Manufactured by Synthetex, LLC

Filter Point
Filter Band™
Uniform Section
Enviromat™
Articulating Block
Hydrocast™ Armor Units

HYDROTEX™

Fabric-formed Concrete Erosion Control and Armoring Systems

CONSTRUCTION & QUALITY CONTROL MANUAL

Contents

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Introduction & General Information

Introduction

HYDROTEX™ brand fabric forms, manufactured by Synthetex are used to construct a wide range of concrete-filled systems that provide outstanding performance in erosion control, scour protection and repair, foundation, environmental and marine construction applications. The fabric forms are constructed of woven, double-layer, synthetic fabric. HYDROTEX linings and mats and HYDROCAST™ Armor Units are installed by positioning fabric forms over the areas to be protected and then pumping high-strength, fine aggregate concrete (structural grout) into the forms. The fabric forms can be placed and filled either underwater or in-the-dry. The high-strength, fine aggregate concrete is used in place of conventional concrete because of its pumpability, high-strength, impermeability, and absorption resistance.

HYDROTEX linings and mats and HYDROCAST Armor Units are used to protect canals, channels, culverts, dams, dikes, embankments, bridge piers, spillways, underwater pipelines, and other hydraulic and marine structures from the forces of flowing water and wave action. HYDROTEX Linings and Mats are also used to protect geomembranes and geosynthetic-clay liners from mechanical damage in landfills, reservoirs, sewage lagoons, ash pits, cooling ponds, and other containment, capping and environmental applications.

In addition to significant performance advantages, HYDROTEX fabric-formed concrete is economical to install. It eliminates the need for heavy equipment, steel reinforcement, and forming and stripping of conventional concrete forms. It generally does not require specialized labor or dewatering of the job site prior to installation.

This manual is designed as a guideline for the construction and quality control for HYDROTEX fabric-formed concrete systems. Prior to the delivery of materials to the job site, its contents should be thoroughly reviewed by those given the responsibility for design, installation and inspection.

The contents of this manual are only general guidelines and do not relieve the contractor of the responsibility to adhere to the Contract Drawings and Specifications. It is recommended that the Engineer of Record review these guidelines and specify any additional, project-specific installation procedures he considers necessary.

General Characteristics of Fabric Forms for HYDROTEX Linings and Mats and HYDROCAST Armor Units

HYDROTEX fabric forms are constructed of high-strength, synthetic yarns formed into woven, double-layer fabrics. Textured yarns comprise a minimum of 50% of the fabric weight for improved adhesion to fine aggregate concrete and better filtration characteristics. The yarns are woven into a network such that the yarns retain their dimensional stability relative to each other, including at the fabric selvages (edges). The selvage edges of the top and bottom layers of fabric are reinforced for a width of 1.35 inches (35 mm) by adding at least 6 warp yarns to the selvage construction. The reinforced selvage edges provide superior strength to sewn seams used in the fabrication of fabric forms.

The fabric forms are designed to serve as filters as well as concrete forms with a permeability selected to permit expulsion of excess concrete mixing water while retaining the cement solids. The fabric forms are resistant to alkalis, acids, organic solvents, and biological organisms.

After the fabric forms are woven and inspected, mill width rolls of fabric are factory assembled either into panels designed to fit project dimensions and topography or into forms of specified dimensions.

The designs of the fabric forms and their woven construction provide HYDROTEX fabric forms with a range of important benefits including:

High Strength, enabling the fabric forms to perform effectively under concrete pumping pressure;

High Elongation, to resist tear and puncture failure and to reduce form contraction;

Excellent permeability, to expel excess mixing water;

Lightweight, for ease of installation; and

Uniformity in dimensions, to assure consistent performance characteristics.

The fabric forms are designed to adhere to the fine aggregate concrete fill. Though it is assumed that the top layer of the fabric form may eventually be lost to abrasion and ultraviolet degradation, the bottom layer is expected to last indefinitely and to provide a low modulus tensile reinforcement.

There are two primary types of HYDROTEX fabric-formed concrete systems - HYDROTEX Linings and Mats and HYDROCAST Armor Units.

Fine Aggregate Concrete

Fine aggregate concrete consists of a mixture of Portland cement, fine aggregate (sand) and water, so proportioned and mixed as to provide a pumpable fine aggregate concrete.

Fine aggregate concrete has a typical mix water/cement ratio of 0.65 to 0.75. The pumping of fine aggregate concrete into the fabric forms causes a reduction in the water content by filtering excess mixing water through the permeable fabric. The reduction of mixing water substantially improves the water/cement ratio of the in-place fine aggregate concrete thereby increasing its strength and durability.

With a typical loss of approximately 15% of the total mixing water, 27 ft^3 (or 1.0 m^3) of pumpable fine aggregate concrete will reduce to approximately 25 ft^3 (0.93 m^3) of hardened concrete. The mixing water reduction will also result in an increase of approximately 8% in the sand and cement per cubic yard (m^3) of concrete. The range of fine aggregate concrete mix proportions provided in Table 1.0 has been developed under a variety of field conditions.

Air Entrainment

Mixes designed with 5% to 8% air content will improve the pumpability of the fine aggregate concrete and the freeze-thaw resistance of the hardened concrete.

Admixtures

Pozzolan grade fly ash may be substituted for up to 35% of the cement as an aid to pumpability. (The pumpability of fine aggregate concrete mixes containing course sand is improved by the addition of fly ash.)

Grout fluidifier, water reducing or set time controlling agents may be used as recommended by their manufacturers to improve the pumpability and set time of the fine aggregate concrete.

Ready-mix

Fine aggregate concrete should be pre-mixed at a concrete batch plant and delivered by ready-mix trucks to the job site. *If a continuous supply of concrete can not be assured a reserve of concrete should be maintained in a holding hopper equipped with an agitator.*

The consistency of the fine aggregate concrete delivered to the job site should be maintained in the 9-11 second range when passed through the 0.75 inch (19 mm) orifice of the standard flow cone that is described in ASTM D 6449 (Fig. 1). *Tests utilizing a concrete slump cone are not appropriate.*

Components:

Portland cement *should conform to ASTM C 150, Type I or II.*

Fine aggregate *should conform to ASTM C 33, except as to grading. Aggregate grading should be reasonably consistent and should not exceed the maximum size which can be conveniently handled with available pumping equipment.*

Water *for mixing should be clean and free from injurious amounts of oil, alkali, organic matter or other deleterious substances.*

Pozzolan, *if used, should conform to ASTM C 618, Class C, F or N.*

Plasticizing and air entraining admixtures*, if used, should conform to ASTM C 494 and ASTM C 260, respectively.*

Table 1.0 Typical Range of Mix Proportions

Material	Mix Proportions lb/yd^3 (kg/m^3)	After Placement Mix Proportions lb/yd^3 (kg/m^3)
Cement	750-850 (445-505)	805-915 (475-540)
Sand	2120-2030 (1255-1205)	2290-2190 (1355-1295)
Water	540-555 (320-325)	460-470 (270-275)
Air	As Required	As Required

Figure 1

Compression Testing of Fine Aggregate Concrete:

The fine aggregate concrete mix should exhibit the physical requirements of Table 2.0 at 28 days, when made and tested in accordance with ASTM C 31 and 39.

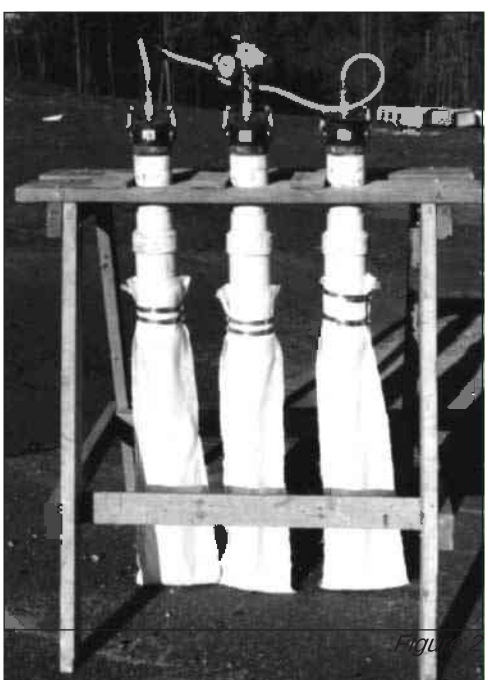
Some specifications require that the contractor prepare test cylinders cast in fabric tubes (test socks) as well as concrete cylinders cast in conventional impermeable molds.

The average compression strength of the concrete cylinders cast in fabric tubes should be at least 10% higher in 7 days than that of companion concrete cylinders made in accordance with ASTM C 31, and not less than 2,500 psi at 28 days.

Preparation of Fabric Tubes:

Fabric formed cylinders are prepared by attaching a 5.5 inch (140 mm) diameter (to allow for fabric stretching of approximately 5 to 10 percent) by 30 inch (762 mm) long fabric tube to a regulator cap (Fig. 27) and filling it with fine aggregate concrete, holding an injection pressure of approximately 10 psi (69 kPa) on the fluid concrete for a period of 10 minutes. A 12 inch (304 mm) long section is cut from the middle of the hardened specimen and capped and tested in the normal manner, with customary correction being applied for the slightly non-standard diameter.

Regulator Caps and fabric tubes are available from Synthetex, LLC.



Pumpability

The fine aggregate concrete mix which is used to fill fabric forms is very fluid compared to a conventional mix (see Table 2.0). A conventional concrete mix has a 4 to 6 inch (100 to 150 mm) slump. However, as the fabric form is filled the excess mixing water in the pumped mix is rapidly expelled through the water-permeable fabric form, resulting in the pumped mix ratio of approximately 0.7 being reduced to a more typical ratio of 0.5. Within thirty minutes after placement, the consistency of the fine aggregate concrete within the fabric forms is that of a very low slump concrete.

Strength and Durability

Fabric formed fine aggregate concrete possesses superior physical properties. The compressive strength of fine aggregate concrete pumped into fabric forms is typically 1.5 to 1.75 times greater than companion samples taken from conventual concrete test cylinders. In addition, the fine aggregate concrete has less than 5% water absorption. This combined with a “case hardening” effect produces a concrete that is abrasion resistant, durable under freeze thaw action, resistant to “break up” caused by thermal cracking, highly impermeable, and resistant to acid, alkali, salt, organic solvents, biological organisms and petrochemicals. It is equivalent to a rich conventional concrete mix placed at an extremely low water/cement ratio. The “case hardening” effect is a result of a higher percentage of the cement in the cement-rich, fine aggregate concrete mix being drawn to the surface of the fabric forms by the expelled excess mixing water.

The higher compressive strength and “case hardening” achieved by the fine aggregate concrete permits concrete linings, mats and armor units to be constructed without reinforcement steel.

Environmental Compatibility

When fine aggregate concrete is pumped into the fabric forms an average of 0.25% of the cement content (with a maximum of 0.5%) is lost through the fabric forms, or the equivalent of approximately 2000 g of cement to a cubic yard (2,600 g/m^3) of concrete pumped. The addition of 40 g of cement to a cubic yard (50 g/m^3) of water will raise the pH value of water approximately 1.0. This should fall well within the nominal pH range (7.0 to 9.5) of potable water.

The following procedures, should assure that the rise in pH during fine aggregate concrete pumping of fabric formed linings, mats or armor units will not exceed 1.0:

- In stagnant water, the total volume of water must be at least 50 times the volume of fine aggregate concrete pumped.
- In flowing water, the rate of water flow in cubic yards per minute (m^3/min) must exceed the rate of fine aggregate concrete pumped in cubic yards per hour (m^3/hr).

Table 2.0 Physical Requirements

Minimum Required Compressive Strength of Concrete psi (MPa)		**Maximum Water Absorption Requirements lb/ft^3 (kg/m^3) Weight Classification - Oven-Dry Weight of Concrete, lb/ft^3 (kg/m^3)**	
Average of Three Tests	**Individual Test**	**105 (1682) to less than 125 (2002)**	**125 (2002) or more**
2,000 (27.6)	1,400 (24.1)	10 (203)	8 (160)

Site Preparation

Standard excavating, grading and compaction equipment should be used to grade and compact the area to be protected and to excavate anchor, flank and toe trenches and aprons. *Specific information on the excavation of trenches is located on page 16 of this manual.*

The areas where the fabric forms are to be placed should be constructed to the lines and grades shown on the Contract Drawings. Where such areas are below the allowable grades, they should be brought to grade by placing compacted layers of select material. Vegetation and obstructions, such as roots and projecting stones, should be removed. Unsuitable soils should be removed and replaced with select material and compacted according to Contract Specifications. *Failure to do so may cause the fabric formed concrete linings, mats or armor units to bridge thus leaving a void beneath the structure.*

Draglines or bulldozers should generally be used for excavation and rough grading of the areas; however, they are not suitable for fine grading. Fine grading should be done with a hydraulic backhoe, grader or similar equipment. In most cases the contractor should be prepared to dress the areas with hand tools prior to placing the fabric forms. If an underwater dredge is used, the dredge operator must avoid overcutting or the cutting of stepped or scalloped slopes, particularly in cohesive soils.

Whenever the concrete linings, mats or armor units extend partially or entirely underwater, it will be necessary to perform underwater inspection and to dress the areas with hand tools prior to placement of the fabric forms. Stepped or scalloped slopes should be leveled first by dragging a steel beam or channel over the slope. *Underwater installation may be facilitated if a leveling course of granular material is placed and dressed prior to placement of the fabric forms.*

Filter Fabric (Geotextiles)

Geotextile filter fabric is often used under fabric-formed concrete linings and mats and concrete armor units (Fig. 3). The filter fabric is a permeable sheet of woven or nonwoven fabric selected in accordance to the gradation and permeability of the subsoils. The filter fabric must have opening sizes small enough to prevent soil from passing through and be permeable enough to allow the required flow of water. The filter fabric should conform to the minimum physical requirements shown in Table 3.0. Filter fabric should be protected from exposure to direct sunlight.

Filter Fabric Installation

If called for in the Contract Drawings and Specifications, filter fabric should be placed over the graded and compacted areas. The filter fabric should be placed loosely but without wrinkles or folds. Filter fabric sheets should be held in position by ballasting with sandbags or using “U”-shaped staples. Filter fabric placement should proceed concrete lining, mat or armor unit placement by no more than 2,000 ft^2 (200 m^2).

As placement of the fabric formed concrete linings, mats or armor units proceeds, the filter fabric should be secured at toes of slopes and buried at crowns of slopes and flank

Slope Stability:

Fabric-formed linings, mats and armor units provide concrete protection for earthen structures subject to flowing water, waves and wind.

Though fabric-formed concrete can be installed on slopes steeper than those suitable for quarry stone or precast concrete blocks or for compacted soil or soil cement construction, ***fabric-formed concrete linings and mats are not designed to improve slope stability.*** *Their inherent weights are selected for the purposes of hydraulic stability and are not to be considered sufficient to impart stability to slopes subject to rotational, global or sliding failure or where severe consolidation of the subgrade is anticipated.*

Fabric-formed armor units, however, may be designed as heavy weight units, *and can be used to constructed structures that act as gravity retention structures for steep slopes subject to failure.*

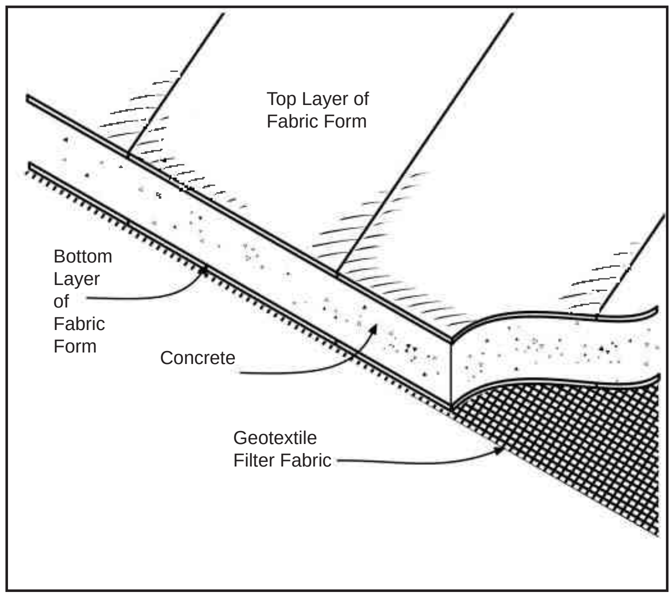


Figure 3

Foot traffic:

Foot traffic on the prepared areas should be at a minimum. Should traffic be unavoidable, the contractor should place board walks along the finished graded areas. This will reduce the amount of hand dressing required to remove footprints. Heavily trafficked areas will reflect through the installed fabric-formed concrete linings or mats as irregularities in the surface.

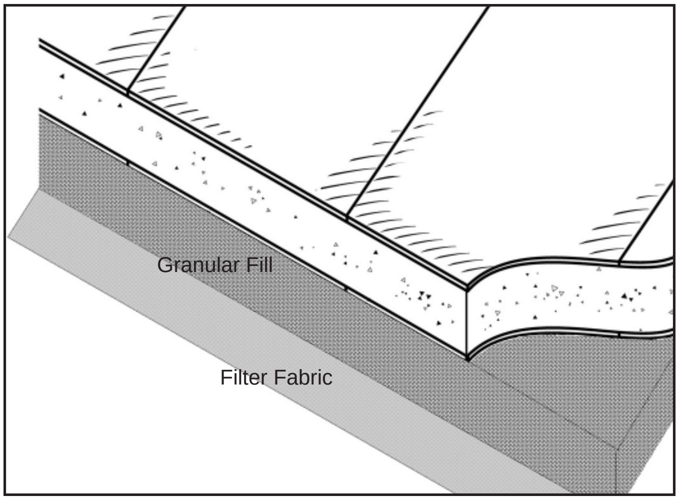


Figure 4

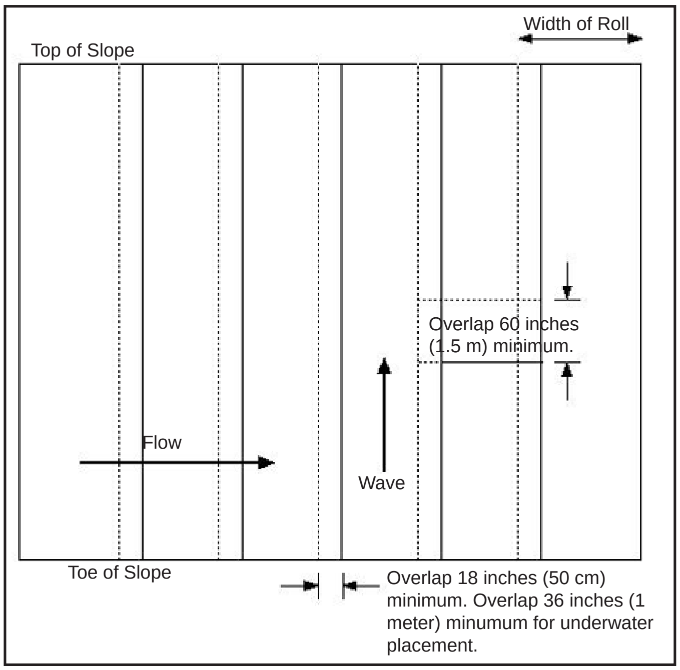


Figure 5

Manufacturer's Certification: *Prior to accepting delivery from the supplier, verify that the filter fabric satisfies all provisions of the Contract Specifications and that mill certificates have been provided.*

Table 3.0 - Filter Fabric [1, 2] Property Requirements

Property	Test Method	Units	Values
Grab Tensile Strength	ASTM D 4632	lbf (N)	90 (400)
Elongation at Break	ASTM D 4632	%	15
Trapezoidal Tear Strength	ASTM D 4533	lbf (N)	30 (130)
Permittivity	ASTM D 4491	sec^{-1}	0.5

Notes:
1. Conformance of filter fabrics to specification property requirements shall be based on ASTM D 4759, "Practice for Determining the Specification Conformance of Geotextiles."
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, "Practice for Sampling of Geosynthetics for Testing."

trenches. *Care must be taken when placing filter fabric to assure that the placement method does not damage the fabric.*

When installing fabric form linings, mats and armor units on silts, sandy silts or fine sand, the specifications may call for the addition of a sublayer. The sublayer serves to prevent serious downslope migration of the subsoil particles. Sublayers should be constructed of granular material.

Granular sublayers, as shown in Figure 4, are placed between the filter fabric and the fabric form. They generally have a thickness of between 3 and 9 inches (8-20 mm).

Filter Fabric Joints

Lapped Joints

Lapped joints are easy to install but require additional filter fabric. The sheets of filter fabric should be placed as shown in Figure 5, with the principal direction (roll length or warp direction) running down the slope. Overlapping of fabric sheets should adhere to the Contract Drawings and Specifications but be at least 18 inches (50 mm) but more generally 36 inches (1 meter), especially when laying underwater. Generally, sheets are overlapped parallel to the slope, as shown in Figure 5, to retain any soil particles migrating along the bank. If soil migration is unlikely or the fabric is being set in flowing water or current the overlap should be reversed.

Seamed Joints

Sewn seams are the most reliable method of joining filter fabric sheets and require the least amount of fabric. Seams are made on-site using portable, hand-held, sewing machines and nylon or polyester sewing thread. Generally, a prayer (flat) seam with a U.S. Federal Standard Type 101 (Fig. 6) stitch is the most suitable.

Combining Lapped and Seamed Joints

Most filter fabric suppliers will factory-sew filter fabric rolls together to form multiple roll width sheets. The contractor may lap the joints of these large sheets thus taking advantage of the ease of lapped joints and the reliability of sewn seams.

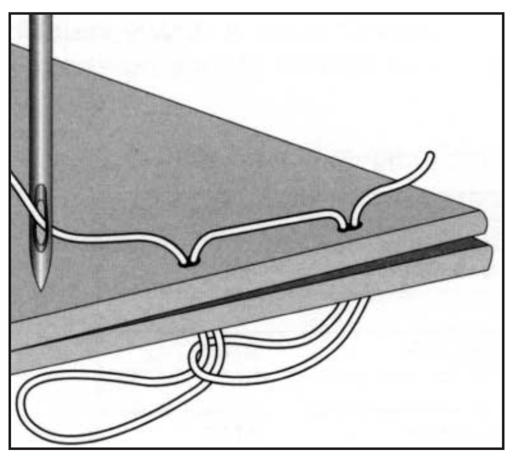


Figure 6

HYDROTEX Linings and Mats

Types of Linings and Mats

HYDROTEX linings and mats are available in five basic styles: Filter Point (FP), Filter Band™ (FB), Uniform Section (US), Enviromat™ (EL & EB), and Articulating Block (AB). Additionally, special fabric forms may be woven to suit the specific requirements of a project. Each is designed with the required strength, stability and permeability properties required to assure the pumping in-place of a durable and abrasion resistant concrete lining or mat system with specific thickness, weight and hydraulic characteristics. Forms of different styles and thickness can be incorporated in the same installation. Table 4.0 provides typical dimensions, weights and volumes for the range of standard HYDROTEX linings and mats. Table 5.0 provides property requirements for the fabric used in form construction.

Filter Point (FP) Linings

Filter Point Linings (Fig. 7) with filtering points (drains) provide erosion resistant, permeable concrete linings for ditches, channels, canals, streams, rivers, ponds, lakes, reservoirs, marinas, and protected port and harbor areas. Filter Point Linings have a cobbled surface and a relatively high coefficient of hydraulic friction in order to achieve lower flow velocities and to reduce wave run-up. The filter points provide for the relief of hydrostatic uplift pressures, increasing the system's stability.

Filter Point Linings were the first type of fabric form for concrete developed. In 1965, a Dutch patent was issued for "fabric-formed slope paving." The form suggested by this patent was later refined to create the first "filter point" lining.

Filter Band™ (FB) Linings

Filter Band Linings (Fig. 8) are similar to Filter Point, providing an effective and highly permeable concrete lining that resists erosive forces. Filter Band differs from Filter Point in that the form creates interconnected, tubular concrete elements that are separated by large, interwoven filter bands. The filter bands provide for greater reduction of uplift pressures than Filter Point Linings. Also, the biaxial alignment of the tubular elements creates two directionally-determined coefficients of hydraulic friction. As a result, Filter Band achieves greater reduction of flow velocity or wave energy than Filter Point.

Filter Band concrete linings are specified in situations similar to those for which Filter Point might be specified, but which also require greater relief of uplift pressures, higher reduction of flow velocities, or greater reduction of wave run up.

Filter Points and Filter Bands:

Filter points and filter bands define the locations at which the two layers of fabric form are interwoven to form water permeable drains. The interweaving of the two layers results in an area of double density, higher strength, single layer fabric. The weave of the fabric at the center of these drain locations incorporates a "Twill Weave" in order to "open up the fabric" and permit the flow of ground water through the drain while retaining soil particles. A twill is a weave characterized by diagonally-oriented yarns woven over then under more than one yarn. Figure 9 illustrates the construction of a filter point with a twill weave center designed to function as a drain as well as a filter. The cross shaped design reduces applied stress to the filter point during concrete pumping. Filter bands are also constructed with a twill weave center.

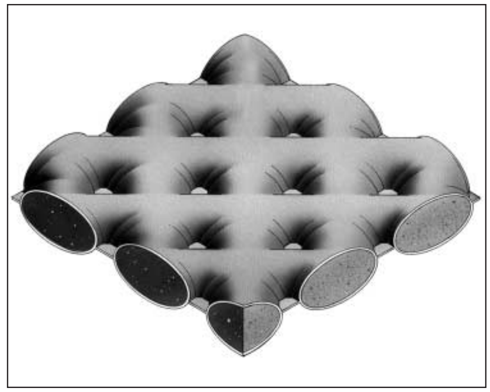


Figure 7

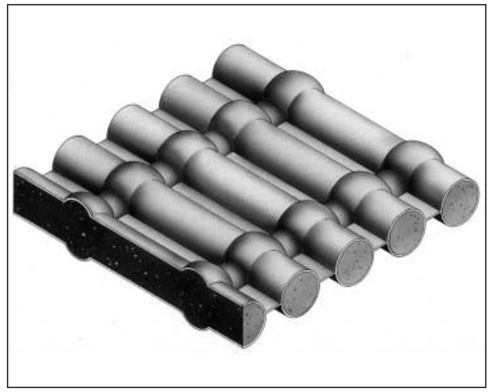


Figure 8

Manufacturer's Certification:

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

- *Manufacturer's name and current address*
- *Full product name*
- *Style and product code number*
- *Form number(s)*
- *Polymer types*
- *Manufacturer's certification statement*

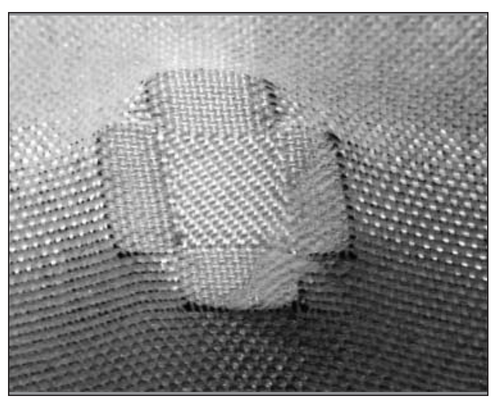


Figure 9

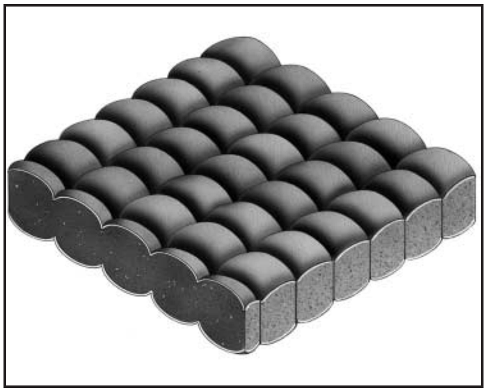


Figure 10

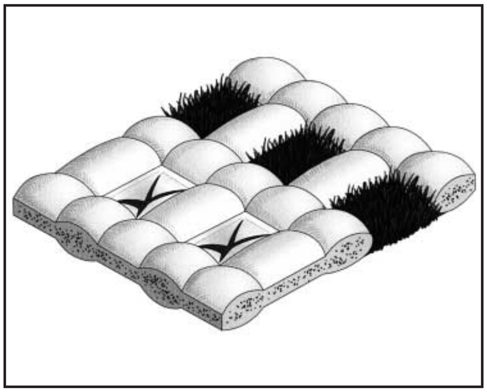


Figure 11

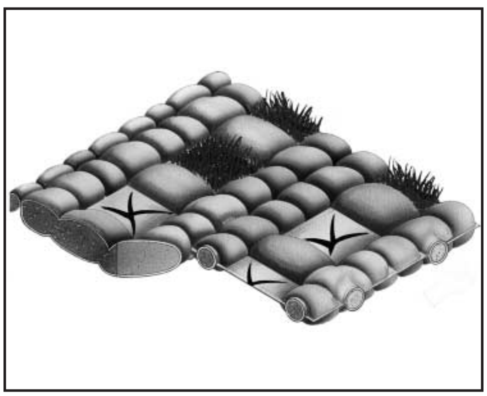


Figure 12

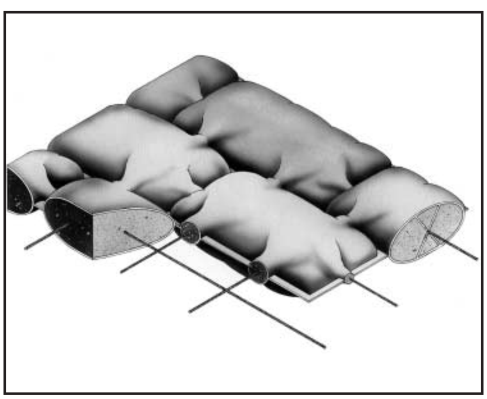


Figure 13

Uniform Section (US) Linings

Uniform Section Linings (Fig. 10) are similar to traditional concrete slope paving. They create a solid, high quality concrete lining with a relatively low hydraulic resistance and uniform cross section. These linings are used to reduce the infiltration or exfiltration of aggressive waste and chemical fluids into or out of open channels and basins. They are also used to reduce exfiltration in arid regions where open channels and basins require watertight linings.

Uniform Section Linings are resistant to leachate and most chemicals. They protect geosynthetic liners from mechanical damage, exposure to UV light, and freeze-thaw cycles. These self-supporting, high strength linings permit construction on steep side slopes and replace the conventional use of clay or sand as liner protection. Placement of the forms and concrete filling can be performed without the use of equipment on the liner. The tensile strength and abrasion resistance of the fabric protect the liner from the pumped concrete.

Enviromat™ (EL and EB) Linings

Enviromat Linings EL (Fig. 11) and EB (Fig. 12) are installed to provide protection against periodic high flows. After installation, vegetation can be planted within the open structure of the lining to create a more natural appearance. Enviromat Linings are used in drainage ditches and on the upper slopes of channels, canals, lakes, reservoirs, rivers, and other water courses as well as for embankments subject to heavy run-off.

Enviromat Linings are comprised of concrete-filled elements and unfilled areas that allow for the establishment of vegetation. Once the concrete sets, the defined unfilled and interwoven areas are opened by cutting the fabric and are planted or are filled with topsoil and seeded. Within a growing season a vegetated cover will normally extend over the lining, resulting in an erosion control system with the hydraulic, ecological and aesthetic features desired. EL linings have a greater open area (~35%) than EB (~20%), so a vegetated cover will be established more rapidly. However, EB linings are designed to articulate and are more tolerant of uneven settlement after installation.

Articulating Block (AB) Mats

Articulating Block Mats (Fig. 13) form cable-reinforced concrete block mattresses that resist erosive forces. They are often constructed where a revetment is exposed to frontal attack by wave action. AB Mats are typically used to protect coastlines, canals, rivers, lakes, reservoirs, underwater pipelines, bridge piers, and other marine structures from propeller wash, ship wakes, wind waves, currents, and high velocity flows. They are also used in environmental construction for landfill caps, down chutes, and collector channels.

The AB fabric form consists of a series of compartments linked by an interwoven perimeter. Grout ducts interconnect the compartments, and high strength revetment cables are installed between and through the compartments and grout ducts. Once filled, the AB Mats become a mattress of pillow-shaped, rectangular concrete blocks. The interwoven perimeters between the blocks serve as hinges to permit articulation. The cables remain embedded in the concrete blocks to link the blocks together and facilitate articulation.

Table 4.0 - Linings and Mats, Typical Dimensions, Weight and Volume

Filter Point	FP220	FP400	FP600	FP800	FP1000	FP1200
Average Thickness, inches (mm)	2.2 (56)	4.0 (102)	6.0 (152)	8.0 (203)	10.0 (254)	12.0 (305)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	25 (121)	45 (220)	68 (330)	90 (440)	113 (550)	135 (661)
Filter Point Spacing, inches (mm)	5.0 (127)	8.0 (203)	10.0 (254)	12.0 (305)	14.0 (356)	16.0 (406)
Area per Filter Point, in^2 (cm^2)	2.0 (12.9)	2.0 (12.9)	6.3 (40.7)	6.3 (40.7)	12.2 (78.7)	12.2 (78.7)
Perimeter per Filter Point, inches (mm)	6.5 (165)	6.5 (165)	11 (279)	11 (279)	15 (381)	15 (381)
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	136 (16.6)	75 (9.1)	50 (6.1)	38 (4.6)	30 (3.6)	25 (3.0)
Shear Resistance, lb/ft^2 (kg/m^2)	11 (54)	20 (98)	30 (146)	40 (195)	50 (244)	60 (293)

Filter Band™	FB400	FB800	FB1200
Average Thickness, inches (mm)	4.0 (102)	8.0 (203)	12.0 (305)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	45 (220)	90 (440)	135 (661)
Filter Band Spacing, inches (mm)	8.0 (203)	16.0 (406)	24.0 (609)
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	75 (9.1)	38 (4.6)	25 (3.0)
Shear Resistance, lb/ft^2 (kg/m^2)	15 (73)	29 (142)	44 (215)

Uniform Section	US300	US400	US600	US800	US1000
Average Thickness, in (mm)	3.0 (76)	4.0 (102)	6.0 (152)	8.0 (203)	10.0 (254)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	34 (165)	45 (220)	68 (330)	90 (440)	113 (550)
Drop Point Spacing, in (mm)	3 x 3 (76 x 76)	3 x 4 (76 x 102)	3 x 6 (76 x 152)	4.5 x 7.5 (114 x 191)	4.5 x 9 (114 x 229)
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	100 (12.1)	75 (9.1)	50 (6.1)	38 (4.6)	30 (3.6)
Shear Resistance, lb/ft^2 (kg/m^2)	14 (68)	18 (88)	28 (137)	37 (181)	46 (224)

Enviromat	EL250	EL400
Average Thickness, inches (mm)	2.5 (64)	4 (102)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	28 (138)	45 (220)
Open (vegetated) Area, %	35	35
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	120 (14.6)	75 (9.1)
Shear Resistance, lb/ft^2 (kg/m^2)	10 (49)	16 (78)

Enviromat	EB300	EB500
Average Thickness, inches (mm)	3.0 (76)	5.0 (127)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	34 (165)	56 (275)
Open (vegetated) Area, %	20	20
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	100 (12.1)	60 (7.3)
Shear Resistance, lb/ft^2 (kg/m^2)	12 (59)	20 (98)

Articulating Block	AB400	AB600	AB800	AB1000	AB1200
Average Thickness, in (mm)	4.0 (102)	6.0 (152)	8.0 (203)	10 (254)	12 (305)
Mass Per Unit Area, lb/ft^2 (kg/m^2)	45 (220)	68 (330)	90 (440)	113 (550)	135 (661)
Mass per Block, lb (kg)	88 (39.8)	188 (85.2)	325 (148)	563 (255)	844 (382)
Nominal Block Dimensions, in (mm)	20 x 14 (508 x 356)	20 x 20 (508 x 508)	20 x 26 (508 x 660)	30 x 24 (762 x 610)	30 x 30 (762 x 762)
Concrete Coverage, ft^2/yd^3 (m^2/m^3)	75 (9.1)	50 (6.1)	38 (4.6)	30 (3.6)	25 (3.0)
Shear Resistance, lb/ft^2 (kg/m^2)	26 (127)	39 (190)	52 (254)	65 (317)	78 (381)

Note: Values shown are typical and will vary with weight of concrete and field conditions.

Physical Requirements: *At the time of delivery to the job site, the fabric used in form construction should conform to the minimum property requirements of Table 5.0. All fabric forms should be free of rips or defects that would interfere with the proper placing of the fabric forms or significantly impair the strength or performance of the construction. Minor holes incidental to the usual method of manufacture or minor rips resulting from shipment and delivery or handling are not grounds for rejection. Small rips or holes are repaired by the contractor in the field by sewing.*

Table 5.0 - Property Requirements - Form Fabric[1, 2]

Property		Test Method	Units	Values
Physical:				
Composition of Yarns				Nylon or polyester
Mass Per Unit Area (double-layer)		ASTM D 5261	oz/yd² (g/m²)	12 (403)
Thickness		ASTM D 5199	mils (mm)	25 (0.6)
Mill Width			in (m)	76 (1.92)
Mechanical:				
Wide-Width Strip Tensile Strength	- Machine	ASTM D 4595	lbf/in (kN/m)	140 (24.5)
	- Cross		lbf/in (kN/m)	110 (19.3)
Elongation at Break	- Machine	ASTM D 4595	%	20
	- Cross		%	30
Trapezoidal Tear Strength	- Machine	ASTM D 4533	lbf (N)	150 (665)
	- Cross		lbf (N)	100 (445)
Hydraulic:				
Apparent Opening Size (AOS)		ASTM D 4751	U.S. Standard Sieve (mm)	40 (0.425)
Flow Rate		ASTM D 4491	gal/min/ft² (l/min/m²)	90 (3665)
Flow Rate through Filter Point or Band (if applicable)		ASTM D 4491	gal/min/ft² (l/min/m²)	7 (285)

Notes:
1. Conformance of fabric to specification property requirements shall be based on ASTM D 4759, "Practice for Determining the Specification Conformance of Geotextiles."
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, "Practice for Sampling of Geosynthetics for Testing."
3. Yarns used in fabric construction shall not contain partially oriented (POY), draw-textured, and/or staple yarns.

Fabric Form Panels

Fabric form mill rolls are factory assembled by sewing several mill widths of fabric forms side-to-side to form large panels. Mill width rolls of fabric forms are cut to the lengths required and their two layers of fabric separately sewn together, bottom layer to bottom layer and top layer to top layer, to form multiple mill width panels (Fig. 14). Site conditions and manpower and equipment resources at the job site will determine the maximum sizes of individual panels.

Ordering Fabric Form Panels

The ordering of fabric form panels should be done in advance of the start of the project, to allow time for the preparation, submittal and approval of layout and shop drawings. Project plans and specifications should be submitted to Synthetex technical support department. Trained technicians translate the site plans, grades, elevations, contours and construction details into CAD systems where they develop cost-effective take-offs and fabric-formed concrete shop and layout drawings, tailored to the project's design requirements. This design technique and CAD layout verification procedure will assure accurate dimensioning and material quantity takeoffs.

Shop and Layout Drawings

Fabric form panel shop drawings are plotted to scale and each panel is numbered. Figure 15 is a typical panel shop drawing. Baffle locations and the edges of the panel which are to be sewn or closed and which are unsewn or left open, for joining to adjacent panels, are clearly marked on each panel shop drawing. The fabric forms are dimensioned to include all aprons, overlaps, and anchor, flank or toe trenches and contraction factors. The forms are over-dimensioned, in both length and width, to make allowance for form contraction as they are filled with fine aggregate concrete. (Contraction factors are discussed on the following page.)

Layout drawings (Fig. 16) showing the field assembly of the fabric form panels for the entire project are prepared. The drawings identify each panel number, its location and sequence of installation, pertinent elevations and coordinates, direction of flow, anticipated water levels, and structures such as roads, curbs, bridges, intake and discharge pipes, culverts, ramps and other existing and future structures that may effect the placement of the fabric formed concrete linings, mats or armor units. In addition, lap joint locations are shown as well as notes regarding special field splicing operations, if required.

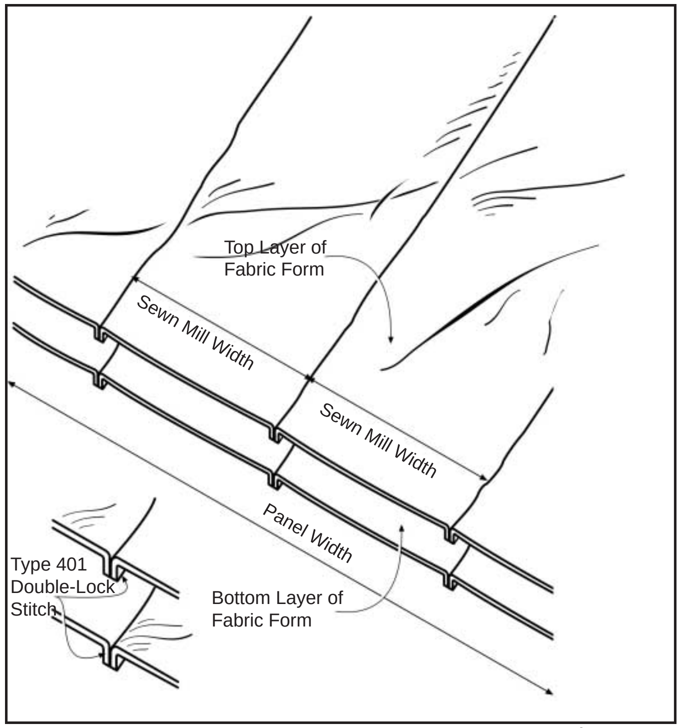


Figure 14

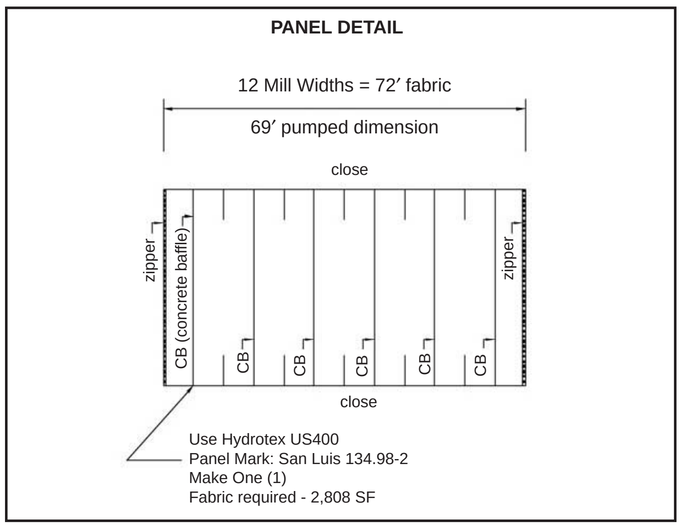


Figure 15

Figure 16

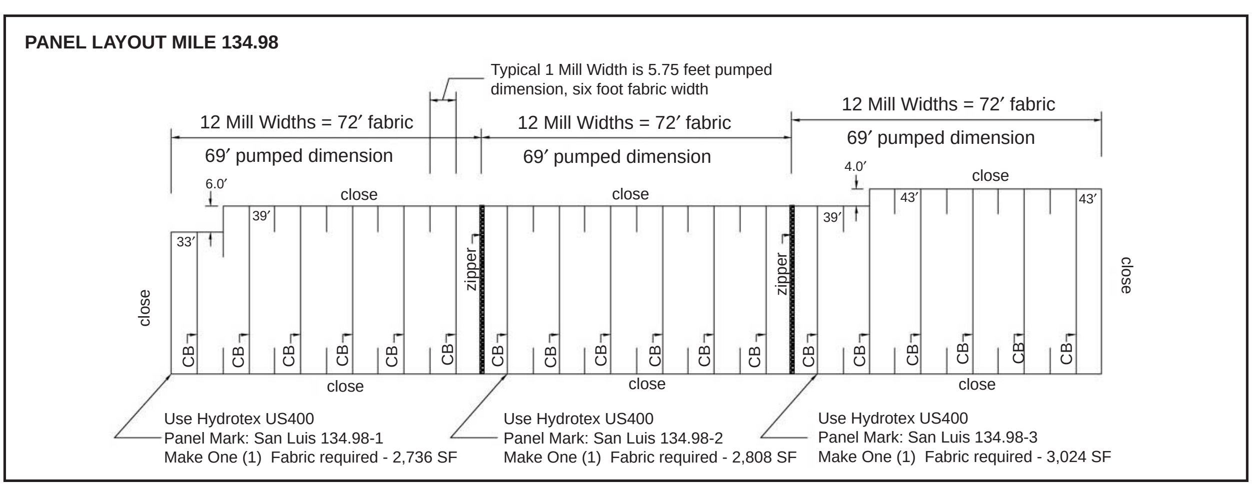


Figure 17

Minor changes in dimensions, grades, contours and field conditions from those shown on the contract drawings may be accommodated by fabric stretch or adjustment during field placement.

A submittal package which includes shop and layout drawings, a list of numbered fabric form panels, panel dimensions and areas, and a manufacturer's certification is assembled and forwarded to the contractor for submittal to the project engineer.

Upon the project engineer's approval of the submittal package Synthetex manufacturing department commences panel fabrication and confirms the delivery schedule.

Proper Storage and Handling of Fabric Forms

Fabric forms are delivered at the job site in trailers or ocean containers. Fabric forms are stacked in a manner that assures ease of unloading. Standard 40 ft (12 m) long trailers or containers hold up to 215,000 ft^2 (20,000 m^2) of fabric forms per load. Fabric forms are normally delivered to the site packaged in accordance with Table 6.0.

Rolls and panels of fabric forms are each wrapped in two layers of protective cover: the first layer (inner layer) is a waterproof, opaque, plastic cover the second (outer layer) is a woven, abrasion resistant, fabric cover (Fig. 17).

When fabric forms are to be inventoried at the job site, they should be kept dry and remain wrapped so that they are protected from the elements during storage and handling. If stored outdoors, they should be elevated and protected with a waterproof cover that is opaque to ultraviolet light. Care should be taken not to damage the fabric forms during unloading, storage and handling.

Note: *The contractor should unload the fabric forms by hand or with a forklift or similar equipment. When lifting rolls or panels of fabric forms make sure that workers have proper back support.*

Table 6.0 - Packaging of Fabric Form Rolls

Product	Filter Point (FP)	Filter Band (FB)	Uniform Section (US)	Enviromat (EL & EB)	Articulating Block (AB)
Roll Width, ft (m)	6.33 (1.92)	6.33 (1.92)	6.33 (1.92)	6.33 (1.92)	6.33 (1.92)
Roll Length, ft (m)	450 (137.2)	450 (137.2)	300 (91.5)	450 (137.2)	450 (137.2)
Gross Weight, lb (kg)	220 (100)	220 (100)	160 (72.7)	220 (100)	240 (109)
Area, ft^2 (m^2)	2,848.5 (264.6)	2,848.5 (264.6)	1,899.0 (176.4)	2,848.5 (264.6)	2,848.5 (264.6)

Contraction of HYDROTEX linings and mats

Contraction factors are a function of site conditions and the fabric form lining or mat style. The definition of “contraction factor” is the length or width of fabric form required divided by the corresponding length or width of the area to be covered by the concrete lining or mat.

The contraction factors provided in Table 7.0 represent typical contraction factors developed by evaluating a large number of installations constructed over typical site conditions (Fig. 18). To use the contraction factors, measure the coverage area (including anchor, toe and flank trenches) and multiply by the contraction factor to obtain the dimensions of the form required.

Example Calculation: Calculate the quantity of Filter Point Fabric Form required for a 200 foot long by 33.2 foot wide mattress lining the drainage channel shown in Figure 19. The *length* of the panel spans the *width* of the channel to allow for more precise sizing. For simplicity in the example calculation, no allocation has been made for flank trenches in the calculation of the panel width.

Total Length of Panel
(spanning the width of the channel):
$[2 (2.0 \text{ ft} + 1.5 \text{ ft}) + 2 ((2.5 \text{ ft})(\sin 26.6°)^{-1}) + 15 \text{ ft}] =$
33.2 ft (10.1 m)
33.2 ft (10.1 m) x 1.1 = 36.5 ft (11.1 m)

Total Width of Panel
(running along the length of the channel):
200 ft x 1.1 = 220 ft (67.1 m)
Adjusting for mill widths multiples:
220 ft/6 ft = 36.7 or 37 mill widths
37 mill widths x 6 ft = 222 ft (67.7 m)

Total Quantity of Fabric Form:
222 ft x 36.5 ft = 8,103 ft^2 (753.1 m^2)

Note: Calculations should be done using the Mill Width and Mill Length factors given in Table 7.0. The Area factors are for rough estimating purposes only. Differing form geometries and the need to round up the width of the panels to mill width multiples can cause the area factors to be slightly inaccurate. In this example, 33.2 ft x 200 ft gives a coverage area of 6,640 ft^2. The actual panel area of 8,103 ft^2 is 1.22 times the coverage area.

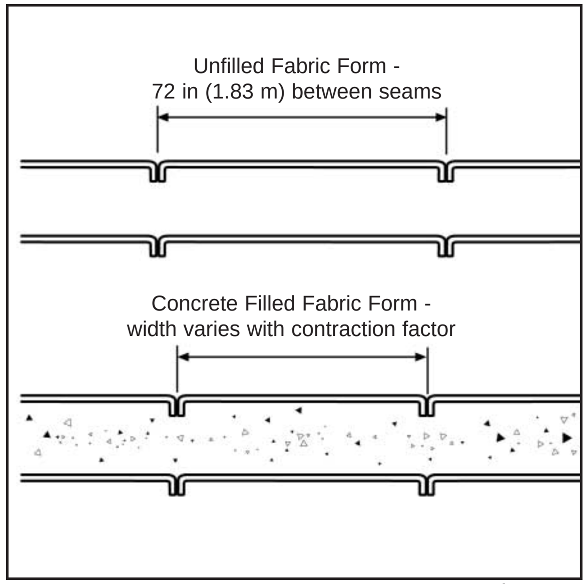


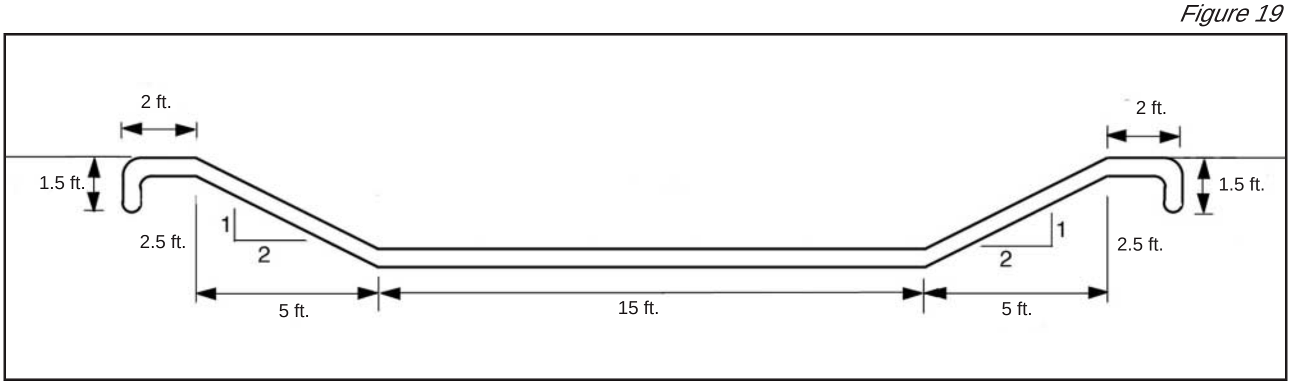
Figure 18

Notes:

The fabricated length dimensions of the fabric form panels are rounded up to the nearest one half foot (150 mm), except for Articulating Block Fabric Forms. Articulating Block Fabric Forms are rounded up to the next full compartment (block). The width dimensions of the panels are in mill width multiples of fabric form. Standard mill width is 72 in (183 mm). However, the width of the last panel in a section may be rounded up to the nearest half mill width.

Additional fabric may be required to allow for tailoring of panels to meet irregular site conditions. These factors range from two to ten percent.

Figure 19



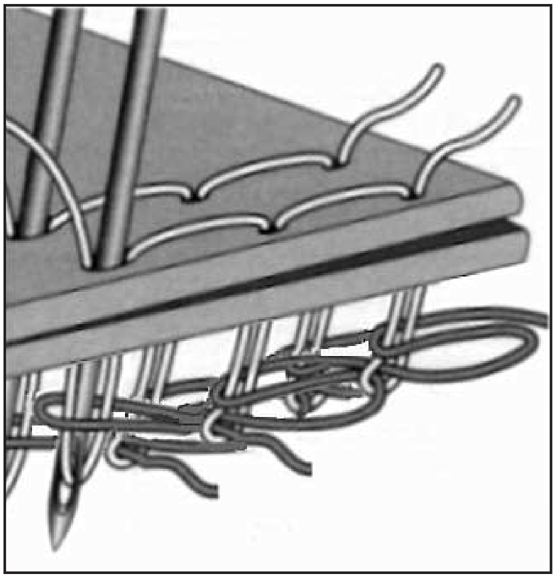


Figure 20

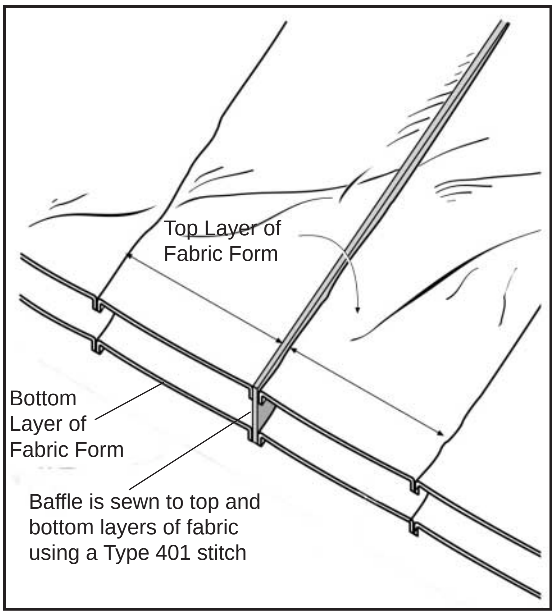


Figure 21

Factory Sewn Seams

All factory sewn seams are made with a double line of Type 401 double-lock stitches (Fig. 20) and are downward facing (Fig. 18). The downward facing seams provide a neat and continuous appearance in the finished fabric forms. 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. Thread used for seaming shall be nylon and/or polyester.

The fabric form panel's two layers of fabric are generally sewn closed along the panel's top and bottom edges (Fig. 15). The side edges of the panel are generally left open to enable field attachment of adjacent panels (Fig. 16). The contractor may request that zippers be attached to the top and bottom layers of fabric along the panel's open edges. The contractor attaches adjacent panels in the field by either sewing or zippering the open edges of fabric together.

Baffles

Baffles are installed at predetermined mill width intervals to regulate the lateral flow of fine aggregate concrete. The baffles are concrete stops made of nonwoven fabric. They extend from the top layer to the bottom layer of the fabric form at corresponding seams of adjacent mill widths (Fig. 21). The location of all baffles are specified on the shop drawings. Typically, baffles are installed every one to six mill widths apart, depending on the fabric form style, size and shape of the fabric form panel, and the project slope's steepness and length.

Irregular Panels

Non-rectangular fabric form panels are occasionally required to account for changes in slope elevations or length, to transverse around sharp curves and turns, and to fit around structures. (Standard rectangular panels may be "warped" around gradual curves or turns as described on page 23 of this manual.) When factory assembling irregular panels the lengths and offsets of individual mill widths of fabric form are dimensioned and cut to the nearest 0.5 ft (150 mm).

When Filter Point and Uniform Section panels are assembled to transverse around sharp curves or turns, panels are constructed with "mirror image" mill widths. Each of the panels will have one or more pairs of mill widths cut on a diagonal to the panel length. The matching sides of the mill widths are cut to obtain true angles and edges, then sewn together to form mitered seams. For Filter Band, Enviromat, and Articulating Block, please refer to page 25.

Table 7.0 - Typical Contraction Factors for HYDROTEX Linings and Mats

	Filter Point (FP)	Filter Band (FB)	Uniform Section (US)	Enviromat (EL)	Enviromat (EB)	Articulating Block (AB)
Mill Width	1.1	1.1	1.05	1.2	1.1	1.1
Mill Length	1.1	1.2	1.05	1.2	1.2	1.1
Area	1.21	1.32	1.1	1.44	1.32	1.21

Weep Tubes
(for Uniform Section Linings)

Plastic weep tubes (drains) are pre-installed at designated locations, along the fabric forms, to relieve hydrostatic pressure (Fig. 22). The tubes have a flange at one end and a point at the other end of a 0.75 inch (19 mm) diameter barrel. The pointed end has four small holes that allow the passage of water but retain large soil particles. There is a flanged cap that is placed over the pointed end and locks in place. Weep tubes are available in lengths of 3, 4, 6, 8, and 10 inches (76, 102, 152, 203, and 254 mm) when measured between the assembled weep tubes flanges. The location of weep tubes, if required, are clearly marked on the fabric form panel shop drawings.

Weep tubes are assembled by forcing the pointed end of the weep tube through both the top and bottom layers of the fabric form and locking the flanged cap over the pointed end (Fig. 23). A small square of filter fabric can be placed over the in-place flanged cap and secured with a fastener (Fig. 24) or the fabric form can be placed over a continuous layer of filter fabric as shown in Figure 23. In either case the filter fabric should prevent fine soil particles from passing through the weep tube.

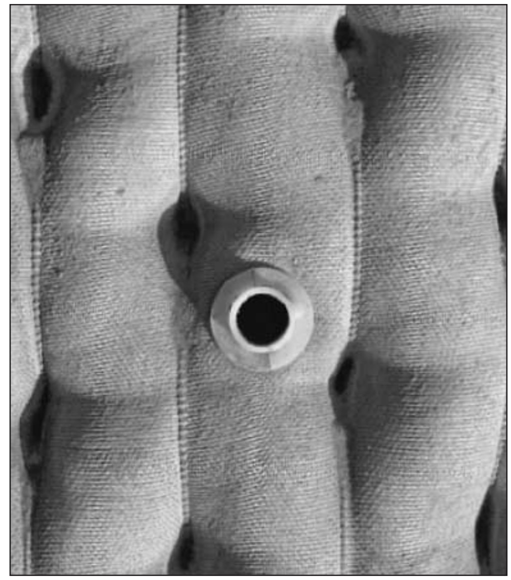


Figure 22

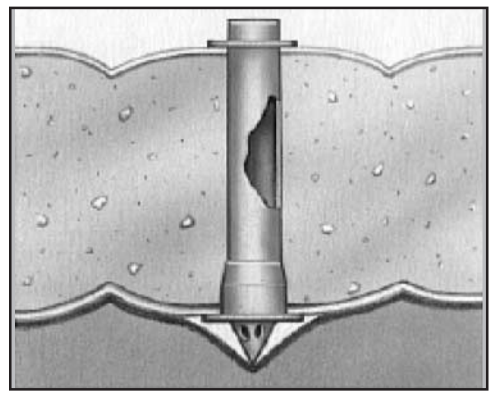


Figure 23

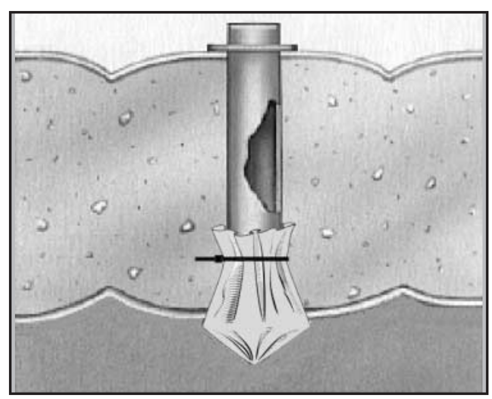


Figure 24

High-Strength Cable
(for Articulating Block Mats)

High-strength cables should be constructed of high tenacity, low elongation, continuous filament polyester fibers. High-strength cables should have a core construction comprised of parallel fibers contained within an outer jacket or cover. The weight of the parallel fiber core should be 65 to 75 percent of the total weight of the cable. High-strength cables are available in a range of diameters and strengths (Table 8.0).

Table 9.0 provides the suggested high-strength polyester cable diameter for the range of Articulating Block Fabric Forms placed on slopes of different lengths. (AB 800, 1000, and 1200 should not be installed on slopes steeper than 1.5:1 except by experienced installers. Please contact Synthetex for further technical assistance.)

Table 8.0 - Nominal Dimensions, Strengths and Weights of High-Strength Polyester Cables			
Cable Diameter, in (mm)	**Weight Per 100 Linear Feet, lb (kg)**	**Average Breaking Strength, lbf (kN)**	**Maximum Allowable Working Load Per Cable, lbf (kN)**
0.250 (6.35)	2.50 (1.13)	3,700 (16.47)	740 (3.29)
0.280 (7.11)	2.80 (1.27)	4,500 (20.03)	900 (4.00)
0.375 (9.53)	4.90 (2.22)	7,000 (31.15)	1,400 (6.23)
0.440 (11.2)	6.60 (2.99)	10,000 (44.50)	2,000 (8.90)
0.500 (12.7)	8.93 (4.05)	15,000 (66.75)	3,000 (13.35)
0.625 (15.9)	13.70 (6.22)	23,000 (102.35)	4,600 (20.47)

All dimensions and tensile strengths are average ± 5%.

Table 9.0 - High Strength Polyester Cable Selection Chart										
Articulating Block Size	**Slope**	**Slope Length, ft (m)**								
		<20 (6.10)	30 (9.14)	40 (12.19)	50 (15.24)	60 (18.29)	70 (21.34)	80 (24.38)	90 (27.43)	100 (30.48)
		Average Breaking Strength of Polyester Cable, lbf (kN)								
AB400	**5:1 - 2:1**	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)
	1.5:1	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	4,500 (20.03)
	1:1	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	4,500 (20.03)	7,000 (31.15)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	10,000 (44.50)
AB600	**5:1 - 2:1**	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)
	1.5:1	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	4,500 (20.03)	4,500 (20.03)	7,000 (31.15)	7,000 (31.15)
	1:1	3,700 (16.47)	4,500 (20.03)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	10,000 (44.50)	15,000 (66.75)	15,000 (66.75)	15,000 (66.75)
AB800	**5:1 - 2:1**	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)
	1.5:1	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	4,500 (20.03)	4,500 (20.03)	7,000 (31.15)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)
	1:1	3,700 (16.47)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	15,000 (66.75)	15,000 (66.75)	15,000 (66.75)	23,000 (102.35)	23,000 (102.35)
AB1000	**5:1 - 2:1**	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)
	1.5:1	3,700 (16.47)	3,700 (16.47)	7,000 (31.15)	7,000 (31.15)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	10,000 (44.50)	10,000 (44.50)
	1:1	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	15,000 (66.75)	15,000 (66.75)	15,000 (66.75)	23,000 (102.35)	23,000 (102.35)	23,000 (102.35)
AB1200	**5:1 - 2:1**	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)	3,700 (16.47)
	1.5:1	3,700 (16.47)	3,700 (16.47)	7,000 (31.15)	7,000 (31.15)	7,000 (31.15)	10,000 (44.50)	10,000 (44.50)	15,000 (66.75)	15,000 (66.75)
	1:1	7,000 (31.15)	10,000 (44.50)	15,000 (66.75)	15,000 (66.75)	23,000 (102.35)	23,000 (102.35)	23,000 (102.35)	23,000 (102.35)	NA

Requirements for Installing and Anchoring Liners and Mats

Slopes

The prepared areas should not be more than 2.5 inches (65 mm) below the grades indicated on the Contract Drawings, and should not vary more than 1.5 inches (40 mm) in 10 feet (3 m) as measured with a straightedge. Where such areas are underwater, they should be backfilled with crushed rock or stone conforming to the grading and quality requirements of 0.75 inch (20 mm) maximum size coarse aggregate for concrete.

Note: *Though fabric-formed concrete can be installed on slopes steeper than those suitable for quarry stone or precast concrete blocks or for compacted soil or soil cement construction, fabric formed concrete linings and mats are not designed to improve slope stability. Their inherent weights are selected for the purposes of hydraulic stability and are not to be considered sufficient to impart stability to slopes subject to rotational, global or sliding failure or where severe consolidation of the subgrade is anticipated.*

Flank, Anchor (side), and Toe Trenches or Aprons

Flank, anchor (side), and toe trenches or aprons should be excavated along the lines, grades and dimensions shown on the Contract Drawings. Trenching equipment works well provided the upper inside edge of the trench is rounded by hand in order that the fabric formed concrete lining or mat extends over a curve rather than a corner at the slope-to-trench transition (Fig. 25).

Crown Protection

Rivers and Channels

The top elevation of a fabric-formed concrete lining or mat installation should be extended to the top of the slope or to a point above the maximum design high water elevation plus a freeboard of a minimum of 2 ft (60 cm) with an additional allowance for run up from waves or boat wakes (Fig. 26).

It is recommended that fabric-formed concrete linings and mats should be extended horizontally at the top of the slope or onto a bench for a minimum distance of 2 ft (60 cm) and then placed in an anchor trench a minimum depth of 1.5 ft (50 cm) (Fig. 26). For sandy soils, a rounded shoulder and sloped trench side is normally used (Fig. 26.1).

Shorelines, Lakes, Reservoirs and Retention Basins

The top elevation of a fabric-formed concrete lining or mat installation should be extended to the top of the slope or to a point above the maximum run up from design waves or boat wakes (Fig. 27).

It is recommended that fabric-formed concrete linings and mats should be extended horizontally at the top of the slope or onto a bench for a minimum distance of 2 ft (60 cm) and then placed in an anchor trench a minimum depth of 2 ft (60 cm) (Fig. 27).

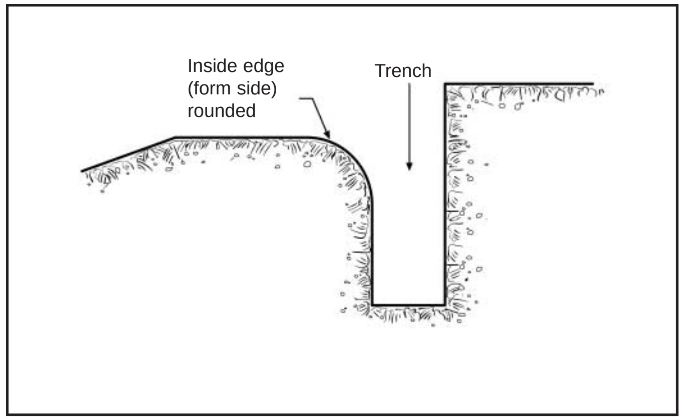


Figure 25

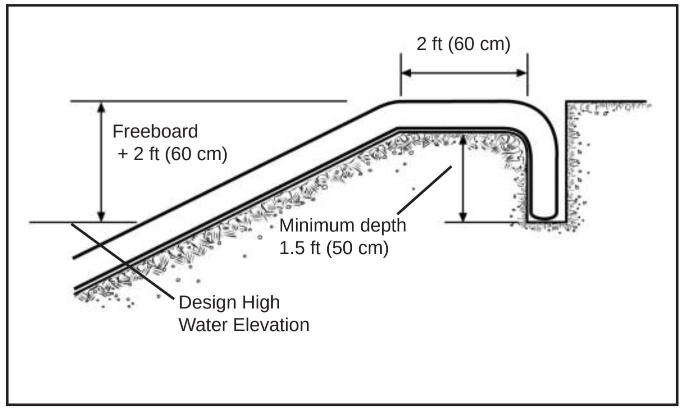


Figure 26

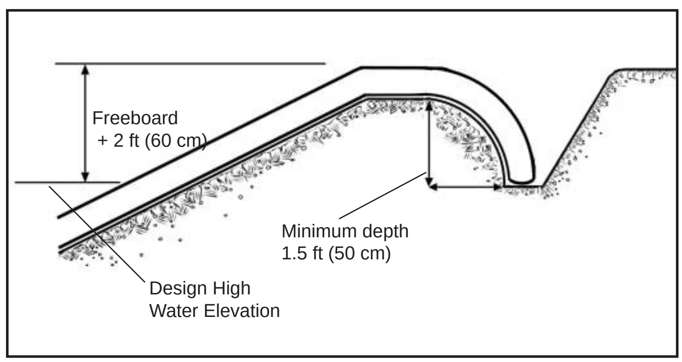


Figure 26.1

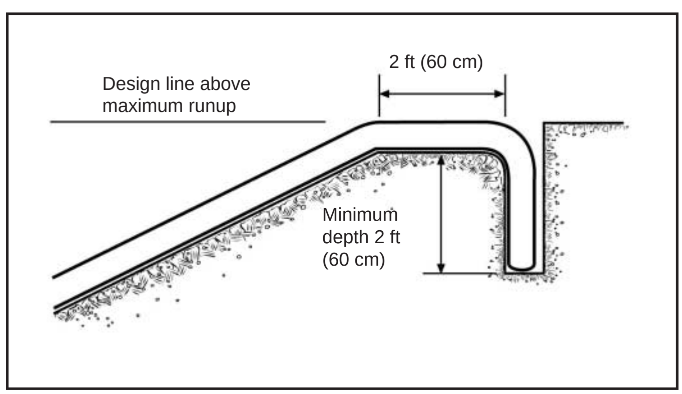


Figure 27

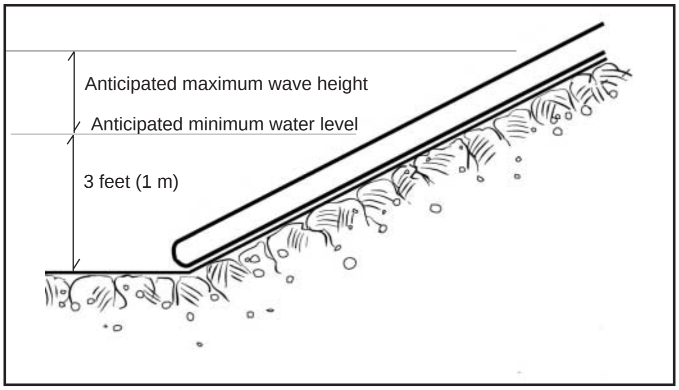


Figure 28

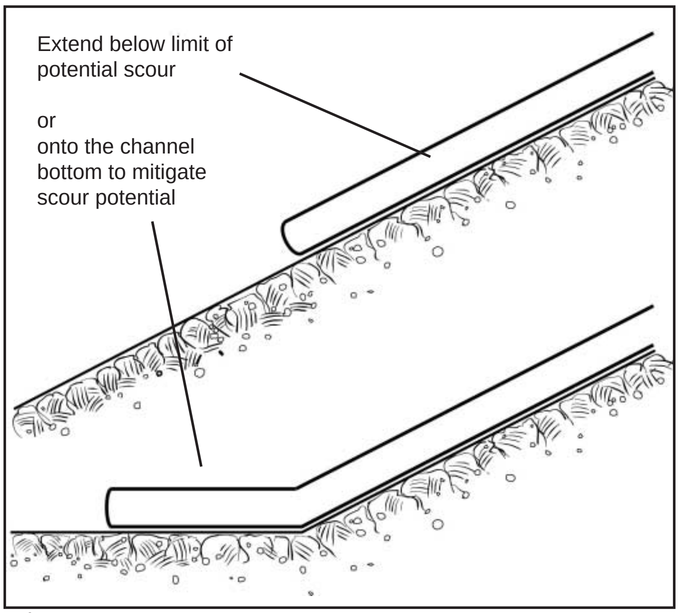


Figure 29

When constructing crown protection for either rivers and channels or shorelines, lakes, reservoirs and retention basins it is important to note that overtopping may cause erosion immediately above the protection that may eventually undermine and collapse the concrete linings, mats and armor units.

Toe Protection

The lower edges of a concrete lining or mat installation should be extended a minimum vertical distance of 3 ft (1 m) below anticipated minimum water level plus a distance equal to the anticipated maximum design wave height (Fig. 28). Additional toe protection may be required where the structure is in the vicinity of commercial shipping or where toe scour is known to be severe. The lower edge of the mat should extend to an elevation below that at which scour might occur or extend onto the channel bottom to mitigate scour (Fig. 29). This procedure will reduce the possibility of washout of soil from beneath the lining or mat.

Flank Trenches

The terminal ends of a fabric formed concrete lining or mat installation should be placed in a flank trench that is excavated at an angle of about 45° from the normal angle of the subgrade.

Rivers and Channels

Though the downstream flank of a concrete lining or mat installation is the most vulnerable point to the tractive forces of flowing water, it is recommended that both the downstream and upstream flanks be protected with flank trenches with a minimum depth of 2 ft (60 cm) (Fig. 30).

Shorelines, Lakes, Reservoirs and Retention Basins

Both flanks of a concrete lining or mat installation are equally vulnerable to the erosive forces of wave action and currents. They should both be protected with flank trenches with a minimum depth of 2 ft (60 cm) (Fig. 30).

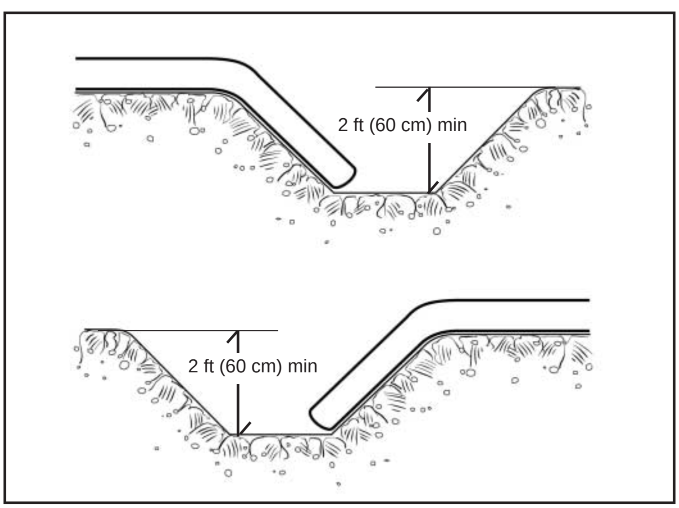


Figure 30

Note:

The requirements listed on these pages for the anchoring and protection of linings and mats are given for guideline purposes only. For an actual installtion, these parameters must be established by a qualified Hydraulics Engineer, based on his calculations of the requirements for a specific project. Synthetex assumes no responsibility for the performance of an installation whose design has not been reviewed by a qualified engineer.

Installation of HYDROTEX Linings and Mats

Equipment and Tools

Because of the simple installation procedure for the HYDROTEX linings and mats, a nominal amount of tools and equipment is required. We suggest that the contractor have on hand the following:

Tools:

- Surveyor's level and rod
- Shovels
- Rakes
- Hammer
- Stakes
- String line
- Rubber boots and gloves
- Pail
- Trowels
- Safety glass or goggles
- Scissors
- Crimping tool (for Articulating Block only)

Equipment:

- Small line concrete pump
- Concrete pump hose - 2 inch (50 mm) diameter
- Injection pipe - 2 inch (50 mm) diameter (Fig. 31)
- Hand-held sewing machine (electric or air powered) with speed control
- Extension cord (if electrical equipment is used)
- Electric generator with ground fault circuit breaker
- Air compressor (if air powered sewing machine is used)
- Narrow trench digging equipment (optional)
- Small, walk-behind flat or vibratory compactor for soil compaction
- Post digger or auger (if steel anchor rods are specified)

Lists of equipment manufacturers are provided in the appendices. However, Synthetex makes no warrantee nor guarantees the performance of equipment provided by another manufacturer.

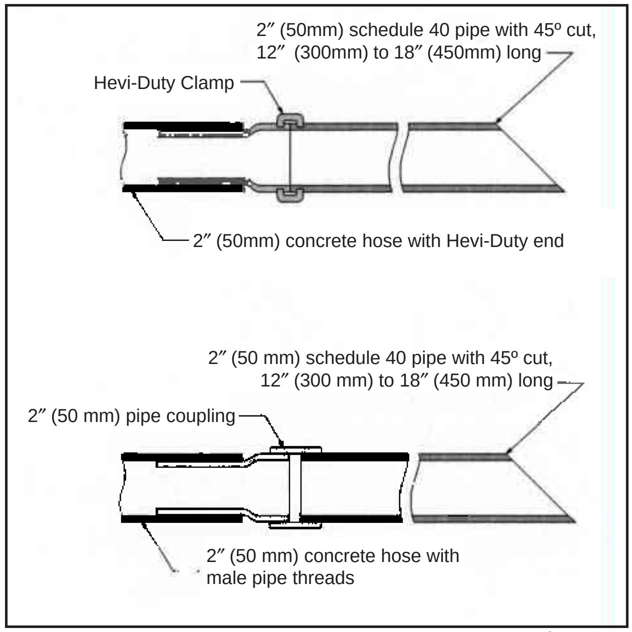


Figure 31

Sequence of Fabric Form Installation

Once the area to be protected has been excavated, graded and compacted to the lines and grades specified in the Contract Drawings and Specifications an installation crew, filter fabric, if required, fabric forms and the tools and equipment listed above should be mobilized to the job site. *Freshly excavated and graded slopes are highly subject to erosion and should be protected from water runoff, flowing water and waves.*

Depending on the location of the area, dimensions, and the rate of subgrade preparation, installation

Equipment Traffic:

Equipment that could crack, cause abrasion, or otherwise damage the concrete should not be allowed on the installed fabric-formed linings and mats.

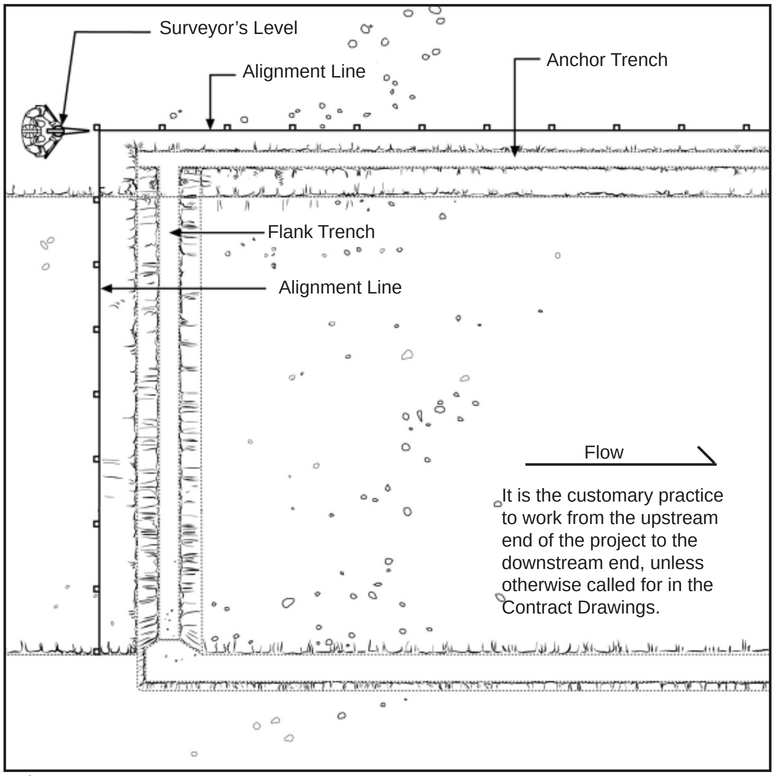


Figure 32

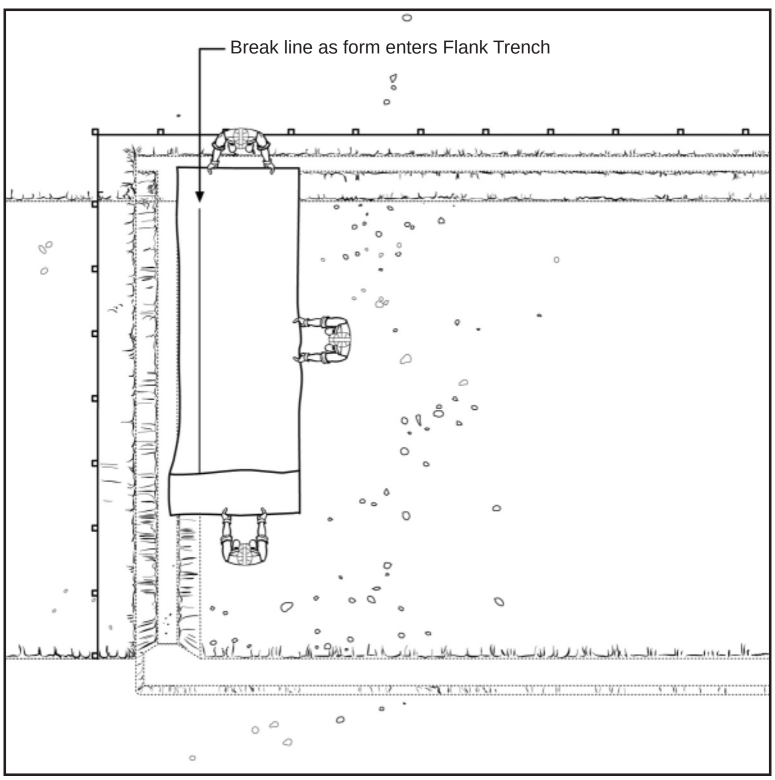


Figure 33

rates of as much as 15 yd^3 (11.5 m^3) of fine aggregate concrete per hour can be achieved by a crew of 3 or 4 laborers, a concrete pump operator and a supervisor.

Establish the starting point

The first step in the installation of fabric formed concrete linings and mats is to establish a starting point. If a working point and direction of placement are shown on the Contract Drawings this should be the starting point. If this is not the case, it is the customary practice to work from the upstream end of the project to the downstream end. In this manner the flow of the water will tend to spread the fabric forms out ahead of the finished work and the finished concrete lining or mat are protected from undercutting (Fig. 32). *Fabric form panel layout drawings, available from Synthetex will recommend starting points and directions of placement for the project.*

Establish the alignment lines

Once a starting point has been established a surveyor's level should be used to determine the longitudinal and slope alignment lines of the fabric formed concrete linings or mats (Fig. 32). String lines should then be placed along the respective alignment lines and staked. Generally, the alignment lines are offset, by a measured distance, to the opposite side of any trench or a minimum of 5 feet (1.5 m) in order not to interfere with the work area (Fig. 32). *The method of establishing reference points and lines should be left to the discretion of the contractor.*

Placement of the filter fabric, if required

Under certain soil conditions or if called for in the Contract Drawings and Specifications, it will be necessary to place filter fabric and/or a granular sublayer under the fabric forms to guarantee the functioning of the filter points, filter bands, permeable interwoven perimeters, or weep tubes. Filter fabric should be selected and placed in accordance with the Contract Drawings and Specifications or in the absence of such directions in accordance with the manufacturer's guidelines. If called for in the Contract Drawings and Specifications, steel anchor rods should be installed prior to placement of a geotextile filter fabric. The anchor rods should be forced through the filter fabric. *Filter fabrics and their installation are discussed, in brief, earlier in this manual.*

Placement of the first fabric form panel

The prefabricated panels are accordion folded and then rolled and marked with the appropriate panel numbers at the factory for easy identification, location and installation.

The first fabric form panel should be carefully placed at the designated starting point and rolled out into position (Fig. 33).

The panel should be extended into position by pulling the leading side of the panel in the direction of the concrete lining or mat placement (Fig. 34). Special care should be taken to assure that the sides and the ends of the panel are exactly parallel to their respective alignment lines.

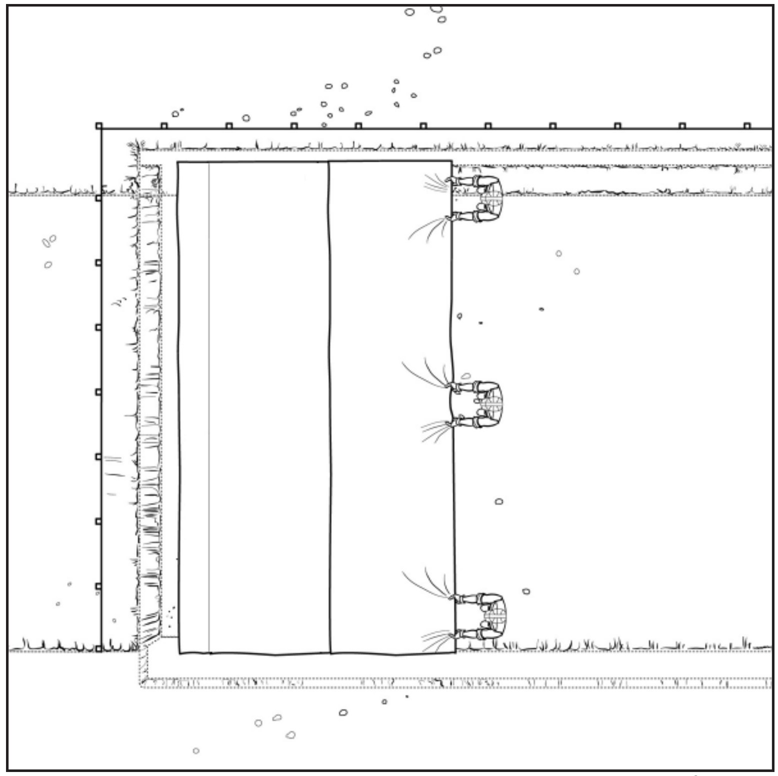


Figure 34

Fabric form panels should be placed loosely, but without folds, to allow for proper filling with fine aggregate concrete. The extra fabric form provided for form contraction should be gathered into temporary tucks at the top of the slope and at each seam (Figs. 35 and 36). Panels that are stretched or taut will not permit the required fabric contraction, therefore the fabric forms will not fill to their required thickness. For example, an 11 mill-width-wide panel of Filter Point fabric form will be 66 feet (20 m) wide. When filled with fine aggregate concrete the width will contract to a finished width of 60 feet (18 m). See Table 7 for the contraction factors of the various form styles. The fabric form in this example should therefore be placed with the seams (which join mill widths) 5.5 feet (1.6 m) apart. If called for in the Contract Drawings and Specifications, steel anchor rods should be forced through both layers of the fabric form.

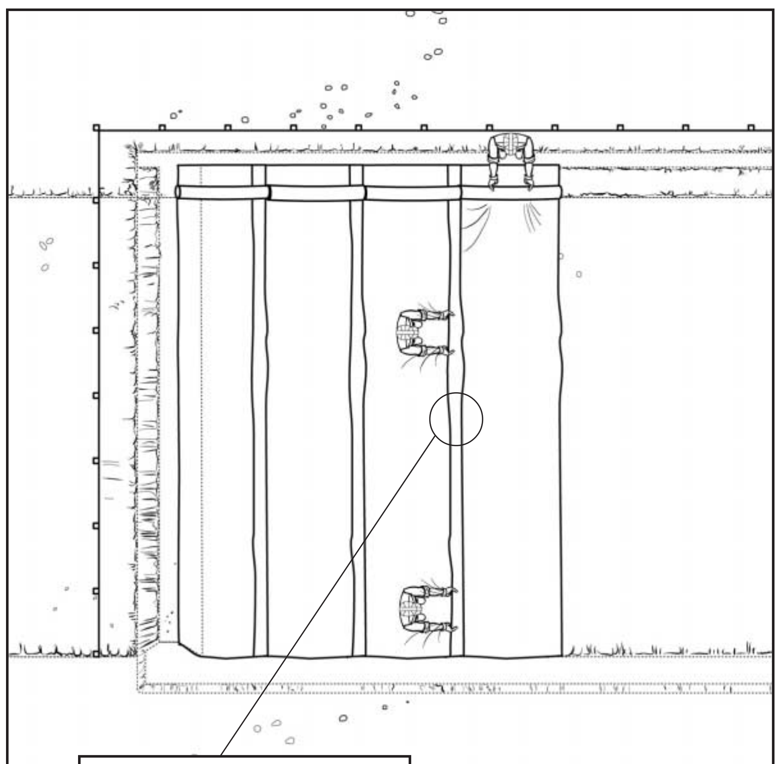


Figure 35

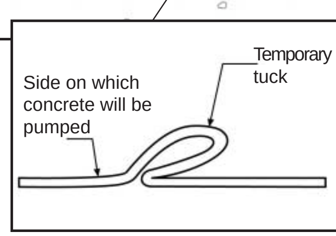


Figure 36 - Detail View of Tuck

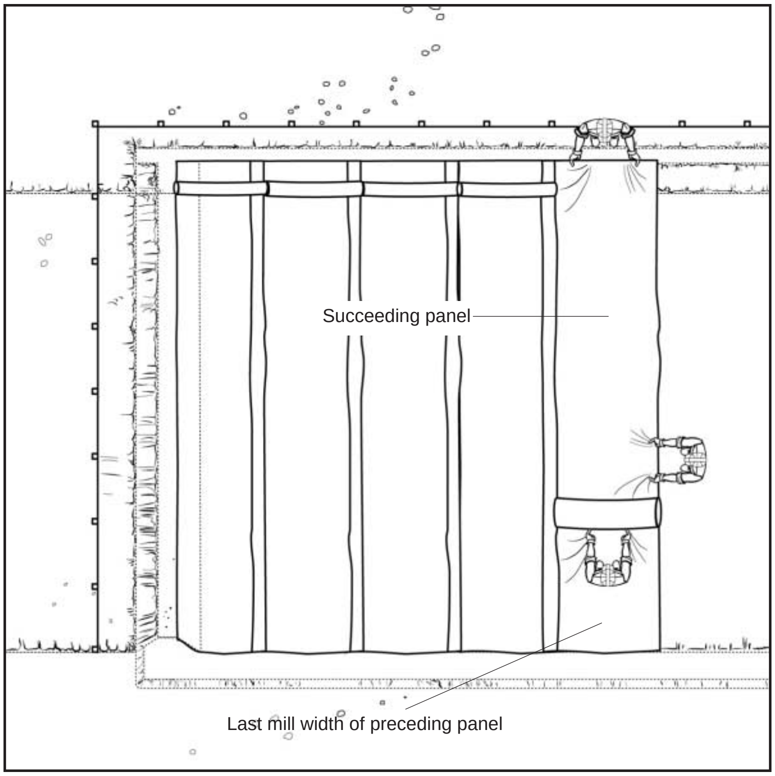


Figure 37

Placement of the second and remaining fabric form panels (sewn seams)

The succeeding panel should be placed atop the last mill width of the preceding panel so that their adjoining sides are abutting, as shown in Figure 37. The succeeding panel is then joined to the preceding panel by sewing. The panels should be joined together, edge-to-edge, by field sewing the top edge to top edge and the bottom edge to bottom edge (Fig. 38 and 39).

Placement of the second and remaining fabric form panels (zippered seams)

The succeeding panel should be placed adjacent to the last mill width of the preceding panel so that their adjoining sides are abutting. The succeeding panel is then joined to the preceding panel by zipping the panels together (Fig. 40).

Note: When installing Articulating Block (AB) Fabric Forms, optional transverse cables are spliced together prior to joining the second layers of fabric.

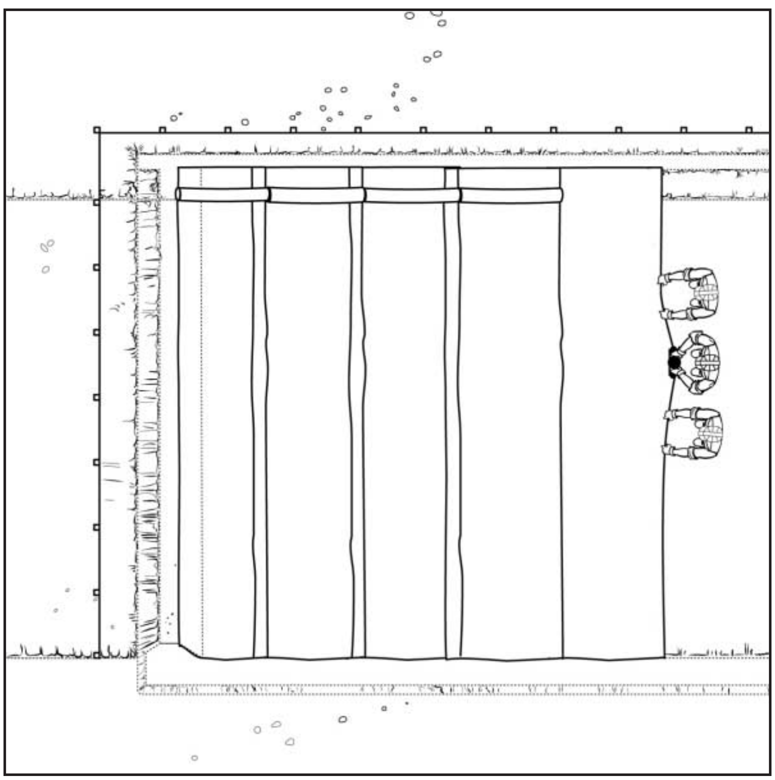
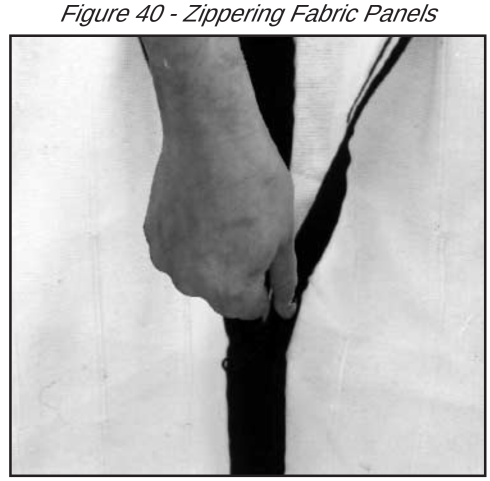


Figure 38

Figure 39 - Sewing Fabric Panels

Figure 40 - Zippering Fabric Panels



- **The second panel** should then be extended in the direction of alignment and all seams should be downward facing (Fig. 41). After the second panel has been positioned, the alignment of the panels should be checked. The alignment of the fabric should be checked periodically since small errors in alignment can progress in severity.

- **The remaining panels** should be placed side-by-side in the same manner. If care has been taken in placing the panels, little if any further adjustment of panels should be required. However, panel alignment is important in providing a uniform and attractive appearance in the finished installation.

Fabric form placement should proceed concrete filling by no more than the distance that can be completed in one day.

If the panels are to be placed underwater or if the aesthetic appearance is not of importance, the time involved in inverting the panels as described above may not be justified. Adjacent panels may be joined by abutting the panels and sewing the bottom and then the top seam. Except for the small tab of fabric that will protrude above the surface of the concrete lining or mat, seaming the fabric in this manner is functional and will not adversely effect the performance of the installation.

Sewn seams should be made using portable, hand-held, sewing machines and nylon or polyester sewing thread. Generally, a prayer seam with a U.S. Federal Standard Type 101 stitch is the most suitable. It is strongly recommended that each seam be made with two parallel passes of the sewing machine to assure a tight seam equivalent to those seams sewn in the factory. *Whenever possible, the second pass of the sewing machine should run in the direction opposite to but parallel to the first pass.*

Three (3) laborers are generally required for the sewing or zippering of seams; one to operate the sewing machine or zipper pull, one to align the fabric form and one to inspect the seam.

Sewing machines suitable for field use are listed in Appendix 2. There are both electric and air powered sewing machines listed. The electric sewing machines should be provided with a speed control rheostat. The air powered sewing machines have a built-in speed control. The air powered machines are more expensive; however, they are safer when working in a wet environment.

All seams sewn in the field shall be not less than 90 lbf/in (15.7 kN/m) when tested in accordance with ASTM D 4884. Colored thread is preferable for seams, since defects such as broken threads, seams too close to the edge of the fabric or a machine that is skipping are immediately apparent.

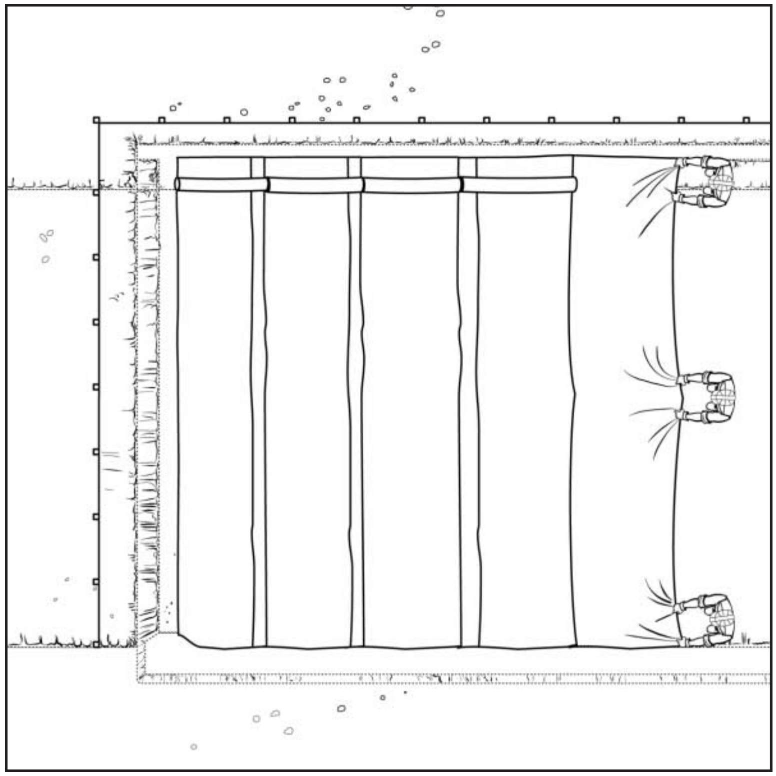


Figure 41

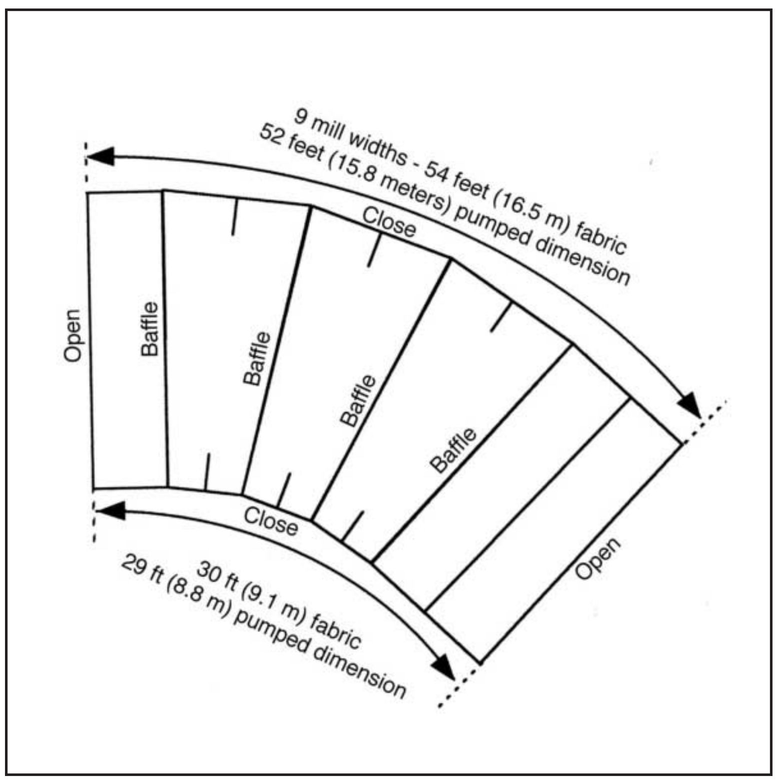


Figure 42

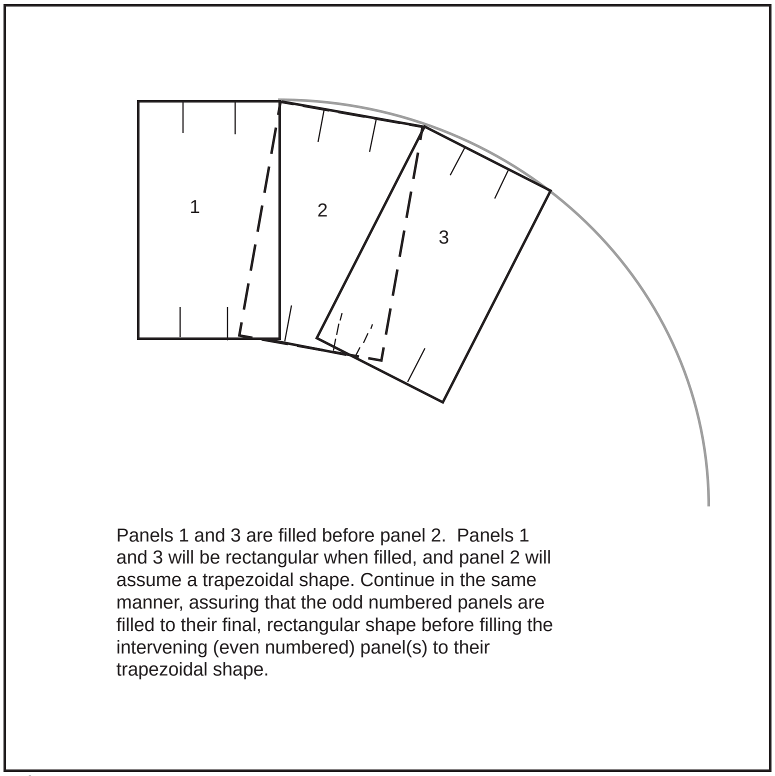


Figure 43

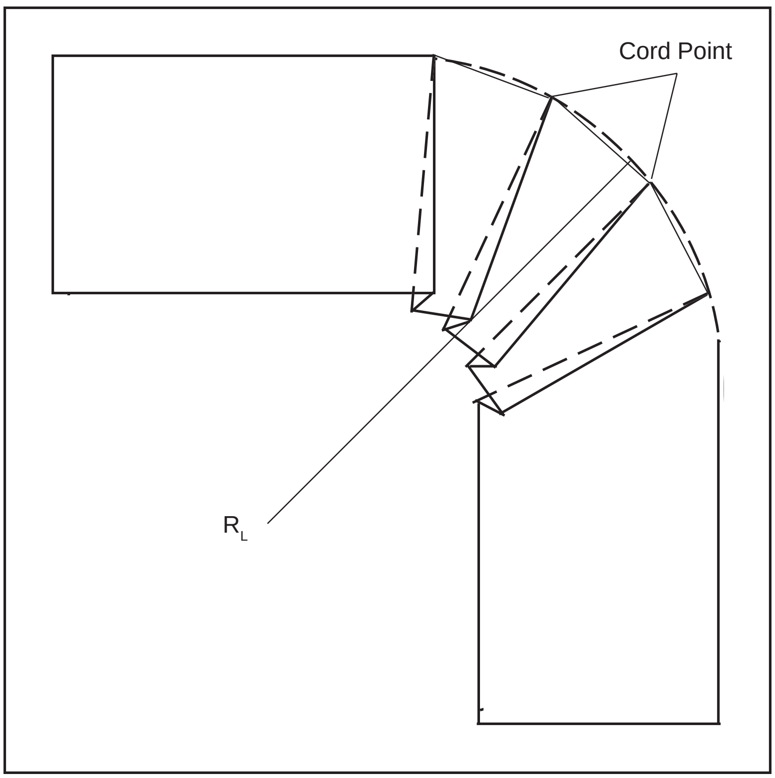


Figure 44

Placement of fabric form panels around curves and turns

Curves or turns may be accomplished by panels with one or more angled mill widths. Panels with angled mill widths should be carefully prefabricated or field assembled by cutting and sewing the mill widths of the fabric form(s) to obtain true angles and edges (Fig. 42).

Curves and turns in the project can also be accomplished by positioning the sides of alternate panels perpendicular to the concrete lining or mat's longitudinal alignment line. The alternate panels should then be pumped to form standard rectangular shaped sections. The intermediate panels should then be pumped. These intermediate panels will form sections with a slightly trapezoidal shape to complete the curve or turn (Fig. 43).

A third method to accomplish curves and turns in the project is to place baffles between each mill width. Then set predetermined seams at one end of the mill width at their normal spacing at cord points along the larger radius of the curve or turn and then set the seams at the other end of the panel at a measured spacing at cord points along the smaller radius of the curve or turn. The excess width of fabric form, between seams, is carefully accumulated into pleats that taper the mill width down toward the smaller radius (Fig. 44).

Placement of fabric form panels into trenches

After the fabric form panels have been positioned, the designated sides of the panels should be folded into the anchor trench, flank trenches and toe trench.

Underwater placement of fabric forms may require the use of divers. The divers can prepare the finished grading, inspect the area to be protected, and position and secure the filter fabric and fabric forms. The securing of the fabric may require sand bags or weights, or lines tied from shore to hold the fabric in position.

A small quantity of bulk (uncut and unassembled) fabric form should be ordered for each project. This fabric can be used for special field tailoring around drains, headwalls and field changes requiring extensions to pre-assembled panels. At least half a roll, about 900 ft² (84 m²), of bulk fabric is recommended.

Sequence of Fine Aggregate Concrete Pumping

Ordering fine aggregate concrete

Fine aggregate concrete is generally delivered to the job site in ready-mix trucks. The order for concrete should be placed a least one day prior to its scheduled delivery to the job site. The concrete supplier should be instructed to fill the water tank of each truck with mix water. *It is common that the first few loads delivered to the job site will not be fluid enough for pumping and will require the addition of mix water.* In order to avoid presetting of the fine aggregate concrete it is recommended that the concrete be delivered in loads of no more than 8 yd^3 (6 m^3). At a minimum, the first load of each day should be checked with a standard flow cone for consistency, in accordance with ASTM D 6449.

Securing the fabric form panels

Beginning at the designated staring point the installation crew should check and adjust the fabric form panel's seams to assure that they are perpendicular to the longitudinal alignment line. After the panel has been properly adjusted fine aggregate concrete is either pumped into the portion of the fabric form panel that has been placed into the anchor trench (Fig. 45) or the form is secured to structures such as a retaining walls, abutments or curbs. *Insert a pipe or reinforcement bar through a hem sewn along the top edge of the fabric form and secure the pipe or bar to an anchor (Fig. 46).* Securing the panel should help control the position of the panel and should prevent the freshly filled fabric form from sliding down the slope. *It must be emphasized that care should be exercised in the alignment and securing of the first fabric form panel. This will ensure the aesthetics of the concrete lining or mat and also hasten the installation of subsequent panels. Fabric should be placed loosely at the connection or anchor to allow for contraction in both directions during filling.*

Inserting the fine aggregate concrete injection pipe

Fine aggregate concrete should be pumped into the fabric form panel by inserting the injection pipe through a small slit cut in the upper layer of fabric (Fig. 47). *Care must be taken not to cut through the bottom layer of the fabric form.* A tight seal should be make by wrapping a piece of nonwoven fabric

Safety:

All on site personnel should wear safety hats, glasses or goggles, rubber gloves and boots at all times. Electric equipment should be provided with ground fault circuit interrupters and circuit breakers. Concrete pumps and hoses should be handled with care and operated in strict accordance with their manufacturer's safety instructions.

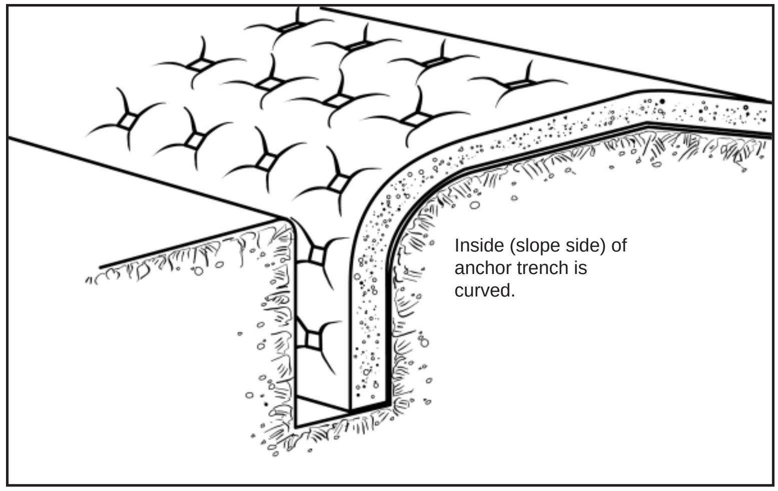


Figure 45

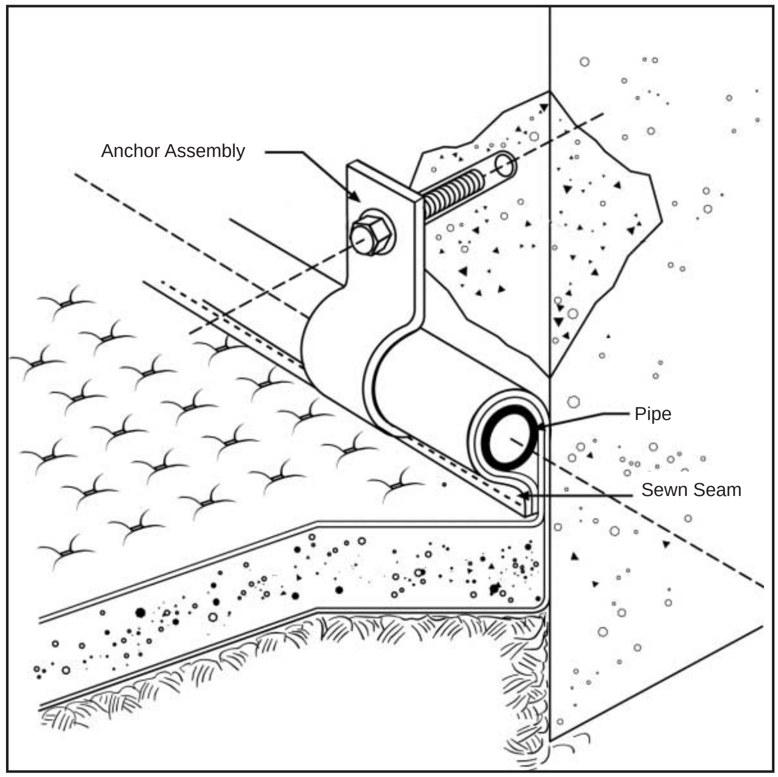


Figure 46

Figure 47

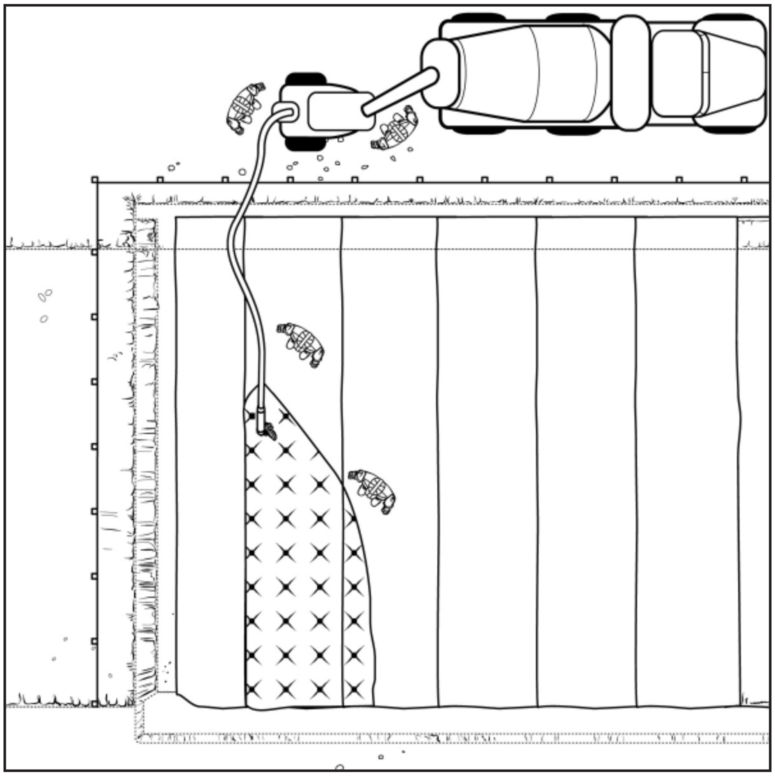


Figure 48

around the pipe. When the pipe is withdrawn, the nonwoven fabric should be stuffed into the hole to provide a temporary closure. When the concrete has stiffened and is no longer fluid, the fabric should be removed and the concrete surface should be smoothed by hand.

Filling the first fabric form panel with fine aggregate concrete

The first section of the first panel has generally been placed into a flank trench. In order to eliminate the sliding of the panel into the trench during fine aggregate concrete filling, the general practice to first fill the second section of the first panel, to anchor the fabric. Starting at the second section of the first panel, the injection pipe should be inserted at a point near the inside of the first baffle and a measured distance along the length of the panel. (See Table 10.0.)

The second panel section should be filled by pumping fine aggregate concrete between the panel's top and bottom layers of fabric. The flow of fine aggregate concrete should be directed toward the toe or lower end of the panel (Fig. 48).

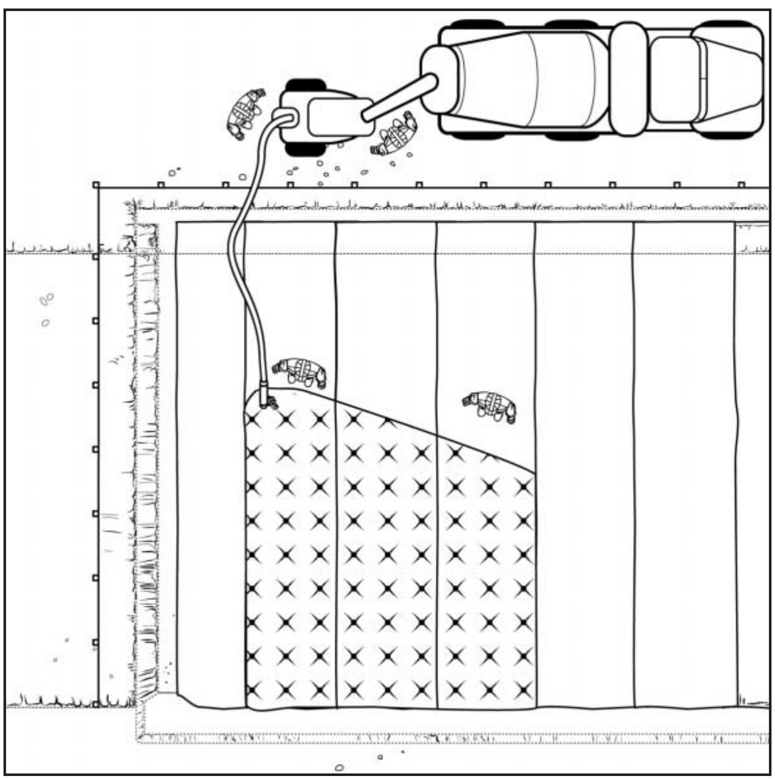


Figure 49

The fine aggregate concrete should fill the toe or lower end of the panel, proceeding gradually up and laterally across to the second baffle of the panel and to an elevation not less than 2 feet (500 mm) above the point of concrete injection (Fig. 49). *Pressure from the concrete fill helps to seal off the point of concrete injection.* If the point of concrete injection is not at the crown of the slope, the injection pipe is reinserted further up the panel and the flow of concrete is once again directed down the panel. *Experienced installation crews are able to pump to an elevation above the point at which the concrete injects.*

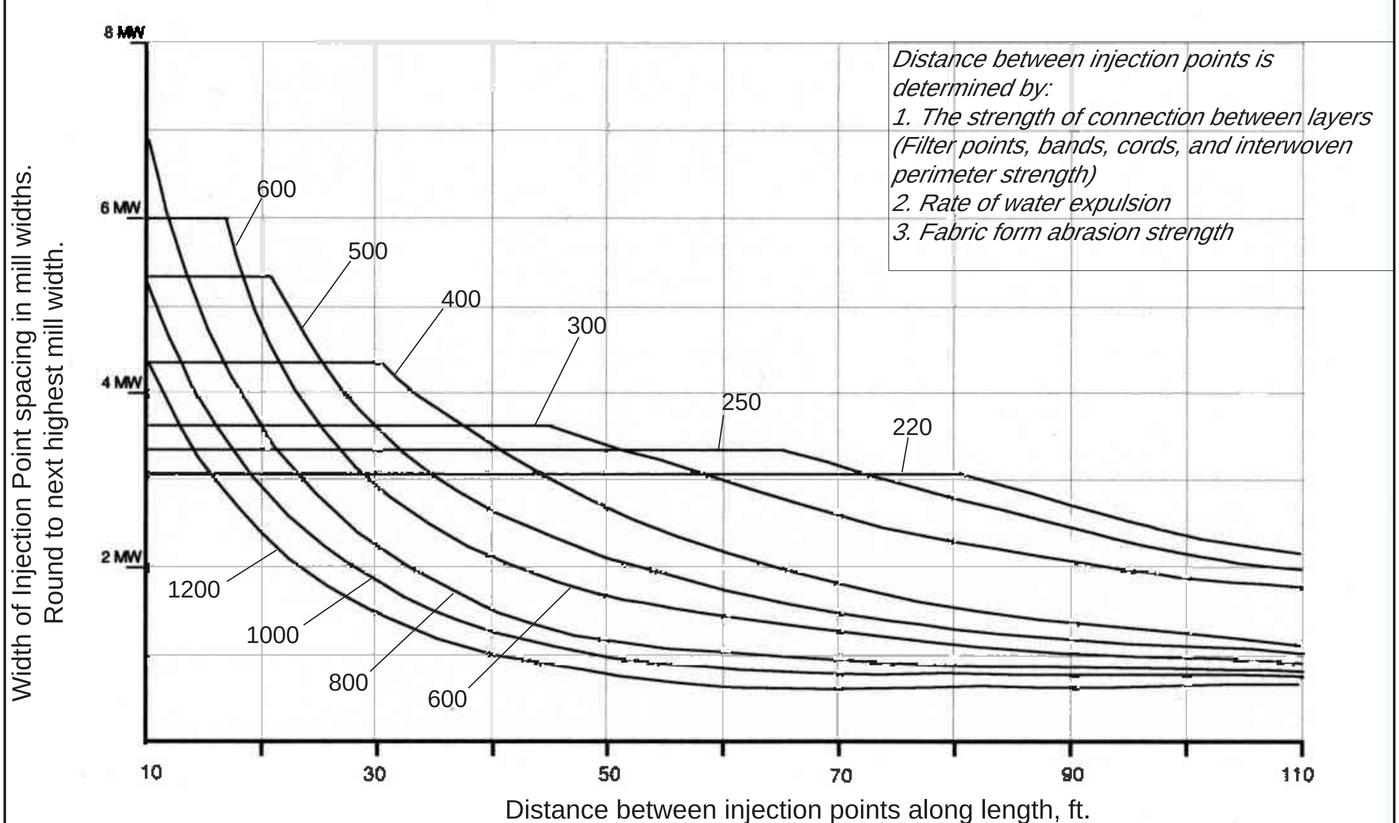
Wetting down of fabric forms:
As fine aggregate concrete is pumped into the fabric forms, excess mixing water will be expelled through the fabric and the concrete will stiffen rapidly. When pumping fabric forms with relatively thin cross-sectional thickness, down a long slope, across a wide section or on a relatively flat surface above water, it may be desirable to wet down the fabric prior to pumping concrete.

Table 10.0 - Maximum Distance Between Injection Points, Measured Along the Length of the Panel (ft/m)					
	Slope	4:1	3:1	2:1	1:1
Product	Size	L	L	L	L
Filter Point	220	35 (10.7)	46 (14)	65 (19.8)	75 (22.9)
	400	64 (19.5)	75 (22.9)	65 (19.8)	41 (12.5)
	600	69 (21.0)	53 (16.2)	37 (11.3)	24 (7.3)
	800	39 (11.9)	30 (9.1)	21 (6.4)	13 (4.0)
	1000	32 (9.8)	24 (7.3)	17 (5.2)	11 (3.4)
	1200	20 (6.1)	15 (4.6)	11 (3.4)	7 (2.1)
Filter Band	400	64 (19.5)	75 (22.9)	70 (21.3)	63 (19.2)
	800	55 (16.8)	42 (12.8)	30 (9.1)	19 (5.8)
	1200	26 (7.9)	20 (6.1)	14 (4.3)	9 (2.7)
Uniform Section	300	48 (14.6)	63 (19.2)	70 (21.3)	75 (22.9)
	400	64 (19.5)	70 (21.3)	75 (22.9)	64 (19.5)
	600	75 (22.9)	64 (19.5)	45 (13.7)	28 (8.5)
	800	33 (10.1)	25 (7.6)	18 (5.5)	11 (3.4)
	1000	22 (6.7)	17 (5.2)	12 (3.7)	10 (3.0)
Enviromat EL	250	40 (12.2)	52 (15.9)	70 (21.3)	75 (22.9)
	400	64 (19.5)	75 (22.9)	60 (18.3)	38 (11.6)
Enviromat EB	300	48 (14.6)	63 (19.2)	75 (22.9)	67 (20.4)
	500	80 (24.4)	67 (20.4)	48 (14.6)	30 (9.1)
Articulating Block	400	60 (18.3)	65 (19.8)	70 (21.3)	75 (22.9)
	600	65 (19.8)	70 (21.3)	75 (22.9)	56 (17.1)
	800	75 (22.9)	70 (21.3)	61 (18.6)	38 (11.6)
	1000	70 (21.3)	54 (16.5)	38 (11.6)	24 (7.3)
	1200	53 (16.2)	40 (12.2)	29 (8.8)	18 (5.5)

Using Tables 10.0 and 10.1 -
First use Table 10.0 to determine the maximum length along the panel between injection points, based upon the slope angle and the product being used. Table 10.1 will then allow you to determine the maximum number of panel widths. Select the length to be pumped along the bottom axis and note where that intersects with the curve for each product thickness. Then read the maximum number of mill widths along the vertical axis. Round to the next highest mill width.

Over pressuring of fabric forms:
Care must be taken, when pumping fabric forms to assure that the fabric is not over pressurized. Over pressurization may cause bursting of filter points, bands or interwoven perimeters or may cause rupturing of interwoven drop cords. The style of the fabric form and field conditions will often determine the rate of vertical rise of the concrete that may be realized in pumping. Table 10.0 provides typical guidelines for pumping fabric forms. For the ease of measurement in the field, the vertical rise in concrete has been converted to slope length.

Table 10.1 - Maximum Distance between Injection Points, measured along the width of the panel (in mill widths)



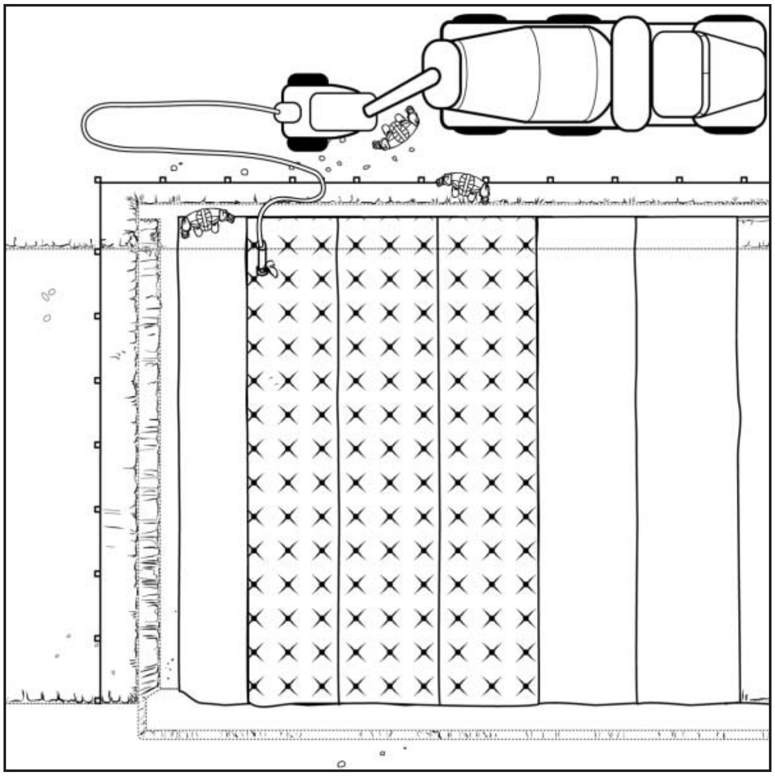


Figure 50

This procedure is repeated until the second section of the first panel has been filled to its specified thickness from baffle to baffle and from the toe or lower end to the anchor trench or top end (Fig. 50).

When installing fabric formed linings or mats on steep slopes or when the installation crew is inexperienced, it is recommended that they first fill the fabric form that has been placed in the anchor trench then proceed to directing the flow of fine aggregate concrete to the toe or lower end of the panel.

As the fabric form panel is being pumped with fine aggregate concrete the panel will contract causing a stretching and tightening of the form. In order to prevent the tightening of the fabric form and the resulting constriction of fine aggregate concrete flow, the installation crew should slowly release the temporary tucks previously placed in the fabric form at the top of the panel. *The temporarily tucks may be accumulated at the top of the panel and held in place by standing on the fabric form. As tension develops the fabric tucks are slowly released.*

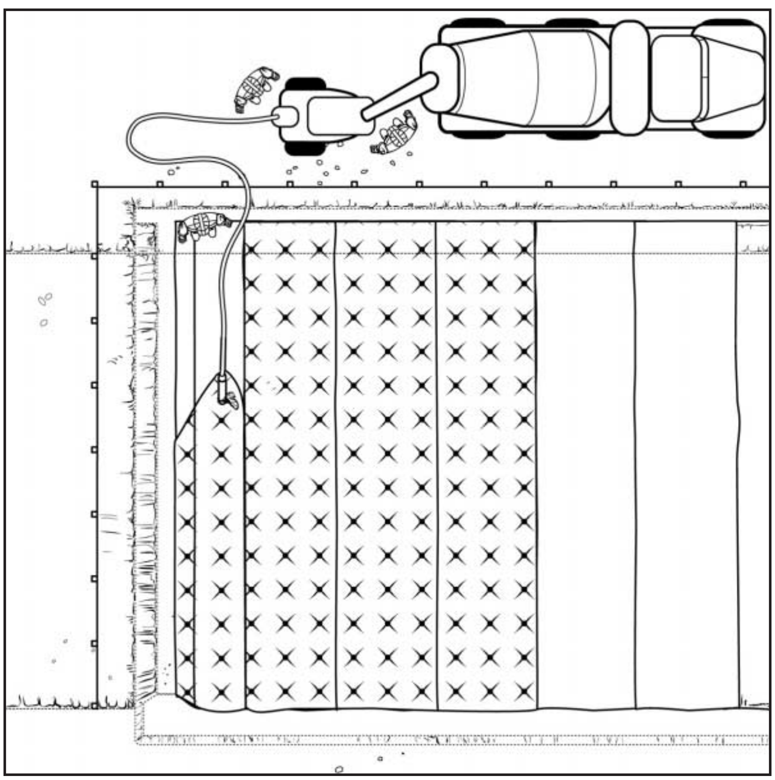


Figure 51

The injection pipe should then be moved to the other side of the first baffle and inserted at a point near the baffle and a measured distance along the length of the panel (Fig. 51). Once again the previous pumping procedure should be repeated until this section of the panel has been filled to its specified thickness from baffle to baffle and from its toe or lower end to its anchor trench or top end.

Filling remaining fabric form panels with fine aggregate concrete

If care has been taken in positioning the panels and in concrete filling the first panel, little if any adjustment of subsequent panels should be required. However, panel alignment should be checked periodically since small errors in alignment can progress in severity. Periodically check the location of the panels with an instrument to assure that proper alignment is being maintained.

Special Considerations

Lap Joints

If the conventional joining of panels, by field sewing of adjacent panels, is impractical or if site conditions or project design preclude a continuous lining or mat a lap joint may be employed. Adjacent panels may be overlapped either transverse to or longitudinal to the installation. In all cases the lap must be shingled to correspond with the direction of flow.

A lap joint may be desirable along the centerline of a wide channel or a channel with changes in bottom width or slope length. It may allow the contractor the flexibility to use a standard panel size to conform to the variable design cross sections.

A lap joint may be constructed by overlapping adjacent fabric form panels by a minimum of 3 feet (1 m). **Butt joints are not permitted.** The proper method for constructing a lap joint is the following pumping sequence (Fig. 52):

- Fill the next to the last mill width of the upstream form, leaving the last section of the upstream and preceding panel unpumped.
- Excavate a terminal trench as described in Figure 52 or in the Contract Drawings.
- Position the side of the succeeding panel approximately 3 feet (1 m) from the last pumped mill width of the preceding panel.
- Pump fine aggregate concrete into the first mill width of the succeeding panel.
- Backfill the terminal trench so that the last mill width of the preceding panel can be laid to form an even transition to the succeeding panel.
- Extend the last mill width of the preceding panel over the indented portion of the first mill width of the succeeding panel and fill this section.

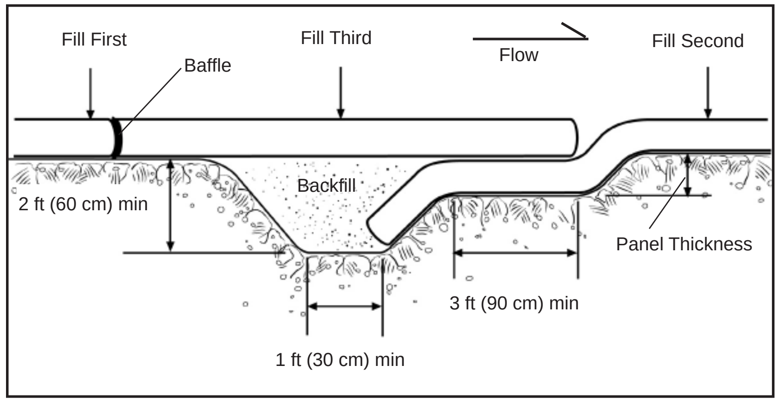


Figure 52

Pipes, piles, culverts, trees and other appurtenances

Fabric forms should be tailored in the field to fit around pipes, piles, culverts, trees and other appurtenances. An opening should be cut in the fabric form that is slightly smaller than the object and the perimeter of the opening is sewn closed. When the fabric form panel is placed the tailored opening is either slid over or wrapped around the object. As fine aggregate concrete is pumped into the section of the panel with the tailored opening it will form snugly around the object (Fig. 53).

An alternate method of construction is to first fill the fabric forms that have been placed in close proximity to the object and then to place a separate collar, snugly around the object, overlapping the primary concrete lining or mat by a minimum of 2 ft (60 cm) (Fig. 54).

Backfilling and compaction of trenches

The backfilling and compaction of anchor, flank and toe trenches and other open excavations should proceed in not less than one hour behind the concrete filling of the fabric formed linings or mats. Anchor and flank trenches should be backfilled and compacted to the top of the concrete linings or mats. Toe trenches should be backfilled as shown on the Construction Drawings. *The trenches of completed sections of concrete linings or mats should be backfilled and compacted by the end of the work day.*

Figure 53

Foot traffic

Foot traffic on the freshly pumped fine aggregate concrete lining or mat should be avoided for a period of not less than one hour after concrete injection or until the concrete is resistant to indentation. Should traffic be unavoidable, the contractor should place board walks along the finished filled concrete areas. This will reduce the amount of objectionable indentation. *Footprints will leave permanent impressions in the installed fabric-formed concrete linings or mats.*

Cleanup

Any fine aggregate concrete that may spill on top of the fabric formed concrete lining or mat should be picked up by hand or trowel and the surface

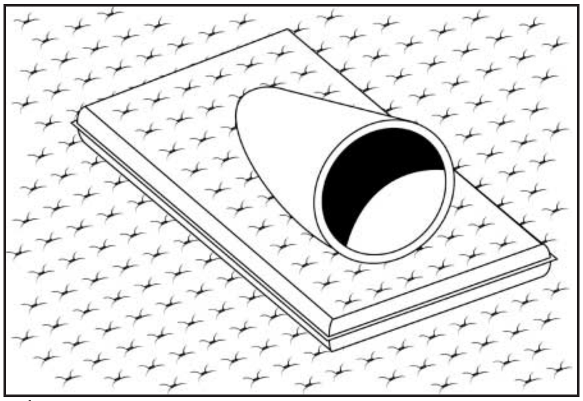


Figure 54

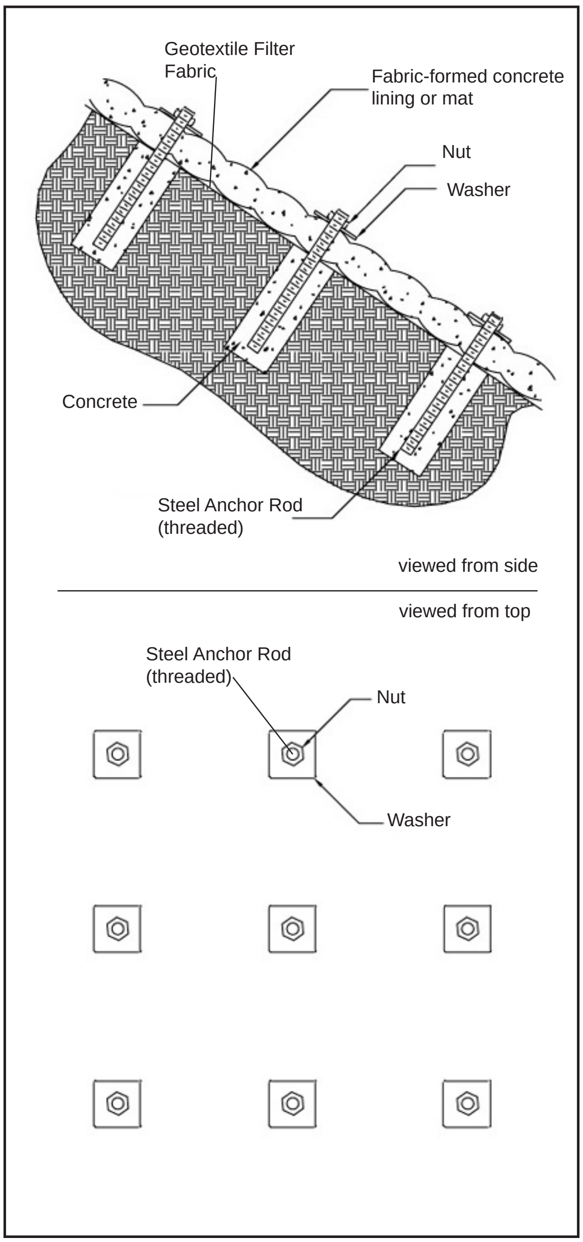


Figure 55

smoothed by cloth or broom. Such unnecessary spillage of concrete will cause an unsightly appearance and may clog the concrete lining or mat's drainage areas such as filter points, filter bands or the permeable interwoven perimeter areas of the fabric forms. *The installation crew should be instructed to carefully "kink" the concrete pump hose when it is moved from one injection point to another or to place the end of the concrete injection pipe in a pail when moving the concrete pump hose.*

The freshly pumped fabric formed concrete linings and mats should never be washed (sprayed) under pressure with water in an effort to clean or remove spills from its surface. A wet cloth should be used for clean up and spill removal.

The cement film that bleeds through the top layer of the fabric forms provides a bond between the fabric form and the concrete fill and a degree of protection against ultraviolet degradation of the fabric. Should this film be removed by washing the uncured concrete linings or mats, cement may be also washed out from beneath the top layer of fabric. The result would be a loss of concrete-to-fabric bond, a sandy, low strength outer surface of concrete and a concrete lining or mat which will exhibit low abrasion resistance and durability.

Finishing (Enviromat EL & EB Linings only)

After the concrete lining has been filled and the concrete has set, the large single-layer areas should be cut out and the resulting open areas filled with void filler to the top of the concrete lining. The void filler material should consist of topsoil, seed and fertilizer in accordance with the Contract Specifications. At no time should more than 200 linear feet (152.5 m) of concrete lining be exposed unfilled.

Below the water line, the void filler material should consist of well-graded aggregate with a maximum size of 1 inch (25 mm). At no time shall more than 500 linear feet (150 m) of Enviromat be exposed unfilled.

Steel Anchor Rods

Where required in the Contract Drawings and Specifications, steel anchor rods should be installed at designated centers along the fabric-formed concrete lining or mat to increase its resisting force (Fig. 55). The diameter of the anchor rods is selected to provide the supplemental shear strength required for the installed area of lining or mat. The threaded anchor rods should be grades 40 or 50 and a 6 inch (152 mm) square washer and nut are placed at the end of each anchor. Typically, the total length of the anchor rod is the sum of the embedment depth, the average thickness of the lining or mat, plus 6 inches (152 mm). The embedment depth of the anchor rod must be sufficient to resist the pullout force applied in line with the rod. The depth is dependent upon the concrete used in the anchor block and the type of soil. *For most conditions, an embedment depth of 24 inches (610 mm) is sufficient.*

Anchor rods are installed by excavating a 6 inch (152 mm) diameter anchor hole with a post digger or auger, filling the hole with concrete, and inserting the anchor rod. Once the concrete has set, a geotextile filter fabric and the fabric form are placed and the anchor rod is forced through the filter fabric and both layers of the fabric form. The form is filled with fine aggregate concrete and allowed to set for a minimum of one hour. A washer is then placed over the exposed end of the anchor rod, and a nut is installed snugly to secure the washer to the top of the lining or mat.

HYDROCAST™ Armor Units

HYDROCAST fabric forms provide an effective forming system for casting large concrete armor units in place, underwater or in-the-dry. Fabric formed concrete armor units meet the requirements for a reliable and economical cast-in-place alternative to heavy quarry stone (rip rap) or large precast concrete blocks. They are used for the construction and repair of erosion control structures such as breakwaters, dikes, seawalls, groins, and jetties as well as for foundation structures (such as underwater pipelines), footing supports, and other hydraulic and marine structures. They are also extensively used by departments of transportation to prevent or repair scour at bridge piers and abutments. Figures 56, 57, 58, and 59 illustrate typical applications of fabric-formed armor units.

When filled with a fine aggregate or conventional concrete they form individual, cylindrical units that assume a flattened cross section, as demonstrated in figures 56 and 57. The concrete is pumped under pressure, resulting in rapid concrete stiffening, improved concrete properties [e.g., “case hardening” of the outer 3 to 6 inches (75 to 150 mm) of concrete], strength and durability. They have the required mass and stability to withstand the severe forces of large storm waves and rapidly flowing water. The concrete armor units may be placed side-by-side or stacked to form an inherently interlocked structure. Since they are concrete filled in place, they can adapt to variations in the subgrade or bottom contours.

Fabric-formed concrete armor unit installations do not require dewatering, a crucial advantage in emergency repair of bridge piers scoured by flood waters. Fabric forms can be positioned and filled with concrete from the surface in shallow water or by divers in deeper water. Unlike quarry stone or precast concrete blocks, they do not require placement by heavy cranes working from the land or from barges.

Fabrication of HYDROCAST Armor Unit Forms

The specially woven double-layer fabric is joined by a perimeter of interwoven and/or sewn seams to form a large fabric form envelope. Fabric used in the construction of armor units shall conform to the physical properties shown in Table 11.0. All sewn seams are folded and sewn with a double line of Type 401 double-lock stitches. The sewing thread used for seaming shall be nylon or polyester. Each fabric form is provided with one or more self-closing inlet valves to accommodate a concrete injection pipe.

HYDROCAST Unit Dimensions

Fabric-formed concrete armor units may be cast in a wide range of sizes and shapes. Synthetex technical staff accurately calculates the length, width and height of the concrete armor unit and the volume of concrete per measure of unit length with the aid of computer programs. Tables 12.0 and 13.0 provide typical dimensions and volumes of fabric-formed concrete armor units, both filled and unfilled.

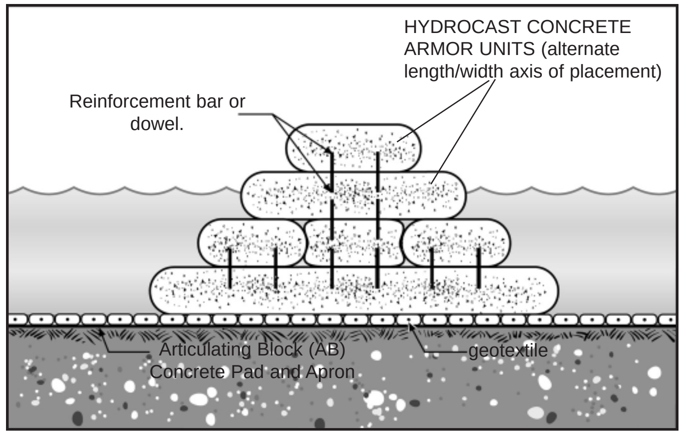


Figure 56 - Groin

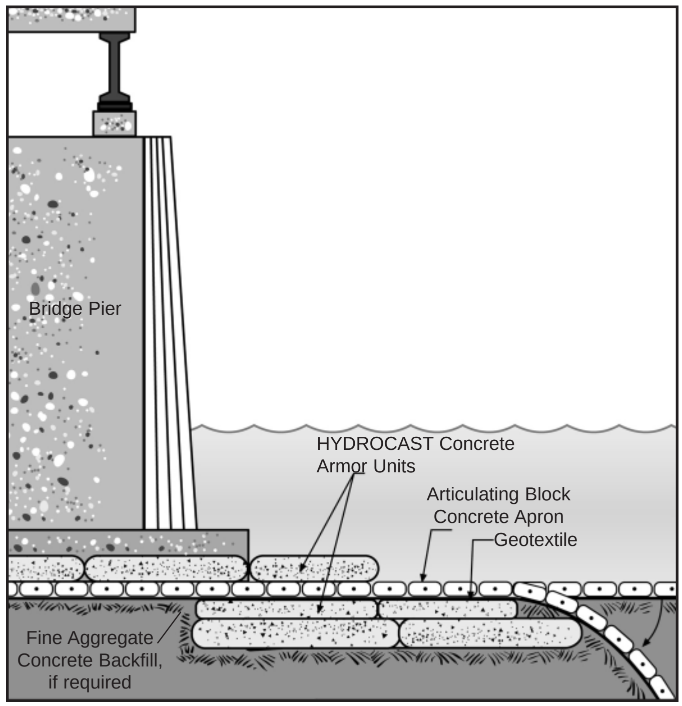


Figure 57 - Repair of Scoured Bridge Pier

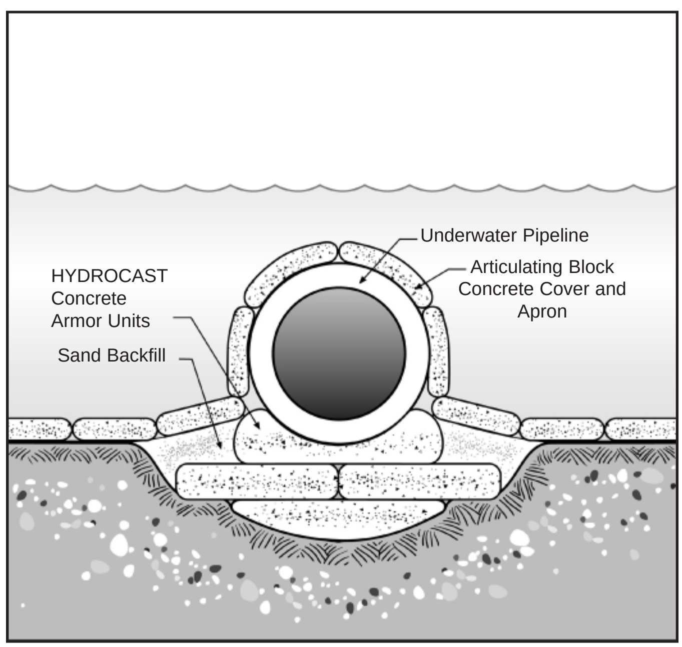


Figure 58 - Pipeline Saddle and Cover

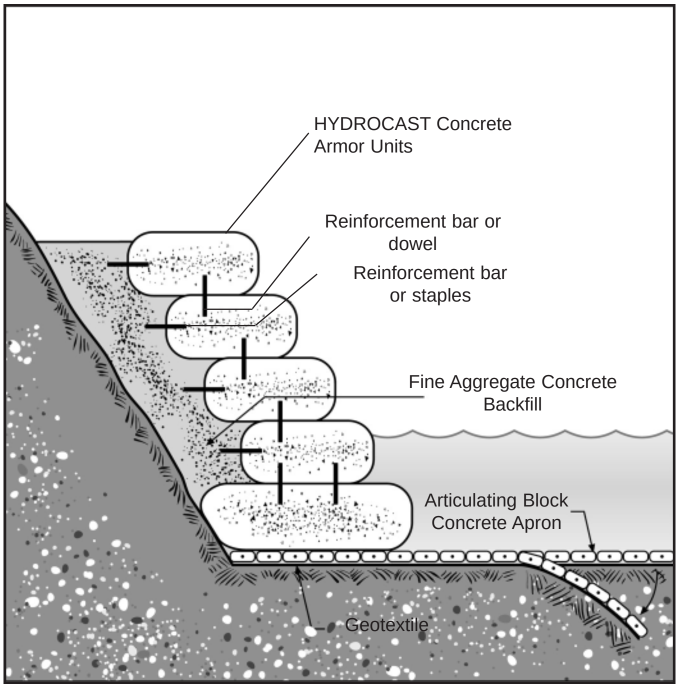


Figure 59 - Seawall or Shoreline Protection

Custom Designs

In addition to the wide range of standard rectangular fabric formed concrete armor units, Synthetex's designers can also design custom shaped forms to accommodate underwater pipelines, footers and other objects (Fig. 60).

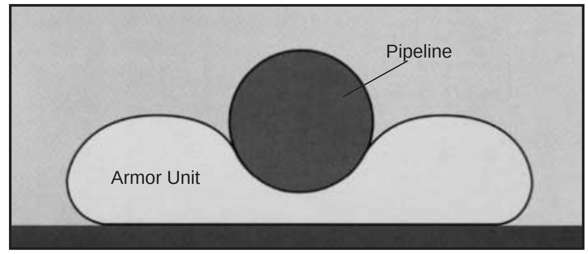


Figure 60

Table 11.0 - Property Requirements - HYDROCAST Armor Unit Fabric[1, 2]				
Property		**Test Method**	**Units**	**Values**
Physical:				
Composition of Yarns				Nylon or polyester
Mass Per Unit Area (double-layer)		ASTM D 5261	oz/yd² (g/m²)	14 (470)
Thickness		ASTM D 5199	mils (mm)	28 (0.7)
Mill Width			in (m)	76 (1.92)
Mechanical:				
Wide-Width Strip Tensile Strength	- Machine/Cross	ASTM D 4595	lbf/in (kN/m)	190 (33.2) / 140 (24.5)
Elongation at Break	- Machine/Cross	ASTM D 4595	%	20 / 30
Trapezoidal Tear Strength	- Machine/Cross	ASTM D 4533	lbf (N)	180 (800) / 115 (510)
Hydraulic:				
Apparent Opening Size (AOS)		ASTM D 4751	U.S. Standard Sieve (mm)	60 (0.250)
Flow Rate		ASTM D 4491	gal/min/ft² (l/min/m²)	50 (2035)

Notes:
1. Conformance of fabric to specification property requirements shall be based on ASTM D 4759, “Practice for Determining the Specification Conformance of Geotextiles.”
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, “Practice for Sampling of Geosynthetics for Testing.”
3. Yarns used in fabric construction shall not contain partially oriented (POY), draw-textured, and or staple yarns.

Ordering Fabric Forms

The ordering of fabric forms should be done in advance of the start of the project, to allow time for the preparation, submittal and approval of layout and shop drawings. Project plans and specifications should be submitted to Synthetex technical support department. Trained technicians translate the site plans, grades, elevations, contours and construction details into CAD systems where they develop cost-effective take-offs and fabric-formed concrete armor unit layout drawings, tailored to the project's design requirements. This design technique and CAD layout verification procedure will assure accurate dimensioning and quantity material takeoffs.

The forms are over-dimensioned, in both length and width, to make allowance for form contraction as they are filled with fine aggregate concrete. Contraction factors are a function of site conditions and finished armor unit dimensions. The definition of "contraction factor" is the length or width of fabric form required divided by the corresponding length or width of the area to be covered by the concrete armor

Manufacturer's Certification:
The manufacturer of the fabric forms should submit a manufacturer's certificate stating that the supplied fabric forms meet the criteria of the manufacturer's specifications, as measured in full accordance with the test methods and standards referenced. The certificates should include the following information about each fabric form shipment:
- *Manufacturer's name and current address*
- *Full product name*
- *Style and product code number*
- *Form number(s)*
- *Polymer types*
- *Manufacturer's certification statement*

Table 12.0 - Unfilled Fabric Form Width/Length to Filled Thickness and Width/Length of Armor Unit

Filled Thickness	**Width/Length of Unfilled Fabric Forms**																
inches ***meters***	24 *0.61*	30 *0.76*	36 *0.91*	42 *1.07*	48 *1.22*	54 *1.37*	60 *1.52*	66 *1.68*	72 *1.83*	78 *1.96*	84 *2.13*	90 *2.29*	96 *2.44*	102 *2.59*	108 *2.74*	114 *2.90*	120 *3.05*
	Width/Length of Filled Fabric Forms - Inches *(Meters)*																
6 ***0.15***	21 *0.52*	27 *0.68*	33 *0.83*	39 *0.98*	45 *1.13*	51 *1.28*	57 *1.14*	63 *1.59*	69 *1.74*	75 *1.89*	81 *2.05*	87 *2.20*	93 *2.35*	99 *2.50*	105 *2.66*	111 *2.81*	117 *2.96*
9 ***0.23***	19 *0.48*	25 *0.63*	31 *0.78*	37 *0.94*	43 *1.09*	49 *1.24*	55 *1.39*	61 *1.55*	67 *1.70*	73 *1.85*	79 *2.00*	85 *2.16*	91 *2.31*	97 *2.46*	103 *2.61*	109 *2.77*	115 *2.92*
12 ***0.30***	17 *0.44*	23 *0.59*	29 *0.74*	35 *0.89*	41 *1.05*	47 *1.20*	53 *1.35*	59 *1.50*	65 *1.66*	71 *1.81*	77 *1.96*	83 *2.11*	89 *2.26*	95 *2.42*	101 *2.57*	107 *2.72*	113 *2.87*
15 ***0.38***		21 *0.52*	27 *0.68*	33 *0.83*	39 *0.98*	45 *1.13*	51 *1.28*	57 *1.44*	63 *1.59*	69 *1.74*	75 *1.89*	81 *2.05*	87 *2.20*	93 *2.35*	99 *2.50*	105 *2.66*	111 *2.81*
18 ***0.46***			26 *0.65*	32 *0.81*	38 *0.96*	44 *1.11*	50 *1.26*	56 *1.42*	62 *1.57*	68 *1.72*	74 *1.87*	80 *2.03*	86 *2.18*	92 *2.33*	98 *2.48*	104 *2.63*	110 *2.79*
21 ***0.53***				30 *0.76*	36 *0.92*	42 *1.07*	48 *1.22*	54 *1.37*	60 *1.52*	66 *1.68*	72 *1.83*	78 *1.98*	84 *2.13*	90 *2.29*	96 *2.44*	102 *2.59*	108 *2.74*
24 ***0.61***					34 *0.87*	40 *1.02*	46 *1.18*	52 *1.33*	58 *1.48*	64 *1.63*	70 *1.79*	76 *1.94*	82 *2.09*	88 *2.24*	94 *2.40*	100 *2.55*	106 *2.70*
27 ***0.69***						39 *0.98*	45 *1.13*	51 *1.29*	57 *1.44*	63 *1.59*	69 *1.74*	75 *1.90*	81 *2.05*	87 *2.20*	93 *2.16*	99 *2.31*	105 *2.66*
30 ***0.76***							43 *1.09*	49 *1.24*	55 *1.39*	61 *1.55*	67 *1.70*	73 *1.85*	79 *2.00*	85 *2.16*	91 *2.31*	97 *2.46*	103 *2.61*
33 ***0.84***								47 *1.20*	53 *1.35*	59 *1.50*	65 *1.66*	71 *1.81*	77 *1.96*	83 *2.11*	89 *2.27*	95 *2.42*	101 *2.57*
36 ***0.91***									51 *1.31*	57 *1.46*	63 *1.61*	69 *1.76*	75 *1.92*	81 *2.07*	87 *2.22*	93 *2.37*	99 *2.53*
39 ***0.99***										56 *1.42*	62 *1.57*	68 *1.72*	74 *1.87*	80 *2.03*	86 *2.18*	92 *2.33*	98 *2.48*
42 ***1.07***											60 *1.53*	66 *1.68*	72 *1.83*	78 *1.98*	84 *2.14*	90 *2.29*	96 *2.44*
45 ***1.14***												64 *1.63*	70 *1.79*	76 *1.94*	82 *2.09*	88 *2.24*	94 *2.40*
48 ***1.22***													69 *1.74*	75 *1.90*	81 *2.05*	87 *2.20*	93 *2.35*

Note: Values shown are typical and will vary with weight of concrete and field conditions.

unit. An example contraction factor calculation is given on page 36 of this manual.

Layout drawings showing the field assembly of the fabric form armor units for the entire project are prepared. The drawings identify each armor unit, its location and sequence of installation, pertinent elevations and coordinates, direction of flow, anticipated water levels, and structures such as roads, curbs, bridges, intake and discharge pipes, culverts, ramps and other existing and future structures that may effect the placement of the fabric-forme d armor units.

Labeling:
The fabric forms should be labeled as per ASTM D 4873, "Guide for Identifying, Storage and Handling of Geosynthetics Rolls".

A submittal package which includes shop and layout drawings, a list of numbered fabric forms, form dimensions and areas, and a manufacturer's certification is assembled and forwarded to the contractor for submittal to the project engineer. Upon the project engineer's approval of the submittal package, Synthetex manufacturing department commences fabric form fabrication and confirms the delivery schedule.

Table 13.0 - Unfilled Fabric Form Width to Filled Volume of Armor Unit

Filled Thickness	**Width of Unfilled Fabric Forms**																
inches ***meters***	24 *0.61*	30 *0.76*	36 *0.91*	42 *1.07*	48 *1.22*	54 *1.37*	60 *1.52*	66 *1.68*	72 *1.83*	78 *1.96*	84 *2.13*	90 *2.29*	96 *2.44*	102 *2.59*	108 *2.74*	114 *2.90*	120 *3.05*
	Volume of Concrete - Cubic Feet per Foot of Length *(Cubic Meter per Meter of Length)*																
6 ***0.15***	0.8 *0.07*	1.1 *0.10*	1.3 *0.12*	1.6 *0.15*	1.8 *0.17*	2.1 *0.20*	2.3 *0.21*	2.6 *0.24*	2.8 *0.26*	3.1 *0.29*	3.3 *0.31*	3.6 *0.34*	3.8 *0.35*	4.1 *0.38*	4.3 *0.40*	4.4 *0.41*	4.7 *0.44*
9 ***0.23***	1.1 *0.10*	1.4 *0.13*	1.8 *0.17*	2.2 *0.20*	2.6 *0.24*	2.9 *0.27*	3.3 *0.31*	3.7 *0.34*	4.1 *0.38*	4.4 *0.41*	4.8 *0.45*	5.2 *0.48*	5.6 *0.52*	5.9 *0.55*	6.3 *0.59*	6.7 *0.62*	7.1 *0.66*
12 ***0.30***	1.2 *0.11*	1.7 *0.16*	2.2 *0.20*	2.7 *0.25*	3.2 *0.30*	3.7 *0.34*	4.2 *0.39*	4.7 *0.44*	5.2 *0.48*	5.7 *0.53*	6.5 *0.60*	6.7 *0.62*	7.2 *0.67*	7.7 *0.72*	8.2 *0.76*	8.7 *0.81*	9.2 *0.86*
15 ***0.38***		1.9 *0.18*	2.5 *0.23*	3.1 *0.29*	3.8 *0.35*	4.4 *0.41*	5.0 *0.47*	5.6 *0.52*	6.3 *0.59*	6.9 *0.64*	7.5 *0.70*	8.1 *0.75*	8.8 *0.82*	9.4 *0.87*	10.0 *0.93*	10.6 *0.99*	11.3 *1.05*
18 ***0.46***			2.7 *0.25*	3.5 *0.33*	4.2 *0.39*	5.0 *0.47*	5.7 *0.53*	6.5 *0.60*	7.2 *0.67*	8.0 *0.74*	8.7 *0.81*	9.5 *0.88*	10.2 *0.95*	11.0 *1.02*	11.7 *1.09*	12.5 *1.16*	13.2 *1.23*
21 ***0.53***				3.7 *0.34*	4.6 *0.43*	5.5 *0.51*	6.3 *0.59*	7.2 *0.67*	8.1 *0.75*	9.0 *0.84*	9.8 *0.91*	10.7 *0.99*	11.6 *1.08*	12.5 *1.16*	13.3 *1.24*	14.2 *1.32*	15.1 *1.40*
24 ***0.61***					4.9 *0.46*	5.9 *0.55*	6.9 *0.64*	7.9 *0.73*	8.9 *0.83*	9.9 *0.92*	10.9 *1.01*	11.9 *1.11*	12.9 *1.20*	13.9 *1.29*	14.9 *1.39*	15.9 *1.47*	16.9 *1.57*
27 ***0.69***						6.2 *0.58*	7.3 *0.68*	8.4 *0.78*	9.5 *0.88*	10.7 *0.99*	11.8 *1.10*	12.9 *1.20*	14.0 *1.30*	15.2 *1.41*	16.3 *1.52*	17.4 *1.62*	18.5 *1.72*
30 ***0.76***							7.6 *0.71*	8.8 *0.82*	10.1 *0.94*	11.3 *1.05*	12.6 *1.17*	13.8 *1.28*	15.1 *1.40*	16.3 *1.52*	17.6 *1.64*	18.8 *1.75*	20.1 *1.87*
33 ***0.84***								9.2 *0.86*	10.6 *0.99*	11.9 *1.11*	13.3 *1.24*	14.7 *1.37*	16.1 *1.50*	17.4 *1.62*	18.8 *1.75*	20.2 *1.88*	21.6 *2.00*
36 ***0.91***									10.9 *1.02*	12.4 *1.15*	13.9 *1.29*	15.4 *1.43*	16.9 *1.57*	18.4 *1.71*	19.9 *1.85*	21.4 *1.99*	22.9 *2.13*
39 ***0.99***										12.8 *1.19*	14.5 *1.35*	16.1 *1.50*	17.7 *1.65*	19.3 *1.79*	21.0 *1.95*	22.6 *2.10*	24.2 *2.25*
42 ***1.07***											14.9 *1.39*	16.6 *1.54*	18.4 *1.71*	20.1 *1.87*	21.9 *2.04*	23.6 *2.20*	25.4 *2.36*
45 ***1.14***												17.1 *1.59*	19.0 *1.77*	20.8 *1.93*	22.7 *2.11*	24.6 *2.28*	26.5 *2.46*
48 ***1.22***													19.4 *1.80*	21.4 *1.99*	23.4 *2.18*	25.4 *2.36*	27.4 *2.55*

Note: Values shown are typical and will vary with weight of concrete and field conditions.

Proper Storage and Handling of Fabric Forms

Fabric forms are delivered at the job site in trailers or ocean containers. Fabric forms are stacked in a manner that assures ease of unloading. Standard 40 ft (12 m) long trailers or containers hold up to 215,000 ft^2 (20,000 m^2) of fabric forms per load.

Armor unit fabric forms are normally shipped boxed. Alternatively they may each be wrapped in two layers of protective cover. The first layer (inner layer) is a waterproof, opaque, plastic cover the second (outer layer) is a woven, abrasion resistant, fabric cover.

When fabric forms are to be inventoried at the job site, they should be kept dry and remain boxed so that they are protected from the elements during storage and handling. If stored outdoors, they should be elevated and protected with a waterproof cover that is opaque to ultraviolet light. Care should be taken not to damage the fabric forms during unloading, storage and handling. *The contractor should unload the fabric forms by hand or with a forklift or similar equipment. When lifting fabric forms make sure that workers have proper back support.*

Contraction of HYDROCAST Armor Units

The definition drawing, Figure 61, illustrates the change in width that occurs when a fabric form is filled with concrete to form an armor unit. Table 12.0 is a guide in determining the required dimensions of an unfilled fabric form for casting a given concrete armor unit size. Table 13.0 is a guide in determining the volume of concrete required to fill a fabric form of given dimensions. The dimensions and volumes are calculated from dimensional equation and may not reflect field conditions.

Equations for determining the filled width and length of HYDROCAST Fabric Forms:

$W = W_f + 0.57T$

$L = L_f + 0.57T$

Where:

- W = Width of unfilled fabric form
- W_f = Width of filled fabric form
- L = Length of unfilled fabric form
- L_f = Length of filled fabric form
- T = Thickness of filled fabric form

Equations for determining the volume of concrete required for filling HYDROCAST Fabric Forms:

$V_f = 0.785\,T^2 + T\,(W_f - T)$

$V_t = (V_f)(L_f)$

Where:

- V_f = Volume of concrete per unit length of filled armor unit
- V_t = Total Volume of the filled armor unit

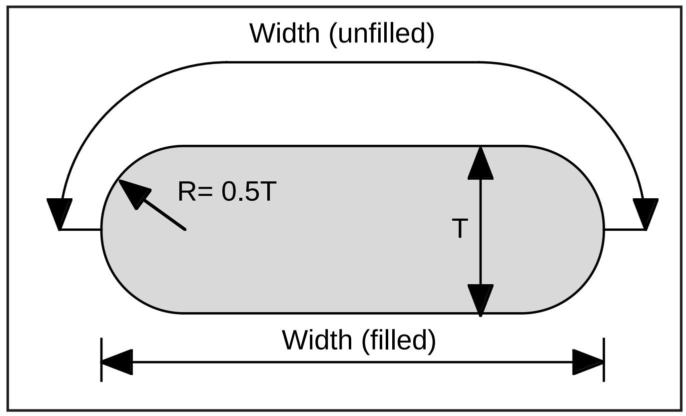


Figure 61

Example Calculation:

Determine the unfilled dimensions and filled volume for a 10 ft (3 m) long by 62 inches (1.57 m) wide by 18 inches (0.46 m) thick armor unit.

From equations:

$W = W_f + 0.57T$ = 62 in + 0.57 x 18 in = 72 in (1.83 m)

$L = L_f + 0.57T$ = 10 in x 12in/ft + 0.57 x 18 in = 130 in or 11 ft

$V = V_f\,L_f$ = 7.3 ft^2 x 10 ft = 73 ft^3 or 2.7 yd^3 (2.1 m^3)

From tables:

From Table 12.0 - For a filled width of 62 in (1.57 m), with a thickness of 18 in (0.46 m) and a length of 10 ft (3 m), a fabric form 11 ft long by 72 in wide would be selected.

From Table 13.0 - The volume of a 62 in (1.57 m) wide, by 18 in (0.46 m) thick and 10 ft (3 m) long fabric form would be approximately 72 ft^3 or 2.7 yd^3.

Note: The concrete-filled thickness of the fabric form should be not more than 70 percent of the width of the unfilled fabric form.

Installation of HYDROCAST Armor Units

Equipment and Tools

Because of the simple installation procedure for HYDROCAST Armor Units, a nominal amount of tools and equipment are required. We suggest that the contractor have on hand the following:

Tools:

- Surveyor's level and rod
- Rakes
- Stakes
- Rubber boots and gloves
- Safety glasses or goggles
- Trowels
- Shovels
- Hammers
- String line
- Pail
- Scissors

Equipment:

- Small line concrete pump
- Concrete pump hose - 2 inch (50 mm) diameter
- Injection pipe - 2 inch (50 mm) diameter
- Hand-held sewing machine (electric or air powered) with speed control
- Extension cord (if electrical equipment is used)
- Electric generator with ground fault circuit breaker
- Air compressor (for air powered sewing machine)
- Small, walk-behind flat or vibratory compactor for soil compaction

A list of equipment manufacturers is provided in the appendices. However, Synthetex, LLC *makes no warrantee nor guarantees the performance of equipment provided by another manufacturer.*

Sequence of Armor Unit Installation

Once the area to be protected has been excavated, graded and compacted to the lines and grades specified in the Contract Drawings and Specifications, an installation crew, filter fabric (if required), fabric forms, and the tools and equipment listed above should be mobilized to the job site. *Freshly excavated and graded slopes are highly subject to erosion and should be protected from water runoff, flowing water and waves.*

Depending on the location of the area, dimensions, and the rate of subgrade preparation, installation rates of as much as 15 yd^3 (11.5 m^3) of fine aggregate concrete per hour can be achieved by a crew of 3 or 4 laborers, a concrete pump operator and a supervisor.

Establish the starting point.

The first step in the installation of fabric-formed concrete armor units is to establish a starting point. If a working point and direction of placement are shown on the Contract Drawings this should be the starting point. If this is not the case, it is the customary practice for channels, streams and rivers to work from the upstream end of the project to the downstream end. In this manner the flow of the water will tend to spread the fabric forms out ahead of the finished work and the finished concrete armor unit is protected from undercutting. For inland and coastal shorelines it is customary practice to install the first course of armor units then proceed to succeeding courses. *Fabric form armor unit layout drawings, available from Synthetex will recommend starting points and directions of placement for the project.*

Establish the alignment lines

Once a starting point has been established a surveyor's level should be used to determine the longitudinal and slope alignment lines of the fabric-formed concrete armor units. String lines should then be placed along the respective alignment lines and staked. Generally, the alignment lines are offset, by a measured distance, to the opposite side of any trench or a minimum of 5 feet (1.5 m) in order not to interfere with the work area. *The method of establishing reference points and lines should be left to the discretion of the contractor.*

Placement of the filter fabric, if required

Under certain soil conditions or if called for in the Contract Drawings and Specifications, it will be necessary to place filter fabric and/or a granular sublayer under the fabric forms to guarantee that soil is not piped through any spaces between the armor units. Filter fabric should be selected and placed in accordance with the Contract Drawings and Specifications or in the absence of such directions in accordance with the manufacturer's guidelines. *Filter fabrics and their installation are discussed, in brief, earlier in this manual (page 7).*

Placement of the first course of armor unit fabric forms

The prefabricated armor unit forms are folded and marked with the appropriate form numbers and dimensions at the factory for easy identification, location and installation.

The first armor unit fabric form, in the first course, should be carefully placed at the designated starting point and unfolded into position (Fig 62). Special care should be taken to assure than the sides and ends of the form are exactly parallel to their respective alignment lines.

Armor unit fabric forms should be placed loosely, but without folds, to allow for proper filling with fine aggregate concrete. The extra fabric provided for form contraction should be extended, Forms that are stretched or taut will not permit the required form contraction, therefore the fabric forms will not fill to their required thicknesses. For example, a 72 inch by 120 inch (183 cm x 305 cm) form is to be filled to a thickness of 30 inches (76 cm). When filled with fine aggregate concrete to this thickness, the width and length of the form will contract by approximately 57% of the thickness, giving a finished armor unit dimension of 55 inches x 103 inches (139 cm x 261 cm). Adjacent armor units (of the same dimensions

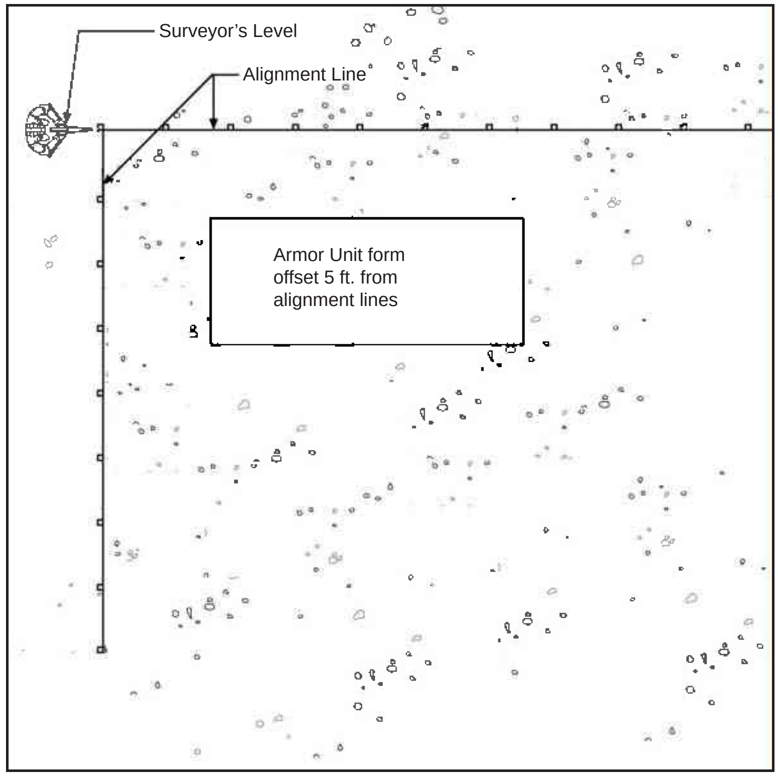


Figure 62

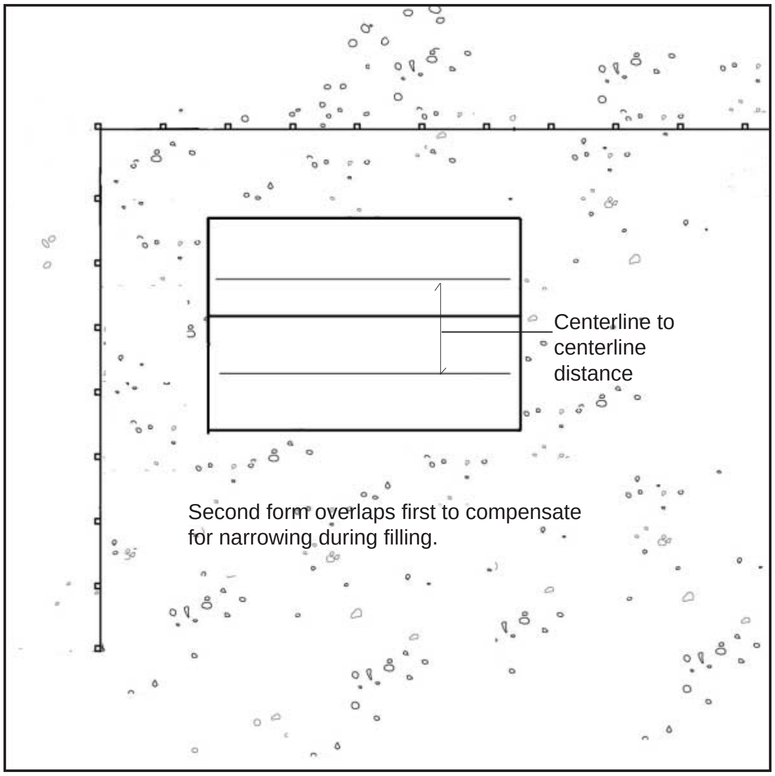


Figure 63

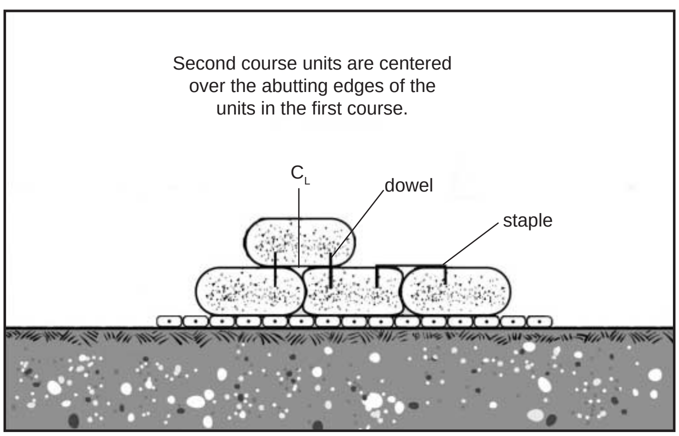


Figure 64

used in this example) should therefore be placed with their centers 17 inches (43 cm) closer together than called for by the unfilled form dimensions.

The second armor unit form in the first course should be placed alongside the first form so that the centerline to centerline distance equals that of the calculated armor unit width after contraction, as shown in Figure 63. After the second armor unit form has been positioned, the alignment of the forms should be checked.

The remaining armor unit forms in the first course should be placed side-by-side in the same manner. The alignment of the forms should be checked periodically since small errors in alignment can progress in severity. Armor unit form alignment is important in providing a uniform and attractive appearance in the finished installation.

Armor unit form placement should precede concrete filling by no more than the distance that can be completed in one day. Where the forms may be exposed to flowing water or wave action, each form should be filled with fine aggregate concrete prior to placement of the adjacent form.

Placement of the second course of armor unit fabric forms

The second course of armor unit forms should be placed atop the fine aggregate concrete filled first course. (See Sequence of Fine Aggregate Concrete Pumping.) The center line of the first form in the second course is positioned directly over the abutting edges of the first two armor units in the first course, as shown in Figure 64. The staggering of the centerlines of the armor units in vertically adjacent courses encourages "nesting" of armor units and facilitates alignment. The remaining forms in the second course should be placed side-by-side in the same manner as the first course. Once again, check alignment periodically since small errors can progress in severity.

When constructing structures subject to wave action, the armor units should be aligned with their long axis facing the principal direction of wave attack.

Underwater placement of fabric-formed armor units may require the use of divers. The divers can prepare the finished grading, inspect the area to be protected, and position and secure the filter fabric and fabric forms. The securing of the forms may require sand bags or weights.

A small quantity of bulk (uncut and unassembled) form fabric should be ordered for each project. The fabric can be used for special field tailoring. At least one half a roll, about 900 ft^2 (84 m^2) of bulk fabric, is recommended.

Sequence of Fine Aggregate Concrete Pumping

Ordering fine aggregate concrete

Fine aggregate concrete is generally delivered to the job site in ready-mix trucks. The order for concrete should be placed a least one day prior to its scheduled delivery to the job site. The concrete supplier should be instructed to fill the water tank of each truck with mix water. *It is common that the first few loads delivered to the job site will not be fluid enough for pumping and will require the addition of mix water.* In order to avoid presetting of the fine aggregate concrete it is recommended that the concrete be delivered in loads of no more than 8 yd^3 (6 m^3). At a minimum, the first load of each day should be checked with a standard flow cone for consistency, in accordance with ASTM D 6449. *The addition of pea gravel to the mix may reduce the cost of materials with a slight increase in labor costs. When pumping concrete with pea gravel, the diameter of the pump hose should be increased.*

Securing the armor unit forms

Beginning at the designated staring point the installation crew should check and adjust the armor unit forms to assure that they are in alignment. After the forms have been properly adjusted, fine aggregate concrete is pumped into forms. *It must be emphasized that care should be exercised in the alignment and securing of the first course of armor units. This will ensure the aesthetics of the concrete armor units and also hasten the installation of subsequent courses.*

Inserting the fine aggregate concrete injection pipe

Fine aggregate concrete should be pumped into the fabric form armor unit by inserting the injection pipe through a self-closing "pocket type" filling valve in the upper layer of the fabric. A tight seal is made when the injection pipe is inserted into the valve. When the pipe is withdrawn, the valve shuts.

Filling the first fabric form armor unit with fine aggregate concrete

Starting at the first fabric form armor unit, the injection pipe should be inserted into the self closing filling valve. The form should be filled by pumping fine aggregate concrete into the form. The fine aggregate concrete should fill the center and corners of the form, proceeding gradually to the specified armor unit thickness. *Pressure from the concrete fill helps close the filling valve.*

The injection pipe should then be moved to the adjacent armor unit form and inserted into the filling valve. Once again, the previous pumping procedure should be repeated until this form has been filled to its specified thickness.

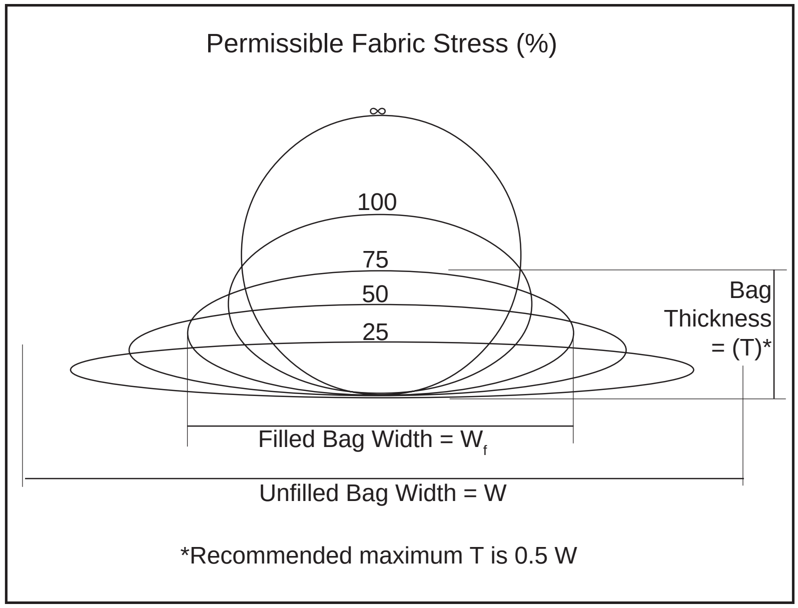


Figure 65

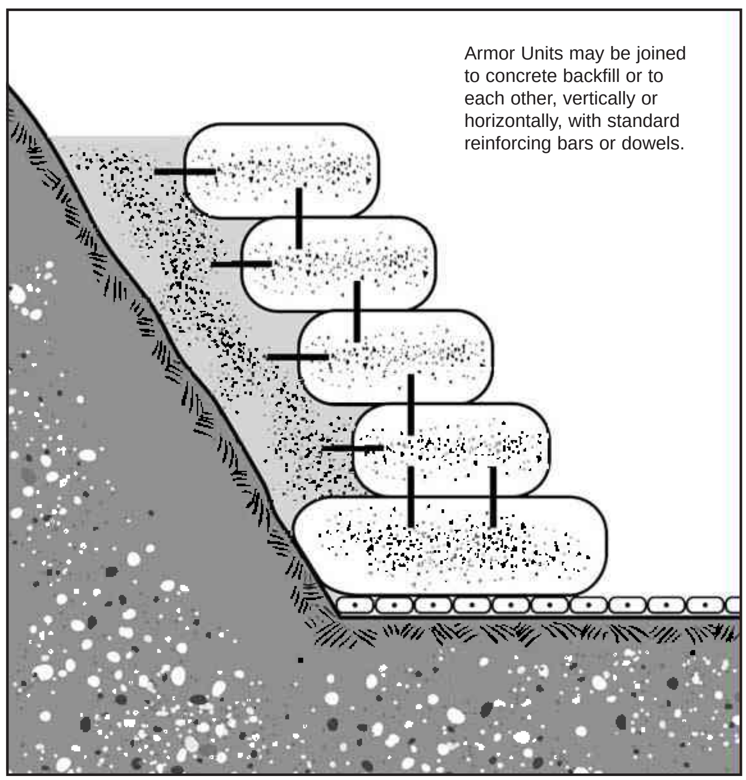


Figure 66

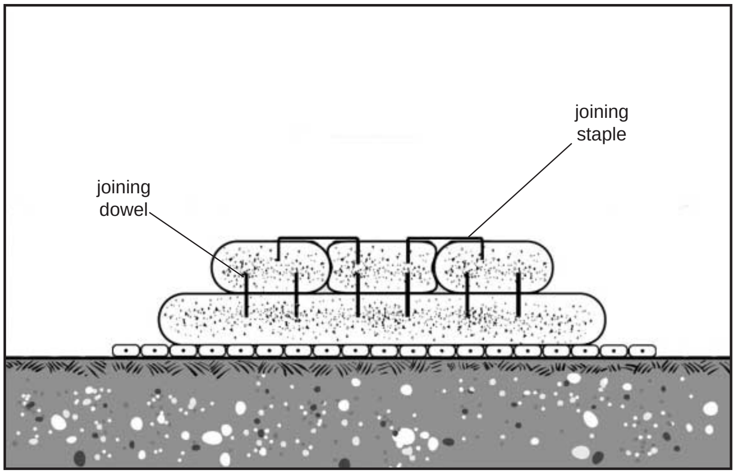


Figure 67- Typical cross section

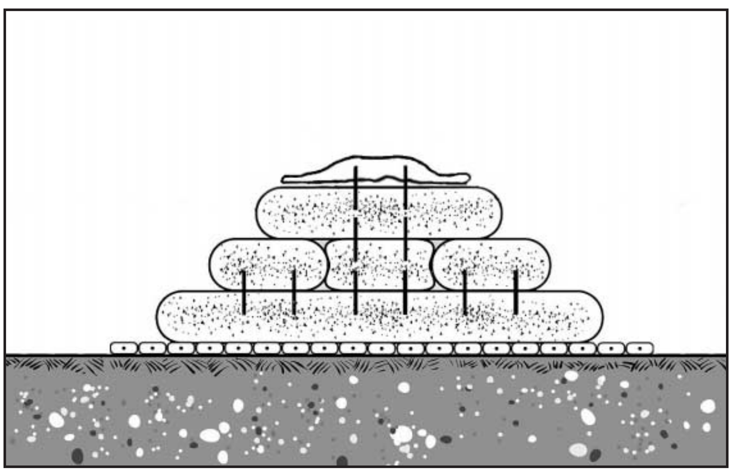


Figure 68- Armor Unit form ready for filling

Overpressuring of fabric forms

Care must be taken when pumping fabric forms to assure that the fabric is not over pressurized. Over pressurization may cause bursting of seams. Please refer to Table 12.0 for recommended filling thicknesses per width. See also Figure 65 for fabric stress at differing fill geometries.

Connecting fine aggregate concrete armor units

Armor units are easily joined by inserting steel reinforcement bars, “dowels” or “staples” as suggested in Figures 66 and 67. When connecting vertically adjacent courses of armor units by inserting dowels, first force the pointed ends of the reinforcement bars through the fabric and into the fresh concrete of the filled armor units. Dowels or staples shall be inserted into the filled unit(s) not less than one half hour and not more than one hour after filling of the unit, unless directed otherwise by the Engineer. The forms in the succeeding course are then threaded over the exposed reinforcement bar ends. The dowels are then forced through the bottom layer of the vertically adjacent fabric form (Fig. 68), and the form is then filled with fine aggregate concrete.

Armor units may be connected side-by-side by inserting staples; bend the reinforcement bars into an elongated “U” shape and force the pointed ends of the reinforcement bars through the fabric and into the fresh concrete of the filled armor units. The dowels and staples assist in holding the forms in place during filling and maintaining the alignment of the armor unit structure. Abutting armor units, if placed laterally, may be installed immediately after placement of the preceding unit(s). If an armor unit 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 armor units.

Where required, reinforcement bar cages are installed in the forms through openings in the forms. The form opening is closed before filling by means of a zipper or a portable sewing machine. Reinforcement bar cages are suspended by tie wires from the upper side of the form to assure centering.

Circumferential straps may be attached to armor unit forms as thickness indicators to facilitate the filling of forms underwater. Slight depressions formed by the straps in the surface of the armor unit indicate to the diver, working by touch, that the form has been filled to the specified thickness.

Circumferential straps of predetermined circumferences and spacing, with or without external restraining reinforcement bars, permit the casting of tapering or irregularly shaped armor units.

Filling remaining fabric form armor units with fine aggregate concrete

If care has been taken in positioning the forms and in concrete filling the first course of armor unit forms, little, if any, adjustment of subsequent courses should be required. However, form alignment should be checked periodically since small errors in alignment can progress in severity. Periodically check the location of the forms with an instrument to assure that proper alignment is being maintained.

Special Considerations

Pipes, piles, culverts, trees, and other appurtenances

Armor unit forms should be tailored in the field to fit around pipes, culverts, trees, and other appurtenances. A form may be field cut and sewn or bulk fabric may be fabricated to fit snugly around the object.

Backfilling and compaction of trenches

The backfilling and compaction of open excavations should not begin until at least one hour after filling the adjacent concrete armor unit. Backfill material may be either select bedding materials or fine aggregate concrete. The excavations should be backfilled as shown on the Contract Drawings. *The open excavations behind completed sections of armor units should be backfilled and compacted by the end of the work day.*

Foot traffic

Foot traffic on the freshly pumped fine aggregate concrete armor unit should be avoided for a period of not less than one hour after concrete injection or until the concrete is resistant to indentation. Should traffic be unavoidable, the contractor should place board walks along the finished filled concrete areas. This will reduce the amount of objectionable indentation. *Footprints will leave permanent impressions in the installed fabric-formed concrete armor units.*

Cleanup

Any fine aggregate concrete that may spill on top of the fabric-formed concrete armor unit should be picked up by hand or trowel and the surface smoothed by cloth or broom. Such unnecessary spillage of concrete will cause an unsightly appearance. This is particularly important along the top of the final course of armor units.

The installation crew should be instructed to carefully “kink” the concrete pump hose when it is moved from one injection point to another or to place the end of the concrete injection pipe in a pail when moving the concrete pump hose.

The freshly pumped fabric-formed concrete units should never be washed (sprayed) under pressure with water in an effort to clean or remove spills from its surface. A wet cloth should be used for clean up and spill removal.

The cement film that impregnates the fabric forms provides a bond between the fabric form and the concrete fill and a degree of protection against ultraviolet degradation of the fabric. Should this film be removed by washing the uncured concrete armor units, cement may be also washed out from beneath the layer of fabric. The result would be a loss of concrete-to-fabric bond, a sandy, low strength outer surface of concrete and a concrete armor units which will exhibit low abrasion resistance and durability.

APPENDIX 1 - CONCRETE PUMPING EQUIPMENT MANUFACTURERS

Manufacturer	**Mayco Pump** **A Multiquip Company** **P.O. Box 6254** **Carson, CA 90749** **USA** **Tel: 310/537-3700** **800/537-3927** **Fax: 310/537-3927**	**Olin Engineering** **15592 Computer Lane** **Huntingdon Beach, CA 92649** **USA** **Tel: 714/897-1230** **Fax: 714/892-9268**	**Schwing America, Inc** **Small Line Division** **5900 Centerville Road** **St. Paul, MN 55127** **USA** **Tel: 612/429-8651** **Fax: 612/429-8616**
Model	**C - 30HD**	**525**	**P - 88**
Performance			
Concrete Output	25 yd^3/hr (19 m^3/hr)	32 yd^3/hr (24 m^3/hr)	25 yd^3/hr (19 m^3/hr)
Concrete Pressure	-	750 psi (53 Bar.)	500 psi (35 Bar.)
Horizontal Pumping Distance	500 ft (150 m)	800 ft (244 m)	500 ft (150 m)
Maximum Aggregate Size	0.5 in (13 mm)	0.5 in (13 mm)	0.5 in (13 mm)
Pump			
Volume Control	Variable - Adjustable stroke and speed	Variable - Adjustable stroke and speed	Variable - Adjustable stroke and speed
Concrete Cylinder Diameter	6 in (150 mm)	5 in (127 mm)	6 in (150 mm)
Concrete Cylinder Stroke	-	12 in (305 mm)	7.75, 6.5, 5.375, or 4.625 in (197 ,165 , 143 , or 118 mm)
Valve Type	Ball valve	Ball valve	Ball valve
Hopper Capacity	6 ft^3 (0.17m^3)	5 ft^3 (0.14m^3)	6 ft^3 (0.17m^3)
Maximum Line Size	2 in (50mm), 2.5 in (62 mm)	4 in (100mm)	3 in (75 mm)
Remote Control	Standard Optional - Radio (Wireless)	Standard Optional - Radio (Wireless)	Standard Optional - Radio (Wireless)
Surge Chamber	-	Standard	-
Engines			
Standard Engine	30 hp (23 kW) Wisconsin Gas	41hp (30kW) Deutz Diesel	30 hp (23 kW) Wisconsin Gas
Optional Engines	30hp (23 kW) Hatz Diesel		20hp (15 kW) Electric 33hp (25 kW) Hatz Diesel
Weight	2200 lbs (999 kg)	3000 lbs (1360 kg)	2360 lbs (1071 kg)

Manufacturer	**Reed Concrete Placing Equipment** **13822 Oaks Ave.** **Chino, CA 91708 USA** **Tel: 909/364-2100** **Fax: 909/364-2140**	**Reinert Manufacturing Co.** **7968 Kentucky Drive, Ste. 1** **Florence, KY 41042 USA** **Tel: 606/525-8488** **Fax: 606/525-2484**	**Thomsen Machinery, Inc.** **101 South Main Street** **Gardena, CA 90248 USA** **Tel: 310/769-4500** **Fax: 310/516-9820**
Model	**B 30**	**ZR - 424**	**Putzmeister P 30G**
Performance			
Concrete Output	30 yd^3/hr (23m^3/hr)	20yd^3/hr (15m^3/hr)	25 yd^3/hr (19 m^3/hr)
Concrete Pressure	1026 psi (70 Bar.)	625 psi (44 Bar.)	425 psi (29 Bar.)
Horizontal Pumping Distance	-	400 ft (120 m)	400 ft (120 m)
Maximum Aggregate Size	1.5 in (38 mm)	1 in (25 mm)	0.5 in (13 mm)
Pump			
Volume Control	Variable - Adjustable stroke and speed	Variable - Adjustable stroke and speed	Variable - Adjustable stroke and speed
Concrete Cylinder Diameter	6 in (150 mm)	4 in (100 mm)	6 in (150 mm)
Concrete Cylinder Stroke	-	24 in (609 mm)	12 in (305 mm)
Valve Type	S valve	S valve	Ball
Hopper Capacity	10 ft^3 (0.28 m^3)	8 ft^3 (0.23 m^3)	6 ft^3 (0.17m^3)
Maximum Line Size	5 in (125 mm)	3 in (75 mm)	-
Remote Control	-	-	Yes
Surge Chamber	-	-	-
Engines			
Standard Engine	54 hp (40 kW)Deutz Diesel	30 hp (23 kW) Wisconsin Gas	30 hp (23 kW) Wisconsin Gas
Optional Engines			37 hp (27 kW) Hatz Diesel 20hp (15 kW) Electric
Weight	4450 lbs (2019 kg)	2000 lbs (978 kg)	2400 lbs (1090 kg)

APPENDIX 2 - HAND-HELD SEWING MACHINES

Manufacturer	**Fischbein Company** **151 Walker Road** **Statesville, N.C. 28625** **Tel: 704/871-1159** **Fax: 704/872-3303**	**American-Newlong, Inc.** **5310 South Harding Street** **Indianapolis, IN 46217** **Tel: 317/787-9421** **Fax: 317/786-5225**	**Union Special Corporation** **One Union Special Plaza** **Huntley, IL 60142** **Tel:800/344-9698** **Fax: 708/669-5804**
Model	**ECR**	**NP-7A**	**2200**
Performance			
Stitches per Minute	-	1500-1600	1200-1700
Stitch	Single thread, 101 stitch	Single thread, 101 stitch	Two thread, single needle, 401 stitch or Single thread, 101 stitch
Stitch Length	-	Fixed 3 SPI (8.5 mm)	Adjustable 3-8.5 SPI
Needle	-	DNx1-#25	-
Drive Motors			
AC	115 V, 1.1 amps 220 V, 0.6 amps	60W 50/60Hz, 1-ph., 12V, 24V, 110V, 220V, or 240V	Electric or Pneumatic
DC	12V, 9 amps	12 V	
Pneumatic	Yes	-	-
Weight	11 lbs (5 kg)	12 lbs (5.3 kg)	11 lbs (5.0 kg)

Hydrotex and Hydrocast products are manufactured by:

SYNTHETEX®