Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS
FOR
FABRIC FORMED CONCRETE STRUCTURE REVETMENT

Effective Date
October 20, 2009

THE STANDARD SPECIFICATIONS, SERIES OF 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

09028.01 DESCRIPTION.

A. Construct 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.

B. Use fabric formed revetment consisting 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.

C. Ensure the fabric formed revetment configuration on this project is 'Articulating Block Mat' with reinforced polyester cable, and/or 'Armor Units' with or without reinforced with polyester cable according to the contract documents.

09028.02 MATERIALS.

A. Fabric Forms.

1. Manufacturers and Products.

a. Acceptable manufacturers and products are shown in Materials I.M. 496.01, Appendix F.

b. Ensure the fabric forms supplied meet the details and specifications of the approved products as modified by this specification.

2. Fabric and Cables.

a. General.

1) Fabricate fabric forms to conform to the dimensions shown in the contract documents. When the plan indicates a finished dimension, adjust the fabric form dimension 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 09028.02, C, for the requirements for concrete grout for the fabric formed concrete revetment (concrete grout).

2) Use fabric forms composed of synthetic yarns formed into a woven fabric. Ensure:

- Yarns used in the manufacture of the fabric are composed of nylon and/or polyester.

- Forms are 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 conforms to the physical, mechanical, and hydraulic requirements referenced herein.
- Fabric forms are free of defects or flaws that significantly affect their physical, mechanical, or hydraulic properties.

3) Ensure fabric used to fabricate the fabric forms meets or exceeds the values shown for the properties shown in Table DS-09028.02-1:

Table DS-09028.02-1: 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 - Cross	 ASTM D 4595 ASTM D 4595	 lbf/in(kN/m) lbf/in(kN/m)	 190 (33.2) 140 (24.5)	 140 (24.5) 110 (19.3)
Elongation at Break - Machine - Cross	 ASTM D 4595 ASTM D 4595	% %	20 30	20 30
Trapezoidal Tear Strength - Machine - Cross	 ASTM D 4533 ASTM D 4533	 lbf (N) lbf (N)	 180 (800) 115 (510)	 150 (665) 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/min/m^2)	50 (2035)	90 (3665)

Notes:
1. Conformance of fabric to specification property requirements is 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 must meet or exceed the minimum values). Sample lots according to ASTM D 4354.

4) Ensure mill widths of fabric are a minimum of 76 inches (1.92 m). Reinforce each selvage edge of the top and bottom layers of fabric for a width of no less than 1.35 inches (35 mm) by adding a minimum of 6 warp yarns to each selvage construction. Cut mill width rolls to the length required. Separately join the double-layer fabric (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 no less than 72 inch (1.82 m) centers.

5) Ensure the following (field sewing will be permitted only to join the factory assembled fabric form panels together):
- All factory-sewn seams face downward upon completion of the revetment.
- All seams sewn in the factory are not less than 90 foot pounds per inch (15.7 kN/m) when tested according to ASTM D 4884.
- All sewn seams and zipper attachments are made using a double line of U.S. Federal Standard Type 401 stitch.
- All stitches are sewn simultaneously and are parallel to each other, spaced between 0.25 inches to 0.75 inches (6 mm to 9 mm) apart.
- Each row of stitching consists of 4 to 7 stitches per inch (per 25.4 mm).

- Thread used for seaming is nylon or polyester, or both.

6) When cables are required, use cables constructed of high tenacity, low elongation, continuous filament polyester fibers. Ensure cables have a core construction consisting of parallel fibers contained within an outer jacket or cover. Ensure the weight (mass) of the parallel core is 65% to 75% of the total weight (mass) of the cable.

7) Use cable of nominal size and rated breaking strength specified in the following sections for the type and size of fabric formed revetment. Splice cables using aluminum compression fittings selected so that the resultant cable splice from use of a single fitting provides a minimum of 80% of the rated breaking strength of the cable. At each splice, use a minimum of two fittings separated by a minimum of 6 inches (153 mm) of cable overlap. Upon completion of the revetment, encase all fittings by concrete grout within the fabric form.

b. Articulating Block Mat.

1) Use fabric forms consisting 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. Use cords to connect the two layers of fabric at the center of each compartment. Ensure the cords are interwoven in two sets of four cords each, one set for the upper layer and one set for the bottom layer. Ensure each cord has a minimum breaking strength of 160 foot pounds (710 N) when tested according to ASTM D 2256.

2) Offset fabric form compartments 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 is the flow direction shown on the plans unless otherwise noted.

3) Ensure fabric form compartments 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. Ensure the concrete grout filled, cross sectional area of each grout duct is no more than 10% of the maximum filled cross sectional area of the block transverse to the duct.

4) Install grout stops at predetermined mill width intervals to regulate the distance of lateral flow of concrete grout. Use nonwoven filter fabric for the grout stop. Ensure the grab tensile strength of the filter fabric is no less than 90 foot pounds per inch (400 N) when tested according to ASTM D 4632.

5) Install cables 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. Ensure two revetment cables perpendicular to mill width direction pass through each compartment. Ensure one revetment cable parallel to the mill width direction passes through the approximate center of each compartment.

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

7) Completely embed in the concrete grout all cables within each compartment.

8) Ensure articulating block mat nominal finished dimensions and properties are those listed in Table DS-09028.02-2:

Table DS-09028.02-2 - Articulating Block Mat Properties

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 is to be 7,000 lbf (31.15kN).

c. Armor Units/Concrete Bags.

1) Use fabric forms consisting of two layers of woven fabric sewn together. Ensure when filled with concrete grout, they form a concrete Armor Unit (concrete bag).

2) Install self-sealing filling valves, suitable for use with an injection pipe at the end of a pump hose for concrete grout, at predetermined locations.

3) When Armor Units are specified, use fabric forms similar to the typical unreinforced bags produced by the manufacturers specified above.

4) When Armor Units Reinforced are specified, make the following modifications to the typical unreinforced bag:

a) Use fabric form that is 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, use a unit that is continuous around the pier.

b) Install grout stops as required to regulate the distance of flow of concrete grout. Use grout stop material consisting of nonwoven filter fabric. Ensure the grab tensile strength of the filter fabric is no less than 90 foot pounds per inch (400 N) when tested according to ASTM D 4632.

c) Space longitudinal cables evenly across the cross section of the Armor Unit. Splice them at joints. Ensure cables are a nominal 0.250 inches (6.35 mm) in diameter and their rated average breaking strength is no less than 3700 foot pounds (16.47 kN). Ensure cords connect the cables to the fabric form as required to position the cables near the center of the finished armor thickness. The number of longitudinal cables required and required nominal finished dimensions and properties are shown in Table DS-09028.02-3:

Table DS-09028.02-3: Armor Unit Properties

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

		8.2 (0.76)	10.0 (0.93)
[a] For information only. [b] For Reinforced Armor Units			

B. Delivery.

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

2. Submit layout and/or shop drawings a minimum of two weeks prior to installation. Ensure these drawings include the dimensions of the fabric form panels, location and type of field seams, and field splicing requirements.

3. Submit a manufacturer's certificate that the supplied fabric forms meet the criteria of this specification, as measured in full accordance with the referenced test methods and standards. Ensure the certificates 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.

1. Ensure materials for concrete grout for the fabric formed concrete revetment (concrete grout) meet the following requirements:

Item	Section (of the Standard Specifications)
Portland Cement	4101
Fine Aggregate	4110 or 4112
Water	4102
Admixtures	4103
Fly Ash	4108

2. Ensure the concrete grout consists of a mixture of Portland cement, fine aggregate, water, admixtures, and fly ash proportioned and mixed to provide a pumpable slurry. The Contractor has the option of using Pozzolan and grout fluidizer.

3. Proportion and mix the concrete grout so that its consistency when delivered to the concrete pump has 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.

4. Ensure the concrete grout has an air content of no less than 5% or no more than 8% of the volume of the grout. Ensure the mix obtains a compressive strength of 2000 psi (13,750 kPa) at 28 days when tested in conformance with Materials I.M. 315.

5. Use mix proportions similar to that for Concrete Grout for Revetment or Gabion per Article 2507.02, B, of the Standard Specifications. Provide the Engineer with a mix design meeting the above requirements. Submit samples of fine aggregate, cement, and fly ash intended for use to the Engineer before the work begins. Once the mix has been designated, do not change without the Engineer's approval.

09028.03 CONSTRUCTION.

A. Equipment.

Obtain the Engineer's approval for mixing and pumping equipment used in preparation and handling of the concrete grout. Ensure proportioning and mixing equipment meets the requirements of Articles 2001.20 and 2001.21 of the Standard Specifications. Ensure the mixing capacity of mixers is sufficient to permit the intended pour to be placed without interruption. Before the mixers are used, remove all oil or other rust inhibitors from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout. Ensure pumping equipment has a variable flow rate to provide enough pressure for pumping without breaking the fabric.

B. Site Preparation.

1. Construct areas on which fabric forms are to be placed to the lines, grades, contours, and dimensions shown on the plans. Remove all obstructions, such as roots and projecting stones. Bring areas below the allowable grades up to grade by placing compacted layers of select material. The Engineer will specify the thickness of layers and the amount of compaction. Where required by the contract documents, identity soft and otherwise unsuitable subgrade soils, excavate, and replace with select materials according to the Standard Specifications.

2. Excavate for and prepare aprons, anchors, terminal, and/or toe trenches according to the lines, grades, contours, and dimensions shown on the plans. Immediately prior to placing the fabric forms, the Engineer will inspect the prepared area. Do not place forms until the area has been approved.

C. Fabric Form Placement.

1. General.

a. Place engineering fabric on the graded surface approved by the Engineer when required by the contract documents. Place fabric forms over the engineering fabric, when required, and within the limits shown on the plans. Anchor the fabric forms 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.

b. Where fabric formed concrete is placed adjacent to a substructure unit, place the fabric forms so that the filled fabric formed revetment is flush with the substructure unit. When placing fabric form, allow for contraction of the fabric form during filling.

c. Make all field seams using two lines of U.S. Federal Standard Type 101 stitches. Use nylon and/or polyester thread. Sew all seams face down. Zipper seams are permitted unless noted otherwise in the contract documents. Ensure the finished strength of the field seams complies with the manufacturer's recommendations.

d. Splice all cables crossing a field seam according to Article 09028.02, A, 2. Upon completion of the revetment, encase all splice fittings by concrete grout within the fabric form.

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

f. Immediately prior to filling with the concrete grout, the Engineer will inspect the assembled fabric forms. Do not pump grout until the fabric seams have been approved. Do not allow unfilled fabric forms to be exposed to ultraviolet light (including direct sunlight) for a period exceeding five calendar days.

2. **Articulating Block Mat.**
   Before filling with concrete grout, join adjacent fabric form panels by field sewing or zippering the two bottom layers of fabric together and the two top layers of fabric together. Use lap joints only at locations shown in the contract documents.

3. **Armor Units.**
   - **a.** Join typical unreinforced Armor Units together following placement of concrete grout as shown in the contract documents.
   - **b.** Before filling with concrete grout, join Reinforced Armor Units 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.
Accurately measure all materials by volume or weight (mass) as they are fed into the mixer. Ensure the quantity of water is such as to produce a grout having a pumpable consistency. Mix grout for no less than one minute. If agitated continuously, the grout may be held in the mixer or agitator for up to 2.5 hours in temperatures below 70°F (21°C) and up to two hours at higher temperatures. If there is a lapse in a pumping operation, recirculate the grout through the pump or through the mixer drum (or agitator) and pump.

E. Concrete Grout Placement.

1. **General.**
   - **a.** Pump concrete grout in such a way that excessive pressure on the fabric forms and cold joints is 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 minutes or more.
   - **b.** After the concrete grout has set, backfill and compact all anchor, terminal, and toe trenches as specified by the Engineer.
   - **c.** Restrict foot traffic on the filled form to an absolute minimum for one hour after filling.
   - **d.** If a fabric formed concrete unit/mat is to bear on previously installed units, the lower units must be allotted a minimum of four 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).
   - **e.** Do not wash (spray) freshly pumped fabric formed concrete under pressure with water in an effort to clean or remove spills from its surface. Maintain the cement film that bleeds through the top layer of the fabric form through curing on finished surfaces exposed to sunlight. Should the film be removed in these areas, repair the film by spreading a thin layer of a water-cement paste over the effected area.

2. **Articulating Block Mat.**
   Following the placement of the fabric forms, cut small slits (of the minimum length to allow proper insertion of the filling pipe) 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. Pump concrete grout between the top and bottom layers of fabric, filling the forms to the recommended thickness and configuration. Temporarily cross holes in the fabric forms left by the removal of the filling pipe by inserting a piece of nonwoven fabric or similar material. Remove the nonwoven fabric when the concrete grout is no longer fluid. Clean and smooth the grout surface at the hole by hand.

3. **Armor Units.**
   - **a.** Following the placement of the fabric form, insert the filling pipe at the end of the concrete grout pump hose through the self-sealing filling valve. Pump concrete grout between the top and bottom layers of fabric, filling the forms to the recommended thickness and configuration.
   - **b.** When the contract documents require joining of adjacent Armor Units by inserting reinforcement bar dowels or staples into the Armor Units, insert the dowels or staples into

the filled unit(s) no less than one half hour and not more than one hour after filling of the unit, unless the Engineer directs otherwise. When the contract documents require joining of vertically adjacent Armor Units, drive reinforcing dowels into the lower unit in the time frames specified in this paragraph. Place the vertically adjacent fabric form over the reinforcing dowels. Force the dowels through the bottom layer of the vertically adjacent fabric form prior to filling that form.

09028.04 METHOD OF MEASUREMENT.
Measurement will be as follows:

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

B. Engineering Fabric.
Article 2507.04 applies.

C. Concrete Grout.
Article 2507.04 applies.

09028.05 BASIS OF PAYMENT.
Payment will be the contract unit price as follows:

A. Fabric Formed Concrete Revetment.

1. Per square yards (square meters) for the type specified.

2. Payment is 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 all required work following filling. The work includes but is not limited to joining field seams, cable splices, plastic for lap areas, and reinforcing bars to join Armor Units.

3. Unless otherwise noted in the contract documents, payment is also full compensation for all bank shaping, excavation, and backfilling necessary to complete the work in conformance with the contract documents.

B. Engineering Fabric.
Article 2507.05 of the Standard Specifications applies.

C. Concrete Grout.
Article 2507.05 of the Standard Specifications applies.