



Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS

FOR

FABRIC FORMED CONCRETE STRUCTURE REVETMENT

Effective Date
November 21, 2006

THE STANDARD SPECIFICATIONS, SERIES OF 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

01083.01 DESCRIPTION.

This work consists of constructing fabric formed concrete revetment as shown on the plans. The revetment is normally used adjacent to bridge substructure units to protect the substructure from excessive scour.

The fabric formed revetment shall consist of specially woven, double-layer synthetic forms filled with a pumpable, fine aggregate concrete grout in such a way as to form a stable revetment of required thickness, weight (mass), and configuration.

The configuration of fabric formed revetment on this project shall be 'Articulating Block Mat' with reinforced polyester cable, and/or 'Armor Units' with or without reinforced with polyester cable in accordance with the contract documents.

01083.02 MATERIALS.

A. Fabric Forms.

1. Manufacturers and Products.

Acceptable manufacturers and products are as follows:

- a. Donnelly Fabricators, Inc., 970 Henry Terrace, Lawrenceville, GA 30045, (770) 339-0108. Products: Texicon™ Articulating Block Mat, Texicon™ Concrete Bags.
- b. Hydrotex Synthetics, Inc., 74 Perimeter Center East, Suite 7420, Atlanta, GA 30346-1803, (800) 225-0023. Products: Hydrotex™ Articulating Block Mat, Hydrocast™ Armor Units.
- c. Armorform, Inc., P.O. Box 710, Jefferson, GA 30549, (706) 367-4661. Products: Armorform™ Articulating Block Mat, Armorform™ Armor Bags.
- d. Approved equal to the above named products.

The fabric forms supplied shall meet the details and specifications of the above named products as modified by this specification.

2. Fabric and Cables.

Fabric forms shall be fabricated to conform to the dimensions shown in the contract documents. When the plan indicates a finished dimension, the fabric form dimension shall be adjusted to provide the finished dimension shown following filling with concrete grout including allowances for form material in anchor, terminal, or toe trenches as applicable. See Article 01083.02, C, for the requirements for concrete grout for the fabric formed concrete revetment (concrete grout).

The fabric forms shall be composed of synthetic yarns formed into a woven fabric. Yarns used in the manufacture of the fabric shall be composed of nylon and/or polyester. Forms shall be woven with a minimum of 50% textured yarns by weight (mass) to improve adhesion to the concrete grout and to improve filtration. Each layer of fabric shall conform to the physical, mechanical, and hydraulic requirements referenced herein. The fabric forms shall be free of defects or flaws that significantly affect their physical, mechanical, or hydraulic properties.

Fabric used to fabricate the fabric forms shall meet or exceed the values shown for the properties shown in the following table:

Table A - Fabric Form Minimum Property Requirements				
Property	Test Method	Units	Armor Unit	Articulating Block Mat
Composition of Yarns			Nylon or Polyester	Nylon or Polyester
Mass Per Unit Area (double-layer)	ASTM D 5261	oz/yd ² (g/m ²)	14 (470)	12 (403)
Thickness	ASTM D 5199	mils(mm)	28 (0.7)	25 (0.6)
Mill Width		in(m)	76 (1.92)	76 (1.92)
Wide-Width Strip Tensile Strength				
-Machine	ASTM D 4595	lbf/in(kN/m)	190 (33.2)	140 (24.5)
- Cross	ASTM D 4595	lbf/in(kN/m)	140 (24.5)	110 (19.3)
Elongation at Break				
- Machine	ASTM D 4595	%	20	20
- Cross	ASTM D 4595	%	30	30
Trapezoidal Tear Strength				
- Machine	ASTM D 4533	lbf (N)	180 (800)	150 (665)
- Cross	ASTM D 4533	lbf (N)	115 (510)	100 (445)
Apparent Opening Size (AOS)	ASTM D 4751	U.S. Std. Sieve (mm)	60 (0.250)	40 (0.425)
Flow Rate	ASTM D 4491	gal/min/ft ² (l/mi n/m ²)	50 (2035)	90 (3665)
Notes:				
1. Conformance of fabric to specification property requirements shall be based on ASTM D 4759.				
2. All numerical values represent minimum average roll values (i.e., average of test results from any sample roll in a lot shall meet or exceed the minimum values). Lots shall be sampled according to ASTM D 4354.				

Mill widths of fabric shall be a minimum of 76 inches (1.92 m). Each selvage edge of the top and bottom layers of fabric shall be reinforced for a width of not less than 1.35 inches (35 mm) by adding a minimum of 6 warp yarns to each selvage construction. Mill width rolls shall be cut to the length required, and the double-layer fabric separately joined, bottom layer to bottom layer and top layer to top layer, by means of sewing thread, to form multiple mill width panels with sewn seams on not less than 72 inch (1.82 m) centers.

All factory-sewn seams shall be downward facing upon completion of the revetment. All seams sewn in the factory shall be not less than 90 lbf/in (15.7 kN/m) when tested in accordance with ASTM D 4884. All sewn seams and zipper attachments shall be made using a double line of U.S. Federal Standard Type 401 stitch. All stitches shall be sewn simultaneously and be parallel to each other, spaced between 0.25 inches to 0.75 inches (6 mm to 9 mm) apart. Each row of stitching shall consist of 4 to 7 stitches per inch (per 25.4 mm). Thread used for seaming shall be nylon and/or polyester. Field sewing shall be permitted only to join the factory assembled fabric form panels together.

Cables, when required, shall be constructed of high tenacity, low elongation, continuous filament polyester fibers. Cable shall have a core construction comprised of parallel fibers contained within an outer jacket or cover. The weight (mass) of the parallel core shall be between 65% to 75% of the total weight (mass) of the cable.

Cable nominal size and rated breaking strength shall be as specified in the following sections for the type and size of fabric formed revetment. Cable splices shall be made with aluminum compression fittings selected so that the resultant cable splice from use of a single fitting shall provide a minimum of 80% of the rated breaking strength of the cable. A minimum of two fittings per splice, separated by a minimum of 6 inches (153 mm) of cable overlap, shall be used at each splice. Upon completion of the revetment all fittings shall be encased by concrete grout within the fabric form.

a. Articulating Block Mat.

Fabric forms shall consist of double-layer woven fabric joined together by narrow perimeters of interwoven fabric into a matrix of rectangular compartments that form a concrete articulating block mat. Cords shall connect the two layers of fabric at the center of each compartment. The cords shall be interwoven in two sets of four cords each, one set for the upper layer and one set for the bottom layer. Each cord shall have a minimum breaking strength of 160 lbf (710 N) when tested in accordance with ASTM D 2256.

Fabric form compartments shall be offset one half a compartment length, in the mill width direction, to form a bonded concrete block pattern. The mill width direction for articulating block mat shall be the flow direction shown on the plans unless otherwise noted.

Fabric form compartments shall each have four grout ducts, two on each side parallel to the mill width direction, to allow passage of the concrete grout between adjacent compartments. Two additional grout ducts, one on each side perpendicular to the mill width direction, is permissible. The concrete grout filled, cross sectional area of each grout duct shall be no more than 10% of the maximum filled cross sectional area of the block transverse to the duct.

Grout stops shall be installed at predetermined mill width intervals to regulate the distance of lateral flow of concrete grout. The grout stop material shall be nonwoven filter fabric. The grab tensile strength of the filter fabric shall be not less than 90 lbf/in (400 N) when tested in accordance with ASTM D 4632.

Cables shall be installed between the two layers of fabric and through the compartments in a manner that provides for longitudinal and lateral binding of the finished articulating block mat. Two revetment cables perpendicular to mill width direction shall pass through each compartment. One revetment cable parallel to the mill width direction shall pass through the approximate center of each compartment.

The cables shall enter and exit the compartments through opposing grout ducts. As an alternate, cable ducts may be provided for insertion of revetment cables between compartments. The diameter of each cable duct shall be 1.0 inch (25.4 mm) maximum.

All cables, within each compartment shall be completely embedded in the concrete grout.

Articulating block mat nominal finished dimensions and properties for the specified size shall be per the following table:

Size	4 inch (100 mm)	6 inch (150 mm)	8 inch (200 mm)
Average Thickness, inches (mm)	4.0 (100)	6.0 (150)	8.0 (200)
Mass Per Unit Area, lb/ft ² (kg/m ²)	45 (220)	68 (330)	90 (440)
Mass per Block, lb (kg)	88 (39.8)	188 (85.2)	325 (148)
Nominal Block Dimensions, inches (mm)	20x14 (508x356)	20x20 (508x508)	20x26 (508x660)
Cable Nominal Diameter, inches (mm)	0.250 (6.35)	0.312 (7.94)	0.312 (7.94) ^(B)
Cable Average Breaking Strength, lbf (kN)	3,700 (16.47)	4,500 (20.03)	4,500 (20.03) ^(B)
Concrete Coverage ^(A) , ft ² /yd ³ (m ² /m ³)	75 (9.1)	50 (6.1)	38 (4.6)

^(A) For information only.

^(B) When the contract documents require 0.375 inches (9.53 mm) cable, the Average Breaking Strength shall be 7,000 lbf (31.15kN).

b. Armor Units/Concrete Bags.

Fabric forms shall consist of two layers of woven fabric sewn together. When filled with concrete grout they shall form a concrete Armor Unit (concrete bag).

Self-sealing filling valves, suitable for use with an injection pipe at the end of a pump hose for concrete grout, shall be installed at predetermined locations.

When Armor Units are specified, the fabric forms shall be similar to the typical unreinforced bags produced by the manufacturers specified above.

When Armor Units Reinforced are specified, the following modifications to the typical unreinforced bag shall be made:

- 1) The fabric form shall be continuous along its length. The intent is to provide a continuous width and thickness of fabric formed concrete along the substructure unit being protected. If the Armor Unit is placed around the circumference of a pier, the unit shall be continuous around the pier.
- 2) Grout stops shall be installed as required to regulate the distance of flow of concrete grout. The grout stop material shall be nonwoven filter fabric. The grab tensile strength of the filter fabric shall be not less than 90 lbf/in (400 N) when tested in accordance with ASTM D 4632.
- 3) Longitudinal cables shall be spaced evenly across the cross section of the Armor Unit. The number of longitudinal cables required are shown in the following table:

Table C - Armor Unit Properties			
Size - Width Unfilled Fabric Form in (m)	No. Longitudinal Cables^(B)	Filled Thickness in (mm) Volume of Concrete^(A) ft³/ft (m³/m)	Filled Thickness in (mm) Volume of Concrete^(A) ft³/ft (m³/m)
24 (0.61)	2	<u>6 (15)</u> 0.8 (0.07)	<u>9 (23)</u> 1.1 (0.10)
36 (0.91)	2	<u>6 (15)</u> 1.3 (0.12)	<u>9 (23)</u> 1.8 (0.17)
48 (1.22)	3	<u>9 (23)</u> 2.6 (0.24)	<u>12 (30)</u> 3.2 (0.30)
60 (1.52)	4	<u>9 (23)</u> 3.3 (0.31)	<u>12 (30)</u> 4.2 (0.39)
72 (1.83)	5	<u>9 (23)</u> 4.1 (0.38)	<u>12 (30)</u> 5.2 (0.48)
84 (2.13)	6	<u>9 (23)</u> 4.8 (0.45)	<u>12 (30)</u> 6.5 (0.60)
96 (2.44)	7	<u>12 (30)</u> 7.2 (0.67)	<u>15 (38)</u> 8.8 (0.82)
108 (2.74)	8	<u>12 (30)</u> 8.2 (0.76)	<u>15 (38)</u> 10.0 (0.93)

^(A) For information only.

^(B) For Reinforced Armor Units

Longitudinal cables shall be spliced at joints.

Cables shall be nominally 0.250 inches (6.35 mm) in diameter and their rated average breaking strength shall be not less than 3,700 lbf (16.47 kN). Cords shall connect the cables to the fabric form as required to position the cables near the center of the finished armor thickness.

Armor Units nominal finished dimensions and properties for the specified size shall be per Table C above.

B. Delivery.

The fabric forms shall be kept dry and wrapped such that they are protected from the elements during shipping and storage. If stored outdoors, they shall be elevated and protected with a waterproof cover that is opaque to ultraviolet light. The fabric forms shall be labeled as per ASTM D 4873.

The Contractor shall submit layout and/or shop drawings a minimum of 2 weeks prior to installation. These drawings shall include the dimensions of the fabric form panels, location and type of field seams, and field splicing requirements.

The Contractor shall submit a manufacturer's certificate that the supplied fabric forms meet the criteria of these Specifications, as measured in full accordance with the referenced test methods and standards. The certificates shall include the following information about each fabric form delivered:

- Manufacturer's name and current address;
- Full product name;
- Style and product code number;
- Composition of yarns; and
- Manufacturer's certification statement.

C. Concrete Grout for Fabric Formed Concrete Revetment.

Materials for concrete grout for the fabric formed concrete revetment (concrete grout) shall meet the requirements of the following:

<u>Item</u>	<u>Section^(A)</u>
Portland Cement	4101
Fine Aggregate	4110, 4111, or 4112
Water	4102
Admixtures	4103
Fly Ash	4108
^(A) of the Standard Specifications	

The concrete grout shall consist of a mixture of Portland cement, fine aggregate, water, admixtures, and fly ash so proportioned and mixed as to provide a pumpable slurry. Pozzolan and grout fluidizer may be used at the option of the Contractor.

The consistency of the concrete grout delivered to the concrete pump shall be proportioned and mixed as to have an efflux time of 9 to 12 seconds when passed through the 0.75 inch (19 mm) orifice of the standard flow cone that is described in ASTM C 939.

The concrete grout shall have an air content of not less than 5% nor more than 8% of the volume of the grout. The mix shall obtain a compressive strength of 2,000 psi (13,750 kPa) at 28 days when tested in conformance with Materials I.M. 315.

Mix proportions shall be similar to that for Concrete Grout for Revetment or Gabion per Article 2507.02, B, of the Standard Specifications. The Contractor shall be responsible for supplying a mix design to the Engineer that meets the above requirements. The Contractor shall submit samples of fine aggregate, cement, and fly ash intended for use to the Engineer before the work begins. After the mix has been designated, it shall not be changed without approval of the Engineer.

01083.03 CONSTRUCTION.

A. Equipment.

Mixing and pumping equipment used in preparation and handling of the concrete grout shall be approved by the Engineer. Proportioning and mixing equipment shall meet requirements of Articles 2001.20 and 2001.21 of the Standard Specifications. Sufficient mixing capacity of mixers shall be provided to permit the intended pour to be placed without interruption. All oil or other rust inhibitors shall be removed from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout before the mixers are used. The pumping equipment shall have a variable flow rate to provide enough pressure for pumping without breaking the fabric.

B. Site Preparation.

Areas on which fabric forms are to be placed shall be constructed to the lines, grades, contours, and dimensions shown on the plans. All obstructions such as roots and projecting stones shall be removed. Where such areas are below the allowable grades, they shall be brought to grade by placing compacted layers of select material. The thickness of layers and the amount of compaction shall be as specified by the Engineer. Where required by the contract documents, soft and otherwise unsuitable subgrade soils shall be identified, excavated, and replaced with select materials in accordance with the Standard Specifications.

Excavation and preparation of aprons as well as anchor, terminal, or toe trenches shall be done in accordance with the lines, grades, contours, and dimensions shown on the plans. Immediately prior to placing the fabric forms, the Engineer will inspect the prepared area, and no forms shall be placed until the area has been approved.

C. Fabric Form Placement.

Engineering fabric shall be placed on the graded surface approved by the Engineer when required by the contract documents. Fabric forms shall be placed over the engineering fabric, when required, and within the limits shown on the plans. ~~Anchoring of the fabric forms shall be accomplished through the use of anchor, terminal, and toe trenches at locations shown on the plans.~~ The fabric forms shall be anchored as required to prevent displacement during curing of grout. Anchorages requiring connection to the structure and not shown on the plans require approval by the Engineer prior to use.

Where fabric formed concrete is placed adjacent to a substructure unit, the fabric forms shall be placed so that the filled fabric formed revetment shall be flush with the substructure unit. Placement of the fabric forms prior to filling shall consider the contraction of the fabric form during filling.

All field seams shall be made using two lines of U.S. Federal Standard Type 101 stitches. Thread used for seaming shall be nylon and/or polyester. All sewn seams shall be downward facing. Zipper seams shall be permitted unless noted otherwise in the contract documents. The finished strength of the field seams shall comply with manufacturers recommendations.

All cables crossing a field seam shall be spliced in conformance with the Article 01083.02, A, 2, above. Upon completion of the revetment all splice fittings shall be encased by concrete grout within the fabric form.

Where fabric formed concrete units/mats lap on top of previously installed units, 6 mils (150 μm) polyethylene sheeting shall be placed on top of the underlying unit to prevent bonding prior to placement of the engineering fabric and fabric forms for the succeeding layer.

Immediately prior to filling with the concrete grout, the Engineer will inspect the assembled fabric forms, and no concrete grout shall be pumped until the fabric seams have been approved. At no time shall the unfilled fabric forms be exposed to ultraviolet light (including direct sunlight) for a period exceeding 5 calendar days.

1. Articulating Block Mat.

Adjacent fabric form panels shall be joined before filling with concrete grout by field sewing or zippering the two bottom layers of fabric together and the two top layers of fabric together. Lap joints shall only be used at locations shown in the contract documents.

2. Armor Units.

Typical unreinforced Armor Units shall be joined together following placement of concrete grout as shown in the contract documents.

Reinforced Armor Units shall be joined before filling with concrete grout by field sewing or zippering the two bottom layers of fabric together and the two top layers of fabric together to form a continuous unit.

D. Proportioning and Mixing Concrete Grout.

All materials shall be accurately measured by volume or weight (mass) as they are fed into the mixer. The quantity of water shall be such as to produce a grout having a pumpable consistency. Time of mixing shall be not less than 1 minute. If agitated continuously, the grout may be held in the mixer or agitator for a period not exceeding 2 1/2 hours in temperatures below 70°F (21°C) and for a period not exceeding 2 hours at higher temperatures. If there is a lapse in a pumping operation, the grout shall be recirculated through the pump or through the mixer drum (or agitator) and pump.

E. Concrete Grout Placement.

Concrete grout shall be pumped in such a way that excessive pressure on the fabric forms and cold joints are avoided. A cold joint is defined as one in which the pumping of the concrete grout into a given form is discontinued or interrupted for an interval of 45 or more minutes.

After the concrete grout has set, all anchor, terminal, and toe trenches shall be backfilled and compacted, as specified by the Engineer.

Foot traffic on the filled form shall be restricted to an absolute minimum for 1 hour after filling.

If a fabric formed concrete unit/mat is to bear on previously installed units, the lower units must be allotted a minimum of 4 hours of cure time before beginning installation of a succeeding, vertically adjacent course of fabric formed unit(s). Abutting fabric formed concrete units/mats may be installed immediately after placement of the preceding unit(s).

The freshly pumped fabric formed concrete shall not be washed (sprayed) under pressure with water in an effort to clean or remove spills from its surface. The cement film that bleeds through the top layer of the fabric form shall be maintained through curing on finished surfaces exposed to sunlight. Should the film be removed in these areas, the film shall be repaired by spreading a thin layer of a water-cement paste over the effected area.

1. Articulating Block Mat.

Following the placement of the fabric forms, small slits shall be cut in the top layer of the fabric form to allow the insertion of the filling pipe at the end of the concrete grout pump hose. These slits shall be of the minimum length to allow proper insertion of the filling pipe. Concrete grout shall be pumped between the top and bottom layers of fabric, filling the forms to the recommended thickness and configuration. Holes in the fabric forms left by the removal of the filling pipe shall be temporarily closed by inserting a piece of nonwoven fabric or similar material. The nonwoven fabric shall be removed when the concrete grout is no longer fluid and the grout surface at the hole shall be cleaned and smoothed by hand.

2. Armor Units.

Following the placement of the fabric form, the filling pipe at the end of the concrete grout pump hose shall be inserted through the self-sealing filling valve. Concrete grout shall be pumped between the top and bottom layers of fabric, filling the forms to the recommended thickness and configuration.

When the contract documents require joining of adjacent Armor Units by inserting reinforcement bar dowels or staples into the Armor Units, the dowels or staples shall be inserted into the filled unit(s) not less than 0.5 hour and not more than 1 hour after filling of the unit, unless directed otherwise by the Engineer. When the contract documents require joining of vertically adjacent Armor Units, reinforcing dowels shall be driven into the lower unit in the time frames specified in this paragraph. The vertically adjacent fabric form shall then be placed over the reinforcing dowels. The dowels shall be forced through the bottom layer of the vertically adjacent fabric form prior to filling that form.

01083.04 METHOD OF MEASUREMENT.

A. Fabric Formed Concrete Revetment.

The quantity of Fabric Formed Concrete Revetment of the type specified, in square yards (square meters), will be the quantity shown in the contract documents for each installation to the nearest 0.1 foot (0.1 m).

B. Engineering Fabric.

The quantity of Engineering Fabric will be measured in accordance with Article 2507.04 of the Standard Specifications.

C. Concrete Grout.

The quantity of Concrete Grout for Fabric Formed Concrete Revetment will be measured in accordance with Article 2507.04 of the Standard Specifications.

01083.05 BASIS OF PAYMENT.

A. Fabric Formed Concrete Revetment.

The Contractor will be paid the contract unit price for Fabric Formed Concrete Revetment of the type specified per square yards (square meters). This payment shall be full compensation for all work, including furnishing the forms and all equipment, tools, and labor necessary to place the forms ready for filling with grout and any required work following filling. The work includes but is not limited to joining field seams, cable splices, plastic for lap areas, reinforcing bars to join Armor Units.

Unless otherwise noted in the contract documents, this payment shall also be full compensation for any bank shaping, excavation, and backfilling necessary to complete the work in conformance with the contract documents.

B. Engineering Fabric.

The Contractor will be paid for the Engineering Fabric in accordance with Article 2507.05 of the Standard Specifications.

C. Concrete Grout.

The Contractor will be paid for the Concrete Grout for Fabric Formed Concrete Revetment in accordance with Article 2507.05 of the Standard Specifications.