**ARTICULATING CONCRETE BLOCK (ACB)**

**SYSTEM SPECIFICATIONS – ARMORFLEX®**

**GENERAL**

**Scope of Work**

The contractor shall furnish all labor, materials, equipment, and incidentals required for, and perform all operations in connection with, the installation of the ArmorFlex® Articulating Concrete Block (ACB) system in accordance with the lines, grades, design and dimensions shown on the Contract Drawings and as specified herein.

**Submittal**

The Contractor shall submit to the Engineer of Record (EOR) evidence of full-scale hydraulic testing in accordance with ASTM D-7277, and if necessary, Factor of Safety (FoS) calculations in support of the proposed ACB system stamped and signed by a Professional Engineer licensed to practice in the state where the project is located. The Contractor shall also submit to the EOR an appropriate geotextile, selected for the site being protected on the basis of the gradation and permeability of the surface soils, which information shall have been provided by the EOR or the designated geotechnical engineer.

The Contractor shall furnish manufacturer's certificates of compliance for ACB/mats, revetment cable, geotextile, and any revetment cable fittings and connectors. The Contractor shall also furnish the manufacturer's specifications, literature, preliminary shop drawings for the layout of the mats, installation and safety instructions, and any recommendations, if applicable, that are specifically related to the project. If a color has been specified for the block, the Contractor shall submit a color chart indicating the specified standard color.

Alternative materials from qualified suppliers may be considered; to qualify, proposed alternative suppliers must own and operate their own manufacturing facility, and shall directly employ a minimum of five (5) registered Professional Engineers. Full documentation consistent with the foregoing must be submitted in writing to the EOR a minimum of twenty (20) business days prior to bid date, and must be pre-approved in writing as an addendum to the bid documents and drawings by the EOR at least ten (10) business days prior to bid date. Submittal packages must also include, as a minimum, the following:

1. Evidence of satisfactory full-scale laboratory testing in accordance with *ASTM D 7277,* *Standard Test Method for Performance Testing of Articulating Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow*, performed on behalf the submitting manufacturer on a qualifying test flume of sufficient length for the test flows to achieve normal depth in all cases, and associated engineered calculations quantifying the FoS of the proposed ACB system under the design conditions of the specific project, stamped and signed by a registered Professional Engineer residing in and licensed to practice in the state where the project is located;
2. A list of 5 comparable projects, in terms of size and applications, in the United States, where the satisfactory performance of the specific alternate ACB system can be verified after a minimum of five (5) years of service life;
3. Information about, or certifications of, all materials associated with the ACB system as detailed above, including (but not limited to) cable, fittings, geotextile, and any other materials required for satisfactory installation in accordance with *ASTM D 6884, Standard Practice for Installation of Articulating Concrete Block (ACB) Revetment Systems*;
4. The names and contact information (phone numbers and e-mail addresses, at a minimum) for the suppliers’ representatives, for technical, production or logistics questions, at least one of whom must reside in the state where the project is located.

**PRODUCT**

**General**

All ACB mats shall be prefabricated as an assembly of concrete blocks having specific hydraulic capacities, and laced with revetment cables. The ACB system may also 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 cracking during shipping and installation. The open cell units have an open area of 18-23% as measured from the base of the mat. Parallel strands of cable shall extend through a minimum of 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 ACB 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 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 EOR 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 ACB mats shall be placed on a filter fabric as specified herein. Under no circumstances shall the filter fabric be permanently affixed or otherwise adhered to the blocks or mats; i.e., the filter fabric shall be independent of the block system.

**Certification (Open-Channel Flow):** ACB mats will only be accepted when accompanied by documented hydraulic performance characteristics that are derived from tests under controlled flow conditions. Testing shall conform to *ASTM D 7277, Standard Test Method for Performance Testing of Articulating Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow*, as amended and updated. Note that all hydraulic performance testing shall be performed in a 2H:1V flume, and that the tested length be long enough that the test flows achieve normal depth in all cases. Analysis and interpretation of the test data shall conform to the guidance contained in *ASTM D 7276, Standard Guide for Analysis and Interpretation of Test Data for Articulating Concrete Block (ACB) Revetment Systems in Open Channel Flow*, as amended and updated.

**Performance (Open-Channel Flow):** The design of the ACB mats shall be in accordance with the Factor-of-Safety design methodology as described in "Erosion and Sedimentation" by Pierre Julien, Cambridge University Press, Second Ed. 2010. The minimum designed safety factor shall be 1.5 by utilizing the following equation.

SF = ((2 / 1) ) / ((1 - 2)0.5 cos  +  (2 / 1) + (3 Fd’ cos  + 4 Fl’) / 1Ws) ≥ 1.5

where 1, 2, 3, & 4 are geometric properties of the block, , are angles characteristic of the site and application,  is the stability number for a sloped surface, Fd & Fl are the drag and lift forces, respectively, and Ws is the submerged weight of the block. ArmorFlex block geometric parameters are available upon request.

The analysis shall be performed based upon the stability of the ACBs 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 accordance with *ASTM D 6884, Standard Practice for Installation of Articulating Concrete Block (ACB) Revetment Systems,* Section 6.3.3. **Site grading requirements may not be used to omit this requirement for standard (non-tapered) block.**

**All design calculations submitted must be based upon the smallest block utilized in the mats. Partial “half blocks” must be analyzed separately.**

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

**ACB HYDRAULIC INFORMATION**

|  |  |  |
| --- | --- | --- |
| Design Volumetric Flow Rate (ft3/sec) |  | ***Specified by EOR*** |
| Minimum Shear Stress (lb/ft2) |  |
| Channel Friction or Bed Slope (ft/ft) |  |
| Channel Side Slopes (\_H:1V) |  |
| Channel Bottom Width (ft) |  |
| Allowable Unit Protrusion (in) | 0.5 |  |

**Articulating Concrete Blocks**

**Scope:** This specification covers ACB mats used for general erosion control, slope stabilization, channel armoring and channel protection. Installations may be exposed to infrequent and/or light-duty vehicular loading, such as for low-water crossings or boat ramps, by specifying a minimum thickness of 6”. Concrete units covered by this specification are made from lightweight or normal weight aggregates, or both. The values stated in U.S. customary units are to be regarded as the standard.

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

1. Portland Cements - Specification C 150, for Portland Cement.
2. Blended Cements - Specification C 595, for Blended Hydraulic Cements.
3. Hydrated Lime Types - Specification C 207, for Hydrated Lime Types.
4. Pozzolans - Specification C 618, for Fly Ash and Raw or Calcined Natural Pozzolans for use in Portland Cement Concrete.
5. Aggregates – Specification C 33, for Concrete Aggregates, except that grading requirements shall not necessarily apply.

**Casting:** The ACB units shall be produced using a dry cast method. Dry cast units obtain strength more quickly than wet cast blocks, and will also achieve a greater uniformity of quality and greater durability.

**Physical Requirements:** At the time of delivery to the work site, the ACB units shall conform to the physical requirements prescribed in Table 2 listed below.

## **PHYSICAL REQUIREMENTS**

|  |  |  |  |
| --- | --- | --- | --- |
| **Compressive Strength Net Area**  **Min. p.s.i (mPa)** | | **Water Absorption**  **Max. lb/ft3 (kg/m3)** | |
| Avg. of 3 units | Individual Unit | Avg. of 3 units | Individual Unit |
| 4,000 (27.6) | 3,500 (24.1) | 9.1 (160) | 11.7 (192) |

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

**Visual Inspection:** All units shall be sound and free of defects which would interfere with the proper placement of the unit, or which would 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.

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

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 upon request at the expense of the contractor.

**Sampling and Testing:** The purchaser (or their authorized representative) shall be accorded access to the relevant manufacturing facility or facilities, if desired, in order to inspect and/or sample the ACB units from lots ready for delivery prior to release for delivery to the job site. Such inspections are at the sole expense of the requesting entity.

Field installation shall be consistent with the way the system was installed in preparation for hydraulic testing pursuant to *ASTM D 7277, Standard Test Method for Performance Testing of Articulating Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow*. Any external restraints, anchors, or other ancillary components (such as synthetic drainage mediums) shall be employed as they were during testing; e.g., if the hydraulic testing installation utilized a drainage layer, then the field installation must also utilize a drainage layer. This does not preclude the use of other section components for other purposes, e.g., a geogrid for strengthening the subgrade for vehicular loading, or an intermediate filter layer of sand to protect very fine-grained native soils.

Hydraulic testing shall be conducted on the thinnest block in a “family” of similar blocks (i.e., same footprint but different thicknesses), with the tested critical shear value then converted to a critical shear at 0° before extrapolation to thicker blocks within the same family. Such extrapolation may not be made from a thicker block to a thinner block. The extrapolation method is detailed in the National Concrete Masonry Association (NCMA) “Design Manual for Articulated Concrete Block (ACB) Revetment Systems”, section 4.2.

Purchaser may request additional testing other than that provided by the manufacturer as needed. Such requested testing will extend any stated lead times for manufacturing and delivery, if the results of such testing are a prerequisite to approval (i.e., approval for release to manufacturing). Costs associated with such testing shall be borne by the purchaser.

**Manufacturer**

Articulating concrete blocks (ACB’s) shall be **ArmorFlex®** **Block and a Half** 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

URL: <http://www.conteches.com/Products/Erosion-Control/Hard-Armor/ArmorFlex>

The selected ARMORFLEX® blocks shall have the following nominal characteristics:

**STANDARD SIZES OF ARMORFLEX® BLOCKS**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CLASS** | **TYPE** | **MIN. WEIGHT**  **(lbs)** | **BLOCK SIZE** | | | **OPEN AREA %** |
| **Length**  **(in)** | **Width**  **(in)** | **Height\***  **(in)** |
| 40BAAH | Open | 59 | 17.4 | 15.5 | 4.75 | 20 |
| 50BAAH | Open | 76 | 17.4 | 15.5 | 6.0 | 20 |
| 70BAAH | Open | 113 | 17.4 | 15.5 | 8.5 | 20 |
| 45BAAH | Closed | 71 | 17.4 | 15.5 | 4.75 | 10 |
| 55BAAH | Closed | 91 | 17.4 | 15.5 | 6.0 | 10 |
| 85BAAH | Closed | 135 | 17.4 | 15.5 | 8.5 | 10 |
| *\*Block height may vary based on local manufacture’s capabilities.* | | | | | | |

**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 size of the revetment cable shall be selected such that the minimum acceptable strength is at least five (5) times that required for lifting of the mats, in accordance with ASTM D-6684 paragraph 5.5.2.

Elongation requirements specified below are based upon stabilized new, dry cable. Stabilization refers to a process in which the cable is cycled fifty (50) times between a load corresponding to 200D2 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 + 5%.

|  |  |  |
| --- | --- | --- |
| 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. Fittings such as sleeves and stops shall be aluminum and washers shall be plastic 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 (GAC). 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 size of the revetment cable shall be selected such that the minimum acceptable strength is at least five (5) times that required for lifting of the mats.

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 or plastic. 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.

**Anchors**

The specifying EOR *may* require, at his/her discretion, permanent anchoring of the mats, e.g., by the use of ancillary earth anchors or attachment to other structures using the lifting cable loops, or through the open cells of an open-cell block. The design of the ArmorFlex system is intended to provide hydraulic stability without the use of such anchors; consequently, any such anchor design shall be by others as approved by the EOR.

**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 standard for sizing geotextile for these applications is AASHTO M-288, Permanent Erosion Control. Either woven or non-woven geotextile are acceptable, as long as they meet the other project requirements.

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 manufacturer's certified test results to the EOR, 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, UV radiation, and temperatures greater than 140°F. To the extent possible, the fabric shall be maintained wrapped in its protective covering. The geotextile shall not be exposed to sunlight or UV radiation until the installation process begins.

## **PHYSICAL REQUIREMENTS**

|  |  |  |  |
| --- | --- | --- | --- |
| **Physical Property** | **Test Procedure** | **Minimum Value** |  |
| Grab Tensile Strength  (Unaged Geotextile) | ASTM D4632 | *IAW AASHTO M288 Class 2* |  |
| Breaking Elongation  (Unaged Geotextile) | ASTM D4632 | 50% max.  (in any principal direction) |  |
| Burst Strength | ASTM D3786 | *IAW AASHTO M288 Class 2* |  |
| Puncture Strength | ASTM D4833 | *IAW AASHTO M288 Class 2* |  |
| A.O.S., U.S. Std. Sieve | ASTM D4751 |  | ***Specified by EOR*** |
| Permittivity | ASTM D4491 |  |

Final acceptance of the filtration geotextile must be made by the EOR based on project specific soil information. Soil characteristics such as grain size distribution, permeability, 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 may require the performance of further sieve and possible hydrometer testing at the discretion of the EOR. The locations for which the material to be tested is extracted shall be approved by the EOR. 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 EOR.

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 EOR, 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.

**Size of ACB Mats**

**General:** The 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 EOR. The maximum mat length may be shorter for heavier blocks.

**Mat Length:** The ACB 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. Obstructions, such as manholes, pipe outfalls, or other fixed structures, will be accommodated to the extent that accurate information is provided about them prior to the preparation of mat layout drawings.

**FOUNDATION PREPARATION, GEOTEXTILE AND MAT PLACEMENT**

**Subgrade Preparation**

**General:** All subgrade preparation shall be performed in accordance with *ASTM D 6884, Standard Practice for Installation of Articulating Concrete Block (ACB) Revetment Systems*, as updated and amended.

**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 individual ACBs. 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 0.5 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 EOR.

Excavation and preparation for all termination trenches or aprons shall be done in accordance to the lines, grades and dimensions shown in the Contract Drawings. The termination 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 termination trench hinge-point shall also be graded uniformly to assure intimate contact between all ACBs and the underlying grade at the hinge-point.

**Inspection:** Immediately prior to placing the filter fabric and ACB mats, the prepared subgrade shall be inspected by the EOR 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.

**Placement of Geotextile Filter Fabric**

**General.** All placement and preparation should be performed in accordance with *ASTM D 6884, Standard Practice for Installation of Articulating Concrete Block (ACB) Revetment Systems,* as updated and amended. Filter Fabric, or filtration geotextile, as specified elsewhere, will be placed within the limits of ACBs shown on the Contract Drawings.

**Placement.** The filtration geotextile will be placed directly on the prepared area, in intimate contact with the subgrade, and free of folds or wrinkles. The geotextile will not be walked on or disturbed when the result is a loss of intimate contact between the ACB and the geotextile or between the geotextile and the subgrade. The geotextile filter fabric will be placed so that the upstream strip of fabric overlaps the downstream strip. The longitudinal and transverse joints will be overlapped at least one and a half (1.5) feet for dry installations and at least three (3) feet for below-water installations. The geotextile will extend at least one (1) foot beyond the top and bottom revetment termination points, or as required by the EOR. If ACBs 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 ACB mats unless the space is concrete filled.

**Placement of ACBs/Mats**

**General.** ACB placement and preparation should be performed in accordance with *ASTM D 6884, Standard Practice for Installation of Articulating Concrete Block (ACB) Revetment Systems*, as amended and updated.

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

**Placement.** The subgrade shall be prepared in such a manner as to produce a smooth plane surface prior to placement of the ACBs or mats. No individual block within the plane of placed ACBs will protrude more than one-half inch or as otherwise specified by the EOR. ACBs should be flush and develop intimate contact with the subgrade section, as approved by the EOR. Proposed hand placing is only to be used in limited areas, specifically identified by the EOR or manufacturers’ mat layout drawings, as approved by the EOR.

If assembled and placed as large mattresses, the ACB mats will 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 will be placed side-by-side, so that the mats abut each other, and/or end-to-end. Mat seams or openings between mats greater than two (2) inches will be backfilled with 4000 p.s.i. non-shrink grout, concrete or other material approved by the EOR. Whether placed by hand or in large mattresses, distinct changes in grade that results in a discontinuous revetment surface in the direction of flow will require backfill at the grade change location so as to produce a continuous surface.

Termination trenches will 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 ACBs for its entire service life. Termination trenches will be backfilled as shown on the Contract Drawings. Backfilling and compaction of trenches will be completed in a timely fashion. No more than 500 linear feet of placed ACBs with non-completed termination trenches will be permitted at any time.

**Finishing.** The cells or openings in the ACBs will be backfilled and compacted with suitable material, as specified by the EOR. Backfilling and compaction will be completed in a timely manner so that no more than 500 feet of exposed mats exist at any time. Finishing requirements are explicitly at the discretion of the EOR.

**Consultation.** The manufacturer of the ACBs/mats shall provide design and construction advice during the design and initial installation phases of the project when required or as necessary, at the discretion of the EOR. The ACB supplier shall provide, at a minimum, one full day or two half-days of on-site project support upon request.