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Geotextile Tube Structures Guidelines for Contract Specifications

by Doyle L. Jones, Jack E. Davis, William R. Curtis, and Cheryl E. Pollock

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) provides an example set of contract specifications for the construction of sediment-filled geotextile tube structures. This technical note represents the state of practice within the U.S. Army Corps of Engineers and is an update of the material published in Wetlands Research Program Technical Note WG-RS-3.2, January 1999 (Davis and Landin 1999). While the example presented here can be used as a guide by U.S. Army Corps of Engineers (USACE) District Contracting Officers preparing their own contract specifications, it is not intended as a substitute for knowledge regarding appropriate applications for geotextile tube structures; these applications are discussed in Davis and Landin (1997, 1998) and Curtis, Pollock and McLellan (2004).

BACKGROUND: Geotextile tubes are polypropylene or polyester tubes, typically 100-1,000 ft (30-300 m) long and 8-45 ft (2.4-14 m) in circumference (Figure 1). These tubes can be filled with sand and used as semipermanent shore protection structures for the purpose of wave attenuation and sediment retention including groins, breakwaters, sills, dune fortification, river training, river grade control, riverbank stabilization, wave attenuation, submerged berms, control groins, dikes, and jetties. Geotextile tubes are positioned empty and then filled by inserting a dredge discharge pipe into ports on the tops of tubes or gravity-filled using a hopper. A typical geotextile tube would sit on top of a scour apron held in place by anchor tubes (Figure 1).

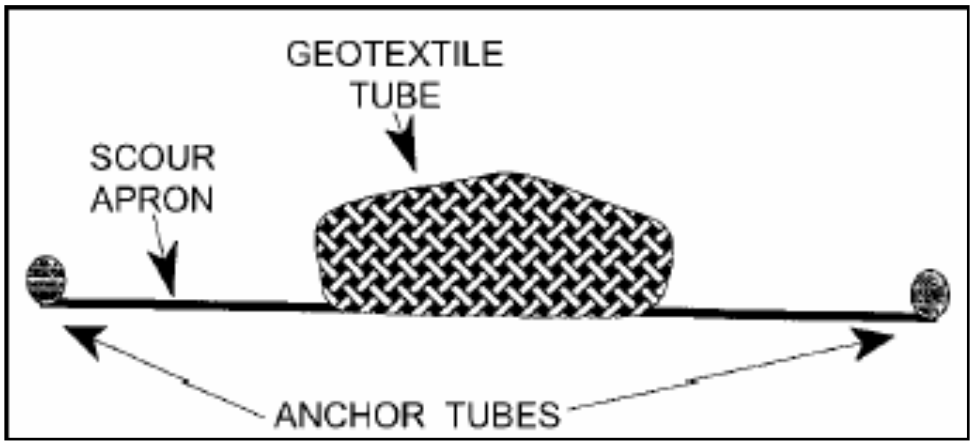

Figure 1. End view of a typical geotextile tube with scour apron and anchor tubes

Many USACE Districts are investigating the use of geotextile tubes as structures in coastal, estuarine, and riverine projects. Several Districts have already constructed such projects. Based on experience with existing projects, some USACE Districts have developed contract specifications for geotechnical tube projects in an effort to limit reliance on the judgment of dredging contractors.

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The example contract specifications provided in this CHETN may assist USACE District contracting officers who are preparing contract specifications for projects using geotextile tubes. Portions of the specifications presented in the example are derived from real contract specifications used by the Baltimore, Detroit, Galveston, Jacksonville, Mobile, Nashville, Norfolk, Philadelphia, and Vicksburg Districts. However, because every project has specific and unique requirements, the example presented here should be modified to accommodate project-specific requirements. The example should be considered a guide highlighting various issues that should be covered by contract specifications. The example also suggests the level of detail required to ensure desirable results. Final contract specifications should be reviewed by District legal staff. Comments with explanatory notes accompany some sections and subsections of the example contract specifications.

CONTRACT SPECIFICATION EXAMPLES

PROJECT TITLE
SECTION ####[1]
GEOTEXTILE TUBE STRUCTURES

1.0 SCOPE OF WORK: The work covered by this section includes: (a) provision of all plant, labor, equipment, and materials; and (b) performance of all operations in connection with the construction of the geotextile tube structures between stations *xxx*[2] and *yyy* (as shown in the attached drawings) using sandy dredged material.

2.0 APPLICABLE PUBLICATIONS: The publications listed in Table 1 form a part of these contract specifications to the extent that they are referenced. The publications are referenced by basic designation only.

> Comments: The American Society for Testing and Materials (ASTM) has developed standards that are useful in a geotextile tube project. Those ASTM standards that are referred to in the text of the actual contract specifications should be included in the "APPLICABLE PUBLICATIONS" section. For the purposes of this example, 18 potentially relevant references have been listed.

[1] Throughout this example, "####" refers to section numbers of the contract. Because the example presented here only represents the contract specifications for geotextile fabric tubes, and not the entire contract, the "####" notation is necessary. In an actual contract, this notation would be replaced with numbers referring to relevant sections of the contract.

[2] Abstract station numbers are used in this example; the example does not include drawings.

Table 1
References

American Society For Testing and Materials (ASTM) Publications	
ASTM Designator	**Year and Title**
ASTM D 422	(1990) Test Methods for Particle Size Analysis of Soils
ASTM D1140	(2000) Amount of Materials Finer than No. 200 Sieve
ASTM D 2487	(2000) Standard Classification for Soils for Engineering Purposes (Unified Soils Classification System)
ASTM D 3786	(1987) Hydraulic Bursting Strength of Knitted Goods and Nonwoven fabrics: Diaphragm Bursting Strength Tester Method
ASTM D 3884	(1992) Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method
ASTM D 4354	(1999) Sampling of Geosynthetics for Testing
ASTM D 4355	(1999) Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
ASTM D 4491	(1999) Water Permeability of Geotextiles by Permittivity
ASTM D 4533	(1996) Trapezoid Tearing Strength of Geotextiles
ASTM D 4595	(1994) Tensile Properties of Geotextiles by the Wide Strip Method
ASTM D 4632	(1997) Grab Breaking Load and Elongation of Geotextiles
ASTM D 4751	(1999) Determining Apparent Opening Size of a Geotextile
ASTM D 4759	(1996) Determining the Specification Performance of Geosynthetics
ASTM D 4833	(2000) Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
ASTM D 4873	(2001) Guide for Identification, Storage, and Handling of Geosynthetic Rolls
ASTM D 4884	(1996) Strength of Sewn or Thermally Bonded Seams of Geotextiles
ASTM D 5261	(1992) Mass Per Unit Area of Geotextiles
ASTM D 5321	(1992) Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

3.0 SUBMITTALS: Government approval is required for submittals with a "GA" designation. Submittals designated "FIO" are for information only. The following shall be submitted in accordance with section ####, CONTRACTOR SUBMITTAL PROCEDURES.

> Comments: The "SUBMITTALS" section lists items that the contractor must submit to the USACE District Contracting Officer. The first two sentences distinguish between submittals that require approval and those that do not. In this example, all submittals require approval.

3.1. Data GA: Submit a written certificate of compliance of geotextile tube manufacturer's catalog cuts, brochures, specifications, and product data for approval. The information provided shall attest that the geotextile tube meets the chemical, physical, and manufacturing requirements stated in these specifications.

> Comments: The contractor is usually given the opportunity to select a manufacturer or supplier provided that the fabric and tube fabrication meet the specifications set forth in the contract. Therefore, the contractor should submit pertinent information from the manufacturer or supplier for approval.

3.2. Statements GA: Submit a Plan of Construction describing the sequence of operations for the construction of the geotextile tube structures. The plan should conform to the general guidelines presented in these contract specifications, but should also include additional information. The plan shall address the approach and techniques required for: (a) fabrication of the geotextile tubes, scour

aprons, and anchor tubes, (b) construction site preparation, (c) placement of the scour apron and anchor tubes, (d) geotextile tube deployment and filling, and (e) monitoring and analysis of parameters such as characteristics of the material to be dredged, pipeline pressure, and hydraulic-fill characteristics. Equipment to be used for geotextile tube placement and filling shall be specified.

3.3. Order of Work GA: The contractor shall submit a work plan to the contracting officer. The plan shall include a detailed description of the proposed method of coating and placement of the geotube assembly and the filling and sealing of the geotubes, measurement method for percent fill criteria, positioning, installation methods, UV protection, and methods of determining accuracy of placement.

> Comments: Criteria for the Plan of Construction may be added or removed as needed from this subsection to suit individual project requirements.

3.4. Reports GA: Submit the results of gradation testing (in accordance with ASTM D 422) on the sand used to fill the geotextile tubes.

> Comments: Samples of the sand used to fill tubes should be collected and analyzed to be sure they meet the contract specifications. The sediment should also be sampled after it is placed in tubes.

3.5. Samples GA: Submit clearly identified samples of each type of geotextile fabric to be used for the geotextile tubes, scour aprons, anchor tubes, and all other geotextiles required for construction of the geotextile tube structures. Each sample should have minimum dimensions of 0.09 m^2 (1 ft × 1 ft) as stated in ASTM D 4354.

> Comments: The size of the sample required depends on the needs for testing. A 0.09-m^2 (1-ft^2) piece of fabric may be sufficient, as suggested in the example. However, some projects have required samples as large as 4.6 m (15 ft) by 1.52 m (5 ft).

4.0 DELIVERY, STORAGE, AND HANDLING

4.1. General: Geotextiles for tubes shall be delivered only after the contracting officer has received and approved the required submittals. Geotextiles shall be labeled, shipped, stored, and handled in accordance with ASTM D 4873 and as specified herein. Each segment of geotextile tube shall be wrapped in an opaque and waterproof layer of plastic during shipment and storage. The plastic wrapping shall be placed around the geotextile in the manufacturing facility and shall not be removed until deployment. Each packaged segment of geotextile tube shall be labeled with the manufacturer's name, geotextile type, lot number, roll number, and roll dimensions (length, width, and gross weight). Appropriate handling equipment and techniques, as recommended by the manufacturer and as mentioned in the submittals and approved by the contracting officer, shall be used. Geotextile and/or plastic wrapping damaged as a result of delivery, storage, or handling shall be repaired or replaced, as directed by the contracting officer, at no additional cost to the government.

> Comments: The "DELIVERY, STORAGE, AND HANDLING" section specifies steps taken to prevent damage to tubes during the construction process. This section

also calls for labeling, which can be important when a variety of tubes are used in a project.

4.2. Handling: Geotextiles shall not be handled with hooks, tongs, or other sharp instruments. Geotextiles shall not be dragged along the ground. Any surface upon which the geotextile may rest or from which it may be deployed shall be leveled and prepared to a relatively smooth condition free of ruts, erosion rills, obstructions, depressions or debris (brush, burrs, or protrusions) greater than 150 mm in height (6 in.) that could snag and tear the fabric. A shallow "swale" or "cradle" may be constructed under low-water conditions on the tube center line to prevent geotextile tubes from rolling during filling operation.

Comments: Although geotextile fabric has an extremely high tensile strength, it can be torn, punctured, and abraded. Contract specifications in the "Handling" subsection may prevent unnecessary damage from inappropriate handling.

4.3. Storage: Geotextile tubes shall be: (a) stored in areas where water cannot accumulate, (b) elevated off the ground, and (c) protected from conditions that will affect the properties or performance of the geotextile. Geotextiles shall not be exposed to temperatures in excess of those recommended by the manufacturer or 140°F (60°C), whichever is less. Outdoor storage shall not be for periods that exceed the manufacturer's recommendations or 2 months, whichever is less. Geotextiles shall not be exposed to direct sunlight prior to deployment for more than 14 days. Geotextiles that are exposed to direct sunlight for more than 14 days will be replaced at no cost to the government.

Comments: Contract specifications for storage may prevent unnecessary damage from inappropriate storage. Some types of damage resulting from inappropriate storage could have long-term consequences for project success, but may not be immediately apparent. For example, extended exposure to sunlight (ultraviolet radiation) will accelerate degradation of geotextile fabrics. The manufacturer or supplier should be consulted for additional information regarding proper storage.

5.0 MATERIALS AND CONSTRUCTION

5.1. Fabric Requirements: The geotextile for the tubes, anchor tubes, and the scour apron/pad shall be a woven monofilament or multifilament pervious sheet of polymeric yarn. Fibers used in the manufacture of the geotextile fabric shall consist of long-chain synthetic polymers composed of at least 85 percent by weight polyolefins, polyesters, or polyamides. Stabilizers and/or inhibitors shall be added to the base polymer if necessary to make the filaments resistant to deterioration by ultraviolet light, oxidation, and heat exposure. Reclaimed or recycled fibers (post-consumer) or polymer shall not be added to the formulation. Geotextiles shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other (including the filaments or yarns at the edges of the fabric). The geotextile physical properties shall equal or exceed the minimum average roll test values (MARV) listed in Table 2, as determined by the standard test methods listed. Acceptance of geotextile shall be in accordance with ASTM D 4759. Strength values shown in Table 2 are for the weaker principal direction. Geotextile fabrics that are not in accordance with ASTM D 4759 shall be replaced as directed by the contracting officer at no additional cost to the government.

Comments: The description of fabric given in the "Fabric Requirements" subsection should be as specific as possible to ensure that fabric selected is of sufficient quality. The properties noted in Table 2 are the properties used to define the fabric. The geotextile test values in Table 2 must be determined for each project. Experts in geotextile tube design and construction, including manufacturing representatives and fabric suppliers, should be consulted to obtain appropriate values for a given application. Fabric samples submitted under the "SUBMITTALS" section can be used to test physical properties of fabric, providing independent confirmation of manufacturer's product information.

Table 2
Geotextile, Type I (Geotextile Tube and Scour Apron) Physical Properties (Woven)

Property	Test Method	Unit	Minimum Test Value
Apparent Opening Size	ASTM D 4751	U. S. Sieve	#60
Puncture Strength	ASTM D 4833	lb	400
Wide Width Tensile – In any direction	ASTM D 4595	lb/in.	1000
Wide Width Tensile Elongation – In Any direction	ASTM D 4595	%	15
Trapezoidal Tear	ASTM D 4533	lb	550
Seam Strength	ASTM D 4884	lb/in.	500

5.2. Ultraviolet (UV) Ray Protection: The geotextiles tube shall be installed with approved protection of the upper half of the filled geotextile tube from UV degradation. The protection shall cover, as a minimum, the upper portion of the filled tube, corresponding to a 90-deg arc with apex located at the approximated center of the tube or any portion of the tube that is exposed to direct sunlight. Tubes covered by sediment or completely submerged do not need UV protection. UV protection may be accomplished using a protective shroud, composed of the specified material, and attached securely around its edges, in an approved manner. Other alternatives, which are documented to provide similar, 100 percent protection from UV during a period typical of the life span of the specified shroud may be proposed by the contractor, and shall be included in the Construction Plan. Alternative UV protection must be approved, in writing, prior to its use on this contract. Physical property requirements of UV shroud material are shown in Table 3.

5.3. Fabrication: Geotextile tubes shall be fabricated by sewing together standard sheets of high-strength, woven geotextile material to form a tubular shape or by weaving the material into a tube shape. The tube shall have a circumference of 9.1 m (30 ft). The tubes may vary in length from a minimum of 45.7 m (150 ft) to a maximum of 106.7 m (350 ft). Tube filling ports shall be spaced at intervals not exceeding 7.6 m (25 ft) along the crest of the tube. Each fill port shall consist of a geotextile sleeve having a length of at least 1.5 m (5 ft) and a circumference slightly greater than that of the filling pipe. In addition, a pressure relief port, consisting of a 1.5-m- (5-ft-) long geotextile sleeve, shall be located not more than 1.5 m (5 ft) from each end of each tube. The port sleeves shall be fabricated of the same geotextile as the tubes and shall have a "drawstring" closure system to assure a secure closure after the completion of filling. Loops or straps shall be incorporated along the sides of the tube every 6.1 m (20 ft) to facilitate deployment and anchoring. The loops or straps shall have the same tensile strength as the tube geotextile. All seams shall be overlapped and folded. All seams shall be completed at the factory.

Comments: Alternative port closures, loops, and straps may be proposed by the contractor. New advancements in the industry provide secure reaccessible port closures. Dimensions listed are examples only.

Table 3
Geotextile, Type II (UV Shroud) Physical Properties (Non-Woven)

Property	Test Method	Unit	Minimum Test Value
Mass Per Unit Area	ASTM D 5261	oz/yd^2	16
Apparent Opening Size	ASTM D 4751	U.S. sieve	100
Permittivity	ASTM D 4491	sec^{-1}	0.7
Puncture Strength	ASTM D 4833	lb	225
Grab Tensile Strength	ASTM D 4632	lb	350
Flow Rate	ASTM D 4491	$gal/min/ft^2$	50
Trapezoidal Tear Strength	ASTM D 4533	lb	130
Ultraviolet Degradation (Percent strength retained at 500 hr)	ASTM D 4355	%	70

Tubes shall have a scour apron with a width of 12.2 m (40 ft) fabricated from the same geotextile material as the tube. The scour apron shall include a 1.8-m (6-ft) circumference anchor tube located along the leading edge of the apron with filling ports as recommended by the manufacturer.

5.4. Scour Pad Placement: The scour apron shall be deployed and the anchor tube shall be filled prior to the filling of the larger geotextile tube. The geotextile scour apron (also referred to as scour pad by some manufacturers) shall be laid smooth to minimize tension, stress, folds, wrinkles, or creases. The ends of each individual pad sheet shall be overlapped a minimum of 3 m (10 ft). Prior to filling of the anchor tube, the pad shall be held in place by anchor-weights or stakes along the front and back edges of the sheets. Stakes shall be used in conjunction with presewn loops along the edge of the scour pad. At no time shall stakes be driven through the scour pad material.

Comments: Scour pad design should follow recommended engineering and manufacturer's guidance.

5.5. Seams: The seams of all geotextiles shall be sewn with an approved geotextile thread. The geotextiles shall be attached at the factory or another approved location. Seams shall be tested in accordance with method ASTM D 4884.

Comments: The "Fabrication" subsection should clearly describe the process for fabrication of the geotextile tubes as well as associated scour aprons, anchor tubes, and any other features of the tube design. The description is best obtained from experienced geotextile tube manufacturer representatives and engineering design consultants. This subsection should provide as much detail as necessary to ensure that the tubes are manufactured properly. The description should at least include the dimensions of the tubes, the design of the seams (e.g., simple overlap, folded overlap), the design and spacing of the filling sleeves or ports, other features such as port tie-offs, pressure-relief ports, and the dimensions of the scour apron and anchor tubes.

5.6. Tests, Inspections, and Verifications for Geotextiles: Geotextiles and factory seams shall meet the requirements specified in Tables 2, 3, and 4. Conformance testing shall be performed on random samples in accordance with quality control practices approved by the contracting officer.

Comments: The "Tests, Inspections, and Verifications for Geotextiles" subsection reiterates requirements for testing of fabrics.

5.7. Fill Materials: Material for filling geotextile tubes will consist of sandy material classified as CH, CL, GP, SM, SC, SP, or SW when classified in accordance with ASTM D 2487 dredged from the designated borrow site shown on the drawings. Other sources of fill shall be approved by the contracting officer. Logs from subsurface investigations of the borrow site and laboratory testing results are presented in Appendix B of these specifications. Suitable material for filling tubes will contain not more than 15 percent fines (percent by weight passing the No. 200 sieve) to minimize subsidence of tubes after filling. Some materials in the borrow area may not be suitable for use in tubes without removal of some of the fines; in this event, the contractor shall locate alternative suitable sand borrow materials or shall process the borrow materials to reduce the fines content to the specified level. If excessive fines are observed during the filling process, the contractor will divert all of the flow to an appropriate hydraulic fill area in the dredged material placement site until more suitable borrow material can be located.

Comments: Drawings in Appendix B are not provided.

5.8. Unsatisfactory Materials: Unsatisfactory materials shall be materials that do not comply with the requirements for satisfactory materials. Unsatisfactory materials include but are not limited to materials containing roots and other organic matter, trash, debris, stones larger than 7.6 cm (3 in.), and materials classified by ASTM D 2487 as PT, OH, and OL with fines more than 15 percent. Unsatisfactory materials shall be replaced as directed by the contracting officer at no additional cost to the government.

Comments: Compatibility of fill material and geotextile fabric is central to project success. The "Fill Materials" subsection specifies the source and nature of fill material and instructs the contractor to monitor fill materials to be sure that specifications are continually met. It is possible that a source of sand identified by pre-work investigations may turn out to contain a substantially different grain-size distribution once the contractor begins dredging. This subsection might identify a recourse to be used in the event that the material identified in pre-work investigations is found to be unsuitable during construction.

5.9. Testing of Fill Materials: Gradation testing of hydraulic fill materials shall be conducted in accordance with ASTM D 422 and ASTM D 1140. One gradation test shall be performed for each tube filled, immediately after completion of filling. The sample of fill material should be taken near the center of each tube and should be representative of material throughout the tube. The sample should be obtained from a filling port and as a core taken through the vertical extent of material in the tube. The fabric should not be punctured. Results of gradation testing shall be provided to the contracting officer within 2 days after the sample is taken. If visual inspection of the fill materials or tube suggests that the percentage of fines may exceed the requirements presented herein, additional

testing may be directed by the contracting officer and replacement of the tube may be required, at the discretion of the contracting officer and at no additional cost to the government.

> Comments: The "Testing of Fill Materials" subsection provides instructions regarding sampling of material within filled or partly filled geotextile tubes. This subsection specifies how the gradation analyses should be done and when results are required. In some cases, results may only be required as part of the construction documentation, but in other cases, test results may be required before continuing construction.

5.10. Installation: Within 30 days after notice to proceed, the contractor shall submit the Plan of Construction called for under the "SUBMITTALS" section of these specifications. The plan shall incorporate the requirements of these specifications with respect to tube (and associated components such as scour apron and anchor tubes) geometry, orientation, fabrics, fabrication, deployment, anchoring, and filling procedures. Fabrication details or installation techniques that differ from those outlined in these specifications may be documented in the Plan of Construction and submitted for consideration by the contracting officer. However, rejection of alternative methods suggested by the contractor shall not constitute a basis for claim against the government.

Prior to installation, the contractor shall visually inspect the geotextile for damage and imperfections. Defective geotextiles shall be marked and repaired at no cost to the government.

> Comments: The "Installation" subsection describes the Plan of Construction, which clearly identifies installation techniques. Experts in geotextile tube design and construction and manufacturing representatives or fabric suppliers should be consulted regarding questions about the Plan of Construction. If the "Installation" subsection suggests a specific technique, the rationale behind the suggestion should be included; then if the contractor chooses to submit an alternative approach to construction, the full scope of desired outcomes can be considered. Contractors may want to submit alternative plans because of their access (or possibly lack of access) to certain types of equipment or for other reasons. Items that would be described in the "Installation" subsection include: the means of deploying the geotextile tubes, how they will be held in place during filling, the filling technique and desired equipment (pipes, deflectors, valves, pressure gauges, etc.) and specialized personnel, where they should be placed, the final dimensions of the tubes, the elevations of various parts of the tubes, techniques for butting the end of one tube against another, requirements regarding bed preparation (fill or excavation), ways to take care of the fabric during deployment, how to replace or repair defective or damaged tubes, identification of allowable tolerances on height, elevation, and alignment, recourses in the event that tolerances are exceeded, recourses in the event that poor quality fill material is encountered during construction, and identification of requirements and qualifications for inspectors such as material manufacturer representatives or engineering consultants. It may be instructive to reference drawings to help describe the installation specifications.

The geotextile tubes shall be hydraulically filled with the sandy material as per these specifications. The tubes will also provide erosion protection from waves. As noted in the "Fabrication" section of these specifications, each tube shall be between 45.7 m (150 ft) and 106.7 m (350 ft) long, and have

a circumference of 9.1 m (30 ft). Past experience suggests that tubes that are about 300 ft (91.5 m) long are best. Longer tubes may be harder to control during the filling process, while shorter tubes require more labor spent in deploying the tubes (because more tubes are required). Tube-length variations may be required to satisfactorily achieve the orientation requirement for the structure. Typical sections of the proposed geotextile tube structure are shown in the drawings. The contractor may deviate from the details of the typical sections if the deviation is identified in the Plan of Construction and approved by the contracting officer:

(a) The contracting officer shall be notified immediately of a fabric or seam failure during the filling process. The geotextile fabric shall be protected during installation from binding, clogging, penetrations, tears, or other damage. Damaged geotextile fabric shall be repaired or replaced. The contracting officer, or his designated representative, shall visually inspect geotextile materials, prior to installation, for damage and imperfections. Damaged geotube assemblies shall be replaced or repaired at no cost to the government. Repair shall be made by placing a patch of the same type of geotextile, which extends a minimum of 0.46 m (1.5 ft) beyond the edge of the damage or defect. Patches shall be continuously fastened using a sewn method or other approved methods recommended by the manufacturer. The machine direction of the patch shall be aligned with the machine direction of the geotube repaired. Geotextiles that cannot be satisfactorily repaired shall be replaced at no additional cost to the government.

(b) The contractor shall have at least one representative of the geotextile tube manufacturer onsite with geotextile tube installation experience to provide assurance of proper deployment and filling procedures. The representative will be present as needed during the construction of the geotextile tube structure.

(c) Each tube shall have a scour apron as specified herein and shown in the drawings. The scour apron shall be deployed prior to deployment of associated geotextile tubes. The length of each section of scour apron used by the contractor shall be identified in the Plan of Construction and approved by the contracting officer. The contractor shall ensure that adjacent lengths of scour apron overlap one another by 6.1 m (20 ft) and that the location of overlap between each length of scour apron is more than 7.6 m (25 ft) from the joint between adjacent geotextile tubes placed on top of the scour apron. The scour apron shall be fully extended and the anchor tubes filled to hold the apron in place while the geotextile tubes are placed on top.

(d) After filling, each tube is expected to achieve an average height of 1.5 m (5 ft) with a variation of ± 0.15 m (0.5 ft) and an average width of about 4 m (13 ft). The crest of each tube shall be placed at + 0.61 m (2.0 ft) mllw with an allowable variation of ± 0.15 m (0.5 ft). In some locations, it may be necessary to remove some foundation material to assure that the top of the tube does not exceed the specified final elevation. The contractor shall use hydraulic methods or gravity fill to fill the geotextile tubes and shall take all necessary actions to ensure that excess water introduced into the fill during filling is drained from the tubes. The tubes shall be monitored for settlement for a minimum of 10 days after the initial filling is complete. After the 10-day monitoring period, settled areas, below minimum elevation or height shall be refilled to bring the elevation to within tolerance. A range of days between 5 and 14 for settlement monitoring is a function of filling methods, fill material and geotextile characteristics of the fill material. Failed seams or ruptures in the tubes shall be repaired and tubes filled to the required elevation. In other locations, sandy material may be used to raise the bed elevation prior to placement of the scour aprons. If such a sand base is used, it shall

extend a minimum of 6.1 m (20 ft) from the center line of the tube (i.e., a total minimum width of 12.2 m (40 ft)). In some locations, removal and replacement of low-strength foundation materials will be required on the basis of geotechnical investigations required by section ####, "Geotechnical Investigations." The final elevation of the tubes shall be measured after all excess water has drained from the tubes. Foundation materials shall be replaced in accordance with the requirements of section ####, "Unsuitable Foundation Material Excavation," prior to construction of the geotextile tube structure covered by this section of the specifications. In all cases, the foundation for the placement of the geotextile scour apron and tubes shall be smooth and free of protrusions that could damage the geotextile.

(e) Each tube shall be placed along a straight line with an allowable lateral deviation of no more than 0.6 m (2 ft) to either side. No portion of a tube shall be filled until the entire tube segment has been fully anchored to the foundation along the correct alignment. The tube shall be filled as evenly as possible. The geotextile tubes shall be prevented from rolling or shifting from the alignment shown. All port closures shall be securely fastened after or between uses.

(f) As shown on the drawings, the ends of each tube shall be tightly butted together. This procedure shall be accomplished by laying out two successive tubes at once and overlapping the ends of the tubes by at least 3 m (10 ft). The overlying tube shall be filled first before the underlying tube is filled. In this way, the overlying tube pins the end of the adjacent tube beneath it.

(g) After completing the deployment and anchoring of the geotextile tube, filling with sand from the borrow area shall be accomplished in accordance with the approved Plan of Construction. Tubes shall be hydraulically or gravity-filled with appropriate equipment sized for above-water filling activities. Fill material shall be slurried and pumped into the tube. Pumping pressures shall be high enough to achieve finished crest height, but not excessive so to cause damage or rupture of tube. Damage or ruptured tubes shall be replaced at the expense of the contractor. Tubes shall be filled as evenly as possible, with the top of the tube at a uniform elevation or slope, without any pronounced humps, bulges, or isolated low unfilled areas. Enough material shall be pumped into tubes to achieve the specified crest height and account for settlement following completion of filling activities. All fill ports shall be left open during initial stages of filling to avoid excessive hydraulic build up and shall be closed as filling is completed at each port location. The discharge line of the dredge shall be fitted with a "Y-valve" to allow control of the rate of filling. The Y-valve system must be fitted with an internal mechanism such as a gate, butterfly valve, ball valve, or pinch valve to allow the contractor to regulate the discharge into the geotextile tube. The discharge pipe shall be fitted with a baffle diffuser to achieve uniform filling of the tube. Any excess discharge shall be directed toward the appropriate hydraulic fill zone. The discharge pipe leading to the geotextile tube shall be fitted with a pressure gauge to monitor filling pressures. Once filling operations commence on a single geotextile tube, the contractor is required to completely fill the tube prior to ending that work shift. In no case will the contractor be permitted to shut down prior to the completion of filling any one geotextile tube. Any damaged geotextile tube resulting from the contractor's failure to control filling rates and pressures shall be repaired or replaced at no additional cost to the government.

(h) Failure to achieve the specified crest elevations or subsidence of material within tubes that results in unacceptably low crest elevations prior to acceptance by the contracting officer shall be corrected by supplemental filling or replacement. Under no circumstances shall a replacement tube be accepted when placed on top of the original tube because the top tube cannot be considered

stable. With the contracting officer's approval, a replacement tube may be placed parallel to and on the leeward side of the original tube. The supplemental filling or replacement shall be done at no additional cost to the government.

(i) Excavation of foundation materials shall be performed to allow the proper placement of the geotextile tubes to the lines and grades shown on the drawings. The foundation surface shall be prepared to a relatively smooth surface condition in accordance with applicable portions of this specification and shall be free from obstructions, debris, depressions, erosion features, or vegetation. The geotextile tubes shall be so placed as to produce a smooth plane surface in continuous contact with the ground surface and any irregularities shall be moved.

(j) All wasted material used in the construction and filling of the geotextile tubes, such as used discharge pipes, wire rope, excess geotextile material, etc., shall be removed from the project site and disposed of in an approved offsite area provided by the contractor. All costs associated with removal of wasted material during construction shall be the total responsibility of the contractor at no additional cost to the government.

5.11. Anchor Tube or Alternative Anchorage: The anchor tube shall be filled only by using the port sleeves. No slits shall be made on the anchor tube for any reason. After filling, the sleeve shall be securely tied with an approved cord as specified, including a second backup securing action. Alternative anchorage, which meets specified criteria, shall be installed as described in the Construction Plan. Physical Property Requirements of anchor tube liners are found in Table 4.

Table 4
Geotextile, Type III (Anchor Tube Liner) Physical Properties (Non-Woven)

Property	Test Method	Unit	Minimum Test Value
Mass Per Unit Area	ASTM D 5261	oz/yd^2	N/A
Apparent Opening Size	ASTM D 4751	U.S. sieve	100
Permittivity	ASTM D 4491	sec^{-1}	1.0
Puncture Strength	ASTM D 4833	lb	N/A
Grab Tensile Strength	ASTM D 4632	lb	250
Flow Rate	ASTM D 4491	$gal/min/ft^2$	75
Trapezoidal Tear Strength	ASTM D 4533	lb	100

Note: N/A = Not Applicable

6.0 PLANT AND EQUIPMENT: The plant and equipment used for the work required shall be determined by the contractor, identified in the Plan of Construction, and shall be approved by the contracting officer.

Comments: The "PLANT AND EQUIPMENT" section of this example provides the contractor with freedom to suggest equipment. Some contract specifications may be written with more specific equipment requirements.

7.0 QUALITY CONTROL: The contractor shall establish and maintain quality control as required in "Contractor Quality Control" of section ####.

8.0 MEASUREMENT AND PAYMENT: All costs in connection with the mobilization and demobilization of the contractor's plant and equipment shall be included in the contract lump sum price. No separate measurement will be made for geotextile tubes. Payment shall be made at the contract lump sum price and shall constitute full compensation for providing all materials necessary for the complete and satisfactory delivery of the geotextile tubes, including the underlying scour apron/pad. No separate payment will be made for transporting and delivering the tubes to the project site.

No separate measurement will be made for installed geotextile tubes. No separate payment will be made for foundation preparation, placement of the underlying geotextile filter cloth, excavation of borrow material, transportation of borrow material, filling of the tubes, coating of the completed tubes, disposal of waste material, and any other incidental items associated with the proper installation of the geotextile tubes or compliance with required permits.

9.0 FINAL EXAMINATION AND ACCEPTANCE: The geotextile tube structure, located between stations *xxx* and *yyy*, shall be surveyed for acceptance no sooner than 6 months after completion of the geotextile tubes. Any subsidence of the top elevation of the geotextile tubes below the planned elevation shall be corrected by supplemental filling or replacement of the tubes that are below the specified elevation at no additional cost to the government. After the completion of final surveys for acceptance, the completed reach shall be examined for acceptance by the contracting officer. Use of any portion of the completed reach for construction activities will not be allowed without prior approval by the contracting officer. Any damage to the accepted reach caused by construction activity shall be repaired by the contractor at no additional cost to the government.

> Comments: Experience has shown that the full impact of subsidence on geotextile tube height may not become apparent for as long as 6 months after filling. The "FINAL EXAMINATION AND ACCEPTANCE" section recognizes the need for a stabilization period before acceptance.

ADDITIONAL INFORMATION: This CHETN was prepared as part of the National Shoreline Erosion Control Development and Demonstration Program (Section 227 of the Water Resources Act of 1996, *http://chl.erdc.usace.army.mil/section227*). Updated contracting specifications were compiled and documented by Mr. Doyle L. Jones, Ms. Cheryl Pollock, and Mr. William R. Curtis of the Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center.

POINTS OF CONTACT: For additional information, contact Ms. Cheryl E. Pollock (601-634-4029, *Cheryl.E.Pollock@erdc.usace.army.mil*) of the Coastal and Hydraulics Laboratory, U.S. Engineer Research and Development Center, Vicksburg, MS.

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