that grading requirements shall not necessarily apply:
 - a. Normal Weight - Specification C 33, for Concrete Aggregates.
- C. Physical Requirements:
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. PHYSICAL REQUIREMENTS			
Compressive Strength Net Area Min. psi (mPa)		Water Absorption Max., lb ₃ /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)

2. Durability. The manufacturer shall satisfy the Owner by proven field performance that the concrete units have adequate durability even if they are to be subjected to a freeze-thaw environment.
3. Sample and test units in accordance with ASTM Methods C 140, Sampling and Testing Concrete Masonry Units. All compressive strengths shall be tested on cubes (3 inch x 3 inch x 3 inch), cut from full Armorflex units.

D. Visual Inspection:

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.
2. Cracks exceeding 0.10 inches in width and/or 0.5 inch in depth shall be deemed grounds for rejection.
3. Chipping resulting in a weight loss exceeding 10 percent of the average weight of the blocks shall be deemed grounds for rejection.
4. Blocks rejected shall be repaired with structural grout or replaced at the expense of the Contractor.

E. Sampling and Testing: The Owner 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.

F. Expense of Tests: Additional testing, other than that provided by the manufacturer, shall be worked out between the manufacturer and the Contractor.

G. Manufacturer: Cellular concrete block systems shall be ARMORFLEX® as manufactured and sold by:

ARMORTEC
 4301 Industrial Drive
 Bowling Green, KY 42102
 Phone: 1-800-305-0523, (270) 843-4659
 Fax: (270) 783-8952

Or Engineer approved equal.

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.	Lbs./Sq.Ft	Length inches (cm)	Width inches (cm)	Height inches (cm)	
40T	Open	62-71	35-40	17.4 (44.2)	15.5 (39.4)	4.75 (22.9)	20
40	Open	62-71	35-40	17.4 (44.2)	15.5 (39.4)	4.75 (22.9)	20

2.3 REVETMENT CABLE AND FITTINGS

- A. 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 percent to 70 percent of the total weight of the cable. The revetment cable shall have the following physical characteristics:

Nominal Cable Diam.	Approx. Circum.	Avg.		Lbs./100 ft (kg/m)	
		Strength Lbs.	(kN)	Min. Lbs. (kg)	Max Lbs. (kg)
1/4"	- 20mm	3,700	(16.4)	2.47 (.04)	2.74 (.04)
5/16"	- 27mm	7,000	(31.1)	3.99 (.06)	4.42 (.07)
3/8"	- 30mm	10,000	(44.5)	4.75 (.07)	5.26 (.08)
1/2"	- 40mm	15,000	(66.7)	8.93 (.13)	9.90 (.15)

NOTE: Polyester cable shall be determined by the Supplier, based on the size of the mats to be installed.

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

	Percent Breaking Strength		
	10%	20%	30%
Permanent Elongation (while working)	0.7	1.8	2.6
Elastic Elongation	0.6	1.4	2.2
Total Stretch	1.3	3.2	4.8

- C. The revetment cable shall exhibit 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.
- D. 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 percent 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.
- E. 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.

- F. 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 percent of the minimum rated cable strength. Any form of non-spaced fittings, such as tying the ends of the cables, shall not be permitted.

2.4 ANCHORS

- A. Earth anchors shall be Manta Ray, MR-88-RA4 as manufactured by Foresight Products, LLC, of Commerce City, CO. or Engineer approved equal.
- B. Anchor Head Material: Shall be hot dip galvanized ductile iron per ASTM A-123.
- C. Anchor Rods and Attachment Hardware Material: Shall be hot dip galvanized steel per ASTM A-153.
- D. Anchor Rods: Shall be a minimum of $\frac{3}{4}$ inch diameter.
- E. Minimum ultimate tensile strength of the anchor and its components (including the anchor and attachment hardware) shall be 10,000 pounds.
- F. All anchors shall be installed with proper equipment according to the manufacturer's instructions for installation with articulated concrete mats.
- G. Anchors shall be installed at the locations and angles shown on the Project plans.
- H. Embedment Depth: Rod length shall be 48 inches with a minimum finished depth of 36 inches.
- I. All anchors shall meet the minimum embedment length (along the axis of the anchor rod) as specified after the proof test as specified below. It shall be the responsibility of the installer to drive the anchors to a sufficient depth prior to proof testing such that the anchors will meet this minimum embedment length after the proof test.
- J. Anchors shall be installed 8 feet on center as measured parallel to the top of dam as indicated on the plans.
- K. Anchors installed at concrete mat ends shall be attached directly to the revetment cables. Those installed in the body of the mat shall be installed with a spreader plate style installation as directed by the manufacturer and approved by the Engineer.
- L. All anchors shall be proof tested along the axis of the anchor rod to the minimum proof test load as directed by the manufacturer and approved by the Engineer. The proof test load shall be held for a period of one minute during which time the movement of the anchor shall not exceed $\frac{1}{2}$ inch.
- M. The installer must keep a record of installation and test for each anchor that records the anchor specifics (anchor and rod model, installation angle), proof test results, final embedment length.

- N. The proof testing device shall have been calibrated or "Load Verified" within the past 1 year. It shall be the responsibility of the installer to supply the Calibration or Load Verification Certificate.

2.5 FILTER FABRIC

- A. See Section 02279 – Filter Fabric.

2.6 SIZE OF CELLULAR CONCRETE MATS

- A. 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 8 feet and a length, which is approved by the Engineer.

3. PART 3 FOUNDATION PREPARATION, GEOTEXTILE AND MAT PLACEMENT

3.1 FOUNDATION PREPARATION

- A. General: Areas on which filter fabric, bedding layer (4 inches of pea stone), second layer of filter fabric, and cellular concrete blocks are to be placed shall be constructed to the lines and grades shown on the Drawings and to the tolerances specified in the Contract Documents, and approved by the Engineer.
- B. Grading: The slope shall be graded to a smooth plane surface to ensure that intimate contact is achieved between the slope face and the filter fabric, between the filter fabric and the stone-bedding layer and between the second layer of filter fabric 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 regraded 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 to a minimum of 95 percent of Standard Proctor density or as specified by the Engineer.
- C. 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 plans. 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.
- D. Inspection: Immediately prior to placing the filter fabric and cellular concrete blocks, the prepared area shall be inspected by the Engineer, and by the manufacturer's representative if requested by the Engineer. No fabric or blocks shall be placed thereon until that area has been approved by the Engineer.

3.2 PLACEMENT OF FILTER FABRIC

- A. General: Filter Fabric shall be placed within the limits shown on the Contract plans.

- B. Placement: The filter fabric shall be placed directly on the prepared area, in intimate contact with the subgrade, and free of folds or wrinkles. The filter fabric 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 filter fabric 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.

3.3 PLACEMENT OF CELLULAR CONCRETE BLOCKS/MATS

- A. General: Cellular concrete block/mats, as specified in Part 2.1 of these Specifications, shall be constructed within the specified lines and grades shown on the Contract plans.
- B. 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.
- C. 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 filter 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 (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.
- D. 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.
- E. 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 seeding shall be completed in a timely manner.
- F. Consultation: The manufacturer of the cellular concrete blocks/mats shall provide construction advice during the design and initial installation phases of the project, when required.

END OF SECTION