
USACE / NAVFAC / AFCEC UFGS-33 46 16 (May 2018)

Preparing Activity: USACE

Superseding
UFGS-33 46 16 (February 2017)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2025

SECTION TABLE OF CONTENTS

DIVISION 33 - UTILITIES

SECTION 33 46 16

SUBDRAINAGE PIPING

05/18

PART 1 GENERAL

- 1.1 UNIT PRICES
 - 1.1.1 Pipe Subdrains
 - 1.1.2 Blind or French Drains
 - 1.1.3 Manholes
 - 1.1.4 Flushing and Observation Risers
 - 1.1.5 Geotextile
- 1.2 REFERENCES
- 1.3 SUBMITTALS
- 1.4 DELIVERY, STORAGE, AND HANDLING
 - 1.4.1 Delivery and Storage
 - 1.4.2 Handling

PART 2 PRODUCTS

- 2.1 PIPE FOR SUBDRAINS
 - 2.1.1 Plastic
 - 2.1.1.1 Polyvinyl Chloride (PVC) and Fittings
 - 2.1.1.2 Corrugated Polyethylene (PE) and Fittings
 - 2.1.1.3 Pipe Perforations
 - 2.1.1.3.1 Circular Perforations in Plastic Pipe
 - 2.1.1.3.2 Slotted Perforations in Plastic Pipe
 - 2.1.2 Corrugated Steel
 - 2.1.3 Corrugated Aluminum Alloy
 - 2.1.4 Precoated Corrugated Steel
- 2.2 GEOTEXTILE
- 2.3 SUBDRAIN FILTER AND BEDDING MATERIAL
- 2.4 DRAINAGE STRUCTURES
 - 2.4.1 Concrete
 - 2.4.2 Mortar
 - 2.4.3 Manholes and Appurtenances
 - 2.4.3.1 Precast Reinforced Concrete Manhole Risers and Tops
 - 2.4.3.2 Precast Concrete Manhole Bases

- 2.4.3.3 Glass Fiber-Reinforced Polyester (FRP)
- 2.4.3.4 Frames and Covers or Gratings
- 2.4.3.5 Steel Ladder
- 2.5 Composite Drains
 - 2.5.1 Filter Fabric
 - 2.5.2 Composite Drains Products
 - 2.5.2.1 Drainage Core
 - 2.5.2.2 Filter Fabric (Minimum Average Roll Values)
 - 2.5.2.3 Composite System
 - 2.5.3 Storage and Handling
 - 2.5.3.1 Composite Drains
 - 2.5.3.2 Protection
 - 2.5.3.3 Exposure
 - 2.5.3.4 Maintenance
 - 2.5.4 Installation Plan and Product Certification
 - 2.5.4.1 Installation Plan
 - 2.5.4.2 Product Certification
 - 2.5.5 WEEP HOLES

PART 3 EXECUTION

- 3.1 EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS
- 3.2 MANHOLES AND FLUSHING AND OBSERVATION RISERS
 - 3.2.1 Manholes
 - 3.2.2 Flushing and Observation Risers
- 3.3 INSTALLATION OF GEOTEXTILE AND PIPE FOR SUBDRAINS
 - 3.3.1 Installation of Geotextile
 - 3.3.1.1 Trench Lining and Overlaps
 - 3.3.2 Installation of Pipe for Subdrains
 - 3.3.2.1 Pipelaying
 - 3.3.2.2 Jointings
 - 3.3.2.2.1 Perforated Corrugated Metal Pipe or Bituminous Coated, Perforated Corrugated Metal Pipe
 - 3.3.2.2.2 Bituminous Coated or Uncoated Corrugated Aluminum Pipe
- 3.4 INSTALLATION OF FILTER MATERIAL AND BACKFILLING FOR PERFORATED SUBDRAINS
- 3.5 INSTALLATION OF BEDDING AND BACKFILL FOR NON-PERFORATED SUBDRAIN OUTFALL PIPE
 - 3.5.1 Plastic Pipe
 - 3.5.2 Corrugated Metal Pipe
- 3.6 INSTALLATION OF AND BACKFILLING FOR BLIND OR FRENCH DRAINS

-- End of Section Table of Contents --

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SECTION 33 46 16

SUBDRAINAGE PIPING 05/18

NOTE: This guide specification covers the requirements for subdrainage systems for drainage of water from under the ground using pipes less than 300 mm in diameter.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

PART 1 GENERAL

1.1 UNIT PRICES

The paragraph as written contemplates taking bids on a unit-price basis. When it is determined that a lump sum contract may be more advisable, the paragraph will be deleted.

Delete paragraph UNIT PRICES for Navy projects.

1.1.1 Pipe Subdrains

Measure the length of pipe installed from end to end along the centerlines without any deduction for the diameter of the manholes. Pipe will be paid for according to the number of linear meters of subdrains placed in the accepted work. Payment for bedding and filter materials, except geotextiles, will be included in the payment for the pipe subdrain system.

1.1.2 Blind or French Drains

Blind or french drains will be paid for by the linear meter and measured from end to end along the centerlines of the completed drains.

1.1.3 Manholes

Manholes to be paid for will be the number of manholes completed with base, rungs or ladders, frames, and covers or gratings (where specified) constructed in the accepted work.

1.1.4 Flushing and Observation Risers

Flushing and observation risers to be paid for will be the number of flushing and observation risers completed with frames and covers (where specified) constructed in the accepted work.

1.1.5 Geotextile

Measure geotextile for payment by the square meter in place. Measure overlapped joints and seams as a single layer of cloth.

1.2 REFERENCES

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
(AASHTO)

AASHTO M 190 (2004; R 2019) Standard Specification for
Asphalt-Coated Corrugated Metal Culvert
Pipe and Pipe Arches

AASHTO M 252 (2009; R 2017) Standard Specification for
Corrugated Polyethylene Drainage Pipe

ASTM INTERNATIONAL (ASTM)

ASTM A27/A27M (2020) Standard Specification for Steel
Castings, Carbon, for General Application

ASTM A47/A47M (1999; R 2022; E 2022) Standard
Specification for Ferritic Malleable Iron
Castings

ASTM A48/A48M (2022) Standard Specification for Gray
Iron Castings

ASTM A123/A123M (2024) Standard Specification for Zinc
(Hot-Dip Galvanized) Coatings on Iron and
Steel Products

ASTM A760/A760M (2015, R 2020) Standard Specification for
Corrugated Steel Pipe, Metallic-Coated for
Sewers and Drains

ASTM A762/A762M (2019) Standard Specification for
Corrugated Steel Pipe, Polymer Precoated
for Sewers and Drains

ASTM A798/A798M (2022) Standard Practice for Installing
Factory-Made Corrugated Steel Pipe for
Sewers and Other Applications

ASTM B745/B745M (2015; R 2021) Standard Specification for
Corrugated Aluminum Pipe for Sewers and
Drains

ASTM C33/C33M (2024a) Standard Specification for
Concrete Aggregates

ASTM C136/C136M (2019) Standard Test Method for Sieve
Analysis of Fine and Coarse Aggregates

ASTM C478M (2018) Standard Specification for Precast
Reinforced Concrete Manhole Sections
(Metric)

ASTM D1621 (2016; R2023) Standard Test Method for
Compressive Properties of Rigid Cellular
Plastics

ASTM D1777 (1996; E 2011; R 2011) Thickness of
Textile Materials

ASTM D1785	(2021) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120
ASTM D2321	(2020) Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
ASTM D2487	(2017; R 2025) Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D3034	(2016) Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
ASTM D3753	(2019) Glass-Fiber-Reinforced Polyester Manholes and Wetwells
ASTM D4355/D4355M	(2014) Deterioration of Geotextiles from Exposure to Light, Moisture and Heat in a Xenon-Arc Type Apparatus
ASTM D4491/D4491M	(2017) Standard Test Methods for Water Permeability of Geotextiles by Permittivity
ASTM D4533/D4533M	(2015) Standard Test Method for Trapezoid Tearing Strength of Geotextiles
ASTM D4632/D4632M	(2015a) Grab Breaking Load and Elongation of Geotextiles
ASTM D4716/D4716M	(2008; R 2013) Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
ASTM D4751	(2020) Standard Test Method for Determining Apparent Opening Size of a Geotextile
ASTM D4873/D4873M	(2017) Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
ASTM D5034	(2009; R 2017) Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
ASTM D570	(2022) Standard Test Method for Water Absorption of Plastics
ASTM D6241	(2014) Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
ASTM F758	(2014; R 2023) Smooth-Wall Poly(Vinyl

Chloride) (PVC) Plastic Underdrain Systems
for Highway, Airport, and Similar Drainage

ASTM F949

(2025) Standard Specification for
Poly(Vinyl Chloride) (PVC) Corrugated
Sewer Pipe with a Smooth Interior and
Fittings

ASTM G21

(2015; R 2021; E 2021) Standard Practice
for Determining Resistance of Synthetic
Polymeric Materials to Fungi

KOREA FOUNDRY COOPERATIVE ASSOCIATION (KFCA)

SPS-KFCA-D4301-5015

(2014; R 2024) Grey Iron Castings

KOREAN INDUSTRIAL STANDARDS (KS)

KS D 3590

(2019; R 2024) Corrugated Steel Pipes and
Sections

KS F 2322

(2020) Standard Test Methods for
Permeability of Saturated Soils

KS K 0520

(2021) Textiles - Tensile Properties of
Fabrics - Determination of Maximum Force
and Elongation at Maximum Force Using the
Grab Method

KS K 0537

(2019; R 2024) Testing Method for Tearing
Strength of Cloth : Trapezoid Method

KS K 0743

(2023) Test Method for Breaking Strength
and Elongation of Geotextiles : Grab Method

KS K 0744

(2023) Test Method for Puncture Strength
of Geotextiles and their Related Products

KS K 0754

(2022) Standard Test Method for
Determining Apparent Opening Size of a
Geotextile

KS M 3404

(2021) Unplasticized Poly(Vinyl
Chloride)(PVC-U) Pipes for General Service

KS M 3600

(2016; R 2021) Structured-Wall Polyvinyl
Chloride(PVC) Pipes for Non-Pressure
Underground Drainage and Sewerage -
Double-Wall Corrugated Pipe and Rib Pipe

KS M ISO 62

(2016; R 2021) Plastics - Determination of
Water Absorption

KS M ISO 844

(2023) Rigid Cellular Plastics -
Determination of Compression Properties

1.3 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy and Air Force projects, or choose the second bracketed item for Army projects.

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Composite Drains; G

The Contractor shall submit an Installation Plan detailing installation procedures for the composite drains.

SD-04 Samples

Geotextile

Pipe and Pipe Fittings

Composite Drains; G

Two samples of each composite drains (at 0.3 meter (1 foot), 2

each).

SD-06 Test Reports

Composite Drains; G

Copies of certified Manufacturer's laboratory test data.

SD-07 Certificates

Geotextile

Pipe and Pipe Fittings

Composite Drains; G

A statement signed by an authorized quality control employee of the Manufacturer certifying that the products meet or exceed technical specifications.

1.4 DELIVERY, STORAGE, AND HANDLING

1.4.1 Delivery and Storage

NOTE: This time restriction applies to pipe containing normal quantities of ultraviolet (UV) inhibitors such as carbon black or titanium dioxide, in geographic areas receiving normal UV exposure. Delays in installation longer than 6 months, from time of manufacturer to time of installation, may be allowed when the Contractor can show that the pipe has been covered or stored indoors for the duration of the additional delay.

Inspect materials delivered to site for damage; unload, and store with minimum handling. Do not store materials directly on the ground. Keep the inside of pipes and fittings free of dirt and debris. Keep, during shipment and storage, geotextile wrapped in burlap or similar heavy duty protective covering. Protect the geotextile from mud, soil, dust, and debris. Do not store geotextile materials in direct sunlight. Install plastic pipe within 6 months from the date of manufacture unless otherwise approved.

1.4.2 Handling

Handle materials in such a manner as to ensure delivery to the trench in sound undamaged condition. Carry pipe to the trench.

PART 2 PRODUCTS

2.1 PIPE FOR SUBDRAINS

NOTE: Where the type of pipe is to be the Contractor's option, the types that are acceptable should be included in this specification. The inapplicable types of pipe should be deleted.

Perforation and slot sizing is based on embedment gradation, flow requirements, and structural considerations. The embedment material gradation is in turn based on the gradation of the surrounding soil. In order to minimize the migration of fines into the coarser material while maintaining adequate permeability, the following criteria should be met:

All soils (except clays without a sand or silt fraction):

$$\frac{(15 \text{ percent size of drainage or filter material})}{(85 \text{ percent size of material to be drained})} = 5 \text{ (max)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(50 \text{ percent size of material to be drained})} = 25 \text{ (max)}$$

$$\frac{(15 \text{ percent size of drainage or filter material})}{(0.4 \text{ (max)})} =$$

All Soils

$$\frac{(15 \text{ percent size of drainage or filter material})}{(15 \text{ percent size of material to be drained})} = 5 \text{ (min)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(\text{slot width})} = 1.2 \text{ (min)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(\text{hole diameter})} = 1.0 \text{ (min)}$$

The minimum recommended subdrain pipe diameter is **150 mm**.

The drawings should indicate which pipes must be perforated (collector pipes) and which pipes must not be perforated (outlet pipes).

Submit samples of **pipe and pipe fittings**, before starting the work. Provide type and sizes of subdrain pipe indicated. Submit certifications from the manufacturers attesting that materials meet specification requirements. Certificates are required for drain pipe and fittings.

2.1.1.1 Plastic

Provide plastic pipe containing ultraviolet inhibitor to provide protection from exposure to direct sunlight. Provide pipe with with bell and spigot or solvent cement joints. Provide manufacturer's standard type fittings conforming to the indicated specification.

2.1.1.1.1 Polyvinyl Chloride (PVC) and Fittings

ASTM D3034, **ASTM F949** or **KS M 3600**, or **ASTM F758**, Type PS 46 or **KS M 3404**.

2.1.1.2 Corrugated Polyethylene (PE) and Fittings

NOTE: AASHTO M 252 Type S pipe has an outer
corrugated pipe wall and a smooth liner. Type SP
pipe is perforated Type S pipe.

AASHTO M 252, Type S or SP as indicated.

2.1.1.3 Pipe Perforations

Provide pipe perforations with a minimum water inlet area of 1,060 mm
squared per linear meter and as specified below.

2.1.1.3.1 Circular Perforations in Plastic Pipe

Cleanly cut circular holes not more than 9.5 mm or less than 4.8 mm in
diameter and arrange in rows parallel to the longitudinal axis of the
pipe. Provide pipe with perforations spaced uniformly along rows. Unless
otherwise recommended by the pipe manufacturer, provide pipe with rows
approximately 38 mm apart and arranged in a staggered pattern so that all
perforations lie at the midpoint between perforations in adjacent rows.
Space the rows over not more than 155 degrees of circumference. Provide
pipe that is not perforated for a length equal to the depth of the socket
at the spigot or tongue end and provide perforations that continue at
uniform spacing over the entire length of the pipe.

2.1.1.3.2 Slotted Perforations in Plastic Pipe

Cleanly cut circumferential slots so as not to restrict the inflow of
water and uniformly spaced along the length and circumference of the
pipe. Provide pipe with slots not exceeding 3.2 mm nor less than 0.8 mm
in width. Provide pipe with individual slot lengths not exceeding 10
percent of the pipe inside nominal circumference on 150 to 200 mm diameter
pipe, and 63.5 mm on 250 mm diameter pipe. Symmetrically space rows of
slots so that they are fully contained in 2 quadrants of the pipe. Center
slots in the valleys of the corrugations of profile wall pipe.

2.1.2 Corrugated Steel

NOTE: Corrugated steel pipe may be installed in
soils with a pH range of 6.0 to 8.0 provided the
resistivity is greater than 2,000 ohm-cm. A
bituminous coating should be used when soil or
ground-water conditions are at or near these limits.

150 to 200 mm diameter pipe has 38 by 6.5 mm
corrugations. Type I pipe has a circular cross
section. Type III pipe is Type I pipe that has been
perforated. Class 1 perforations are 4.8 mm to 9.5
mm in diameter with four rows of perforations. Each
perforation is located on the inside crests or along
the neutral axis of the corrugations.

ASTM A760/A760M, Type I or III or KS D 3590, as indicated with a coating
conforming to AASHTO M 190, Type A. Provide Class 1 perforations in Type

III pipe. Pipe sheet thickness 1.63 mm.

2.1.3 Corrugated Aluminum Alloy

NOTE: Corrugated aluminum pipe without bituminous coating may be installed in soil with pH range of 5.5 to 8.5 if the resistivity is greater than 500 ohm-cm or 5.0 to 9.0 where the resistivity is greater than 1,500 ohm-cm. This type of pipe should not be installed in material classified as OH or OL according to the Unified Soil Classification System as presented in ASTM D2487. Bare aluminum alloy pipe has satisfactory corrosion resistance in clean granular materials even when subjected to sea water.

Fully bituminous coated corrugated aluminum pipe may be considered in soils where the pH range is 6.0 to 8.0 and resistivity is greater than 2,000 ohm-cm.

150 to 200 mm diameter pipe has 38 by 6.5 mm corrugations. Type I pipe has a circular cross section. Type III pipe is Type I pipe that has been perforated. Class 1 perforations are 4.8 mm to 9.5 mm in diameter with four rows of perforations. Each perforation is located on the inside crests or along the neutral axis of the corrugations.

ASTM B745/B745M, Type I or III, as indicated with a bituminous coating conforming to AASHTO M 190, Type A. Provide Class 1 perforations in Type III pipe. Pipe sheet thickness 1.63 mm.

2.1.4 Precoated Corrugated Steel

NOTE: 150 to 200 mm diameter pipe has 38 by 6.5 mm corrugations. Type I pipe has a circular cross section. Type III pipe is Type I pipe that has been perforated. Class 1 perforations are 4.8 mm to 9.5 mm in diameter with four rows of perforations. Each perforation is located on the inside crests or along the neutral axis of the corrugations.

ASTM A762/A762M, Type I or III, as indicated. Provide Class 1 perforations in Type III pipe.

2.2 GEOTEXTILE

NOTE: When geotextile is not used in the drainage system, the requirement for geotextile will be deleted from this specification. When geotextile is used in the drainage system it may be specified either by referencing AASHTO M 288, requirements in Section 31 05 19.13 GEOTEXTILES FOR EARTHWORK (first set of brackets), or by specifying the requirements

in this paragraph (remaining brackets).

Design criteria for geotextiles are based on the equivalent opening size (AOS), percent open area (POA), and geotextile permeability (Kg). The AOS is defined as the number of the US Standard Sieve having openings closest in size to the largest openings in the geotextile. The AOS specified should be based on the criteria described below. To perform piping criteria computations, express the AOS as the equivalent US standard sieve opening in millimeters. The AOS can be used for woven and nonwoven geotextiles. Where a designer desires to use "percent open area," the percent open area should be based on the criteria below. The percent open area should be used only for woven fabrics. The permeability test can be used for nonwoven and woven geotextiles.

The AOS test is a means of evaluating the piping resistance of a geotextile, and the percent open area test is intended to assure adequate flow through the geotextile and adequate resistance to reduction in permeability over time (clogging). The percent open area test is an indirect test which has been shown to correlate with a woven geotextile's long term permeability. The permeability test measures the ability of the geotextile to pass water without any soil on the fabric. This test does not provide a direct measure of field performance of the geotextile.

Specify geotextile properties which will allow retention of the soil being protected, permit sufficient flow through the fabric, and prevent clogging. The designer should select the AOS, POA, and Kg, based on the following criteria:

Protected Soil Percent Passing 0.075 mm Sieve	Piping (a.) Maximum AOS (mm)	Woven Minimum POA	Nonwoven Minimum POA
Less than 5 percent (b.)	D85 (c.)	10 percent	Ks (d.)
5 to 50 percent (b.)	D85	4 percent	Ks
50 to 85 percent	(a.) D85 (b.) Upper Limit on AOS is AOS - 0.212 mm	4 percent	Ks
More than 85 percent	(a.) D85 (b.) Lower Limit on AOS is AOS - 0.125 mm		Ks

Protected Soil Percent Passing 0.075 mm Sieve	Piping (a.) Maximum AOS (mm)	Woven Minimum POA	Nonwoven Minimum POA
a. When the protected soil contains appreciable quantities (20 to 30 percent) of material retained on the 4.75 mm, sieve, use only the soil passing the 4.75 mm, sieve in selecting the AOS of the filter fabric.			
b. These protected soils may have a large permeability and thus the POA of Kg may be a critical design factor.			
c. D85 is the grain size in millimeters for which 85 percent of the sample by weight has smaller grains.			
d. Kg is the permeability of the nonwoven fabric, and Ks is the permeability of the protected soil.			

The AOS requirement should be specified as a range to allow for manufacturing tolerances. The smallest sieve opening size of the AOS range should not be smaller than the openings of a 0.125 mm US Standard Sieve. It is preferable to specify a geotextile with openings as large as allowed by the criteria.

Fabric strength requirements vary with intended use and construction procedures. Recommended values are:

Type	Minimum	Test
Tensile	444.8 N	ASTM D4632/D4632M grab test 25 mm square and 300 mm per minute constant rate at traverse.
Elongation	15 percent	ASTM D4632/D4632M determine apparent breaking elongation.
Puncture	177.8 N	ASTM D3787 except polished steel ball replaced with a 8 mm diameter solid steel cylinder with a hemispherical tip centered within the ring clamp.
Tear	177.8 N	ASTM D4533 trapezoidal tear strength.

Collector pipes should not be wrapped with geotextile. If the geotextile is used to line a trench, the collector pipe should be separated from the geotextile by a minimum of 150 mm of granular backfill material.

Submit samples of geotextile and certifications from the manufacturers attesting that geotextile meets specification requirements. Filter fabric shall be a pervious sheet of polyester, nylon, or polypropylene filaments woven or otherwise formed into a uniform pattern with distinct and measurable openings. The filter fabric shall provide an equivalent opening size (AOS) no finer than the US Standard Sieve No. 0.125 mm and no coarser than the US Standard Sieve No. 4.75 mm. AOS is defined as the number of the US Standard sieve having openings closest in size to the

filter fabric openings. The filaments shall consist of a long-chain synthetic polymer composed of at least 85 percent by weight of propylene, ethylene, or vinylidene-chloride, and shall contain stabilizers and/or inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The fabric shall have a minimum physical strength of 444.8 N in any direction when tested in accordance with ASTM D5034 or KS K 0743 using the grab test method with 645.2 square mm jaws and a constant rate of travel of 304.8 mm per minute. Elongation at failure shall be between 30 and 70 percent. The fabric shall be constructed so that the filaments will retain their relative position with respect to each other. The edges of the fabric shall be salvaged or otherwise finished to prevent the outer material from pulling away from the fabric. The fabric shall be woven into a width that may be installed as shown without longitudinal seams.

2.3 SUBDRAIN FILTER AND BEDDING MATERIAL

NOTE: The thickness and gradation of the filter material for use with pipe subdrains and blind or french drains will be determined by soil conditions and subsoil drainage requirements. Filter material will be graded in accordance with the requirements of UFC 3-250-01, as applicable. The filter material placed adjacent to perforated pipe will be of a size that will prevent the entrance of any of the filter material into the drain. Graded (composite or layered) filters will be used where specified, and cross sections will be as indicated on the drawings. See UFC 3-250-01 for dimensions of filter and bedding material around pipe. Where site conditions require more than one filter gradation, the drawings will indicate areas of different gradation and the table expanded.

Provide subdrain filter and bedding material composed of washed sand, sand and gravel, crushed stone, crushed stone screenings, or slag composed of hard, tough, durable particles free from adherent coatings. Filter material may not contain corrosive agents, organic matter, or soft, friable, thin, or elongated particles. Provide filter material that is evenly graded between the limits specified in TABLE I. Gradation curves will exhibit no abrupt changes in slope denoting skip or gap grading. Provide filter materials that are clean and free from soil and foreign materials. Remove and replace filter blankets found to be dirty or otherwise contaminated with material meeting the specific requirements, at no additional cost to the Government.

TABLE I		
	Type I Gradation E 11 ASTM C33/C33M	Type II Gradation 57 ASTM C33/C33M
ASTM C136/C136M Sieve Size, mm	Percent Passing	Percent Passing
37.5	--	100
25.0	--	90 - 100
9.5	100	25 - 60
4.75	95 - 100	5 - 40
2.36	--	0 - 20
1.18	45 - 80	--
0.30	10 - 30	--
0.15	0 - 10	--

2.4 DRAINAGE STRUCTURES

2.4.1 Concrete

Provide concrete and reinforced concrete conforming to the requirements for 27 MPa concrete in Section [03 30 00 CAST-IN-PLACE CONCRETE][03 30 53 MISCELLANEOUS CAST-IN-PLACE CONCRETE].

2.4.2 Mortar

Provide mortar for connections to drainage structures that is composed of one part by volume of portland cement and two parts of sand. Provide sufficient quantity of water in the mixture to produce a stiff workable mortar. Use water that is clean and free of injurious acids, alkalies, and organic impurities. Use the mortar within 30 minutes from the time the ingredients are mixed with water.

2.4.3 Manholes and Appurtenances

2.4.3.1 Precast Reinforced Concrete Manhole Risers and Tops

ASTM C478M.

2.4.3.2 Precast Concrete Manhole Bases

ASTM C478M. Provide bases that allow suitable connection with influent and effluent lines and to provide a suitable base structure for riser sections.

2.4.3.3 Glass Fiber-Reinforced Polyester (FRP)

ASTM D3753.

2.4.3.4 Frames and Covers or Gratings

Except as otherwise permitted, provide frames and gratings, or frames and covers of either cast iron with tensile strength test not less than [ASTM A48/A48M](#) Class 25 or [SPS-KFCA-D4301-5015](#), Type GC 200, or steel conforming to [ASTM A27/A27M](#), Class 65-35. Required weight, shape, and size are indicated on the drawings. Frames and covers not subjected to vehicular traffic or storage may be of malleable iron where indicated. Provide malleable-iron frames and covers conforming to [ASTM A47/A47M](#) and of the weight, shape, and size indicated.

2.4.3.5 Steel Ladder

Provide a steel ladder where the depth of a manhole exceeds 1.2 m. The ladder will be not less than 400 mm in width, with 19.1 mm diameter rungs spaced 304.8 mm apart. Provide two stringers that are a minimum 9.5 mm thick and 50.8 mm wide. Adequately anchor ladder to the wall by means of steel inserts spaced not more than 1.83 m apart vertically, and install so as to provide at least 152.4 mm of space between the wall and the rungs. Galvanize ladders and inserts after fabrication in conformance with [ASTM A123/A123M](#).

2.5 Composite Drains

Composite drains shall consist of a nonwoven polyester or polypropylene filter fabric which is factory bonded to one side of a three-dimensional drainage core panel or strip. The drainage core shall be a high-impact resistant polymetric sheet of either polystyrene or high density polyethylene (HDPE) composition, and shall have high compression resistance and long-term durability. Composite drains shall be delivered to the site with the filter fabric already bonded to the drainage core by the product manufacturer. The bond between filter fabric and drainage core shall be of such strength that fabric distortion and intrusion into the core flow channels do not occur when the drain is backfilled against. Installation of the composite drains shall be continuous over the length of the retaining walls as delineated on the contract drawings and specified herein.

2.5.1 Filter Fabric

The filter fabric shall serve as a filtering media to allow the passage of groundwater into the drainage core while retaining backfill soil particles without clogging the open pores of the fabric. All seepage entering the drainage core shall be discharged by means of a perforated or slotted drain pipe running along the back of the retaining wall as shown on the contract drawings. Weep holes extending through the wall shall serve as the backup discharge system.

2.5.2 Composite Drains Products

2.5.2.1 Drainage Core

- a. Thickness: minimum 11.2 mm (0.44 inch) per [ASTM D1777](#).
- b. Minimum Compressive Strength: 2.69 kg per square centimeter at max 10 percent deflection per [ASTM D1621](#) or [KS M ISO 844](#).
- c. Composition: high density polyethylene or high-impact resistant

polystyrene.

2.5.2.2 Filter Fabric (Minimum Average Roll Values)

- a. Composition: nonwoven polyester or polypropylene.
- b. Grab Tensile Strength: minimum 59 kg per ASTM D4632/D4632M or KS K 0520.
- c. Grab Tensile Elongation (all directions): minimum 50 percent per ASTM D4632/D4632M or KS K 0743.
- d. Trapezoidal Tear Strength: minimum 18 kg per ASTM D4533/D4533M or KS K 0537.
- e. Puncture Strength: minimum 930 N per ASTM D6241 or KS K 0744.
- f. Apparent Opening Size (AOS): 70 to 80 U.S. sieve size per ASTM D4751 or KS K 0754.
- g. Water Flow Rate: minimum 150 gal per min per square foot per ASTM D4491/D4491M or KS F 2322.
- h. Coefficient of Permeability: minimum 0.2 cm per sec per ASTM D4491/D4491M.
- i. Moisture Absorption: not less than 0.05 percent per ASTM D570 or KS M ISO 62. But square test specimen for homogeneous plastics, test specimen for rods, or test specimen for tubes shall be applied in case of KS M ISO 62.
- j. UV Resistance: at least 70 percent of minimum grab tensile strength retained after 150 hours exposure per ASTM D4355/D4355M.

2.5.2.3 Composite System

- a. In-Plane Flow Capacity: minimum 11 gpm per foot width at 2,000 psf confining pressure and hydraulic gradient of 1.0 per ASTM D4716/D4716M.
- b. Fungus Resistance: no growth per ASTM G21.
- c. Resistant to naturally occurring soil alkalis and acids in normal soil environments.
- d. Product will not be eaten by insects or rodents.
- e. Requires no maintenance after installation.
- f. Width (Vertical Direction): complete wall coverage to the limits shown on the contract drawings, with filter fabric wrap extending a minimum of 75 mm beyond all terminal edges of the drainage core per roll, sheet or panel.
- g. Length (Horizontal Direction): product roll or panel lengths as necessary to install continuous composite drains per contract drawings and specifications.

2.5.3 Storage and Handling

2.5.3.1 Composite Drains

Composite drains shall be labeled, stored, and handled according to **ASTM D4873/D4873M**, the manufacturer's recommendations, and as provided in these specifications.

2.5.3.2 Protection

Drains shall be kept wrapped, dry, and protected from the elements at all times during shipping and storage. If stored outdoors, the drains shall be elevated above ground level and protected with a waterproof, opaque cover. The temperature of the stored products shall not be allowed to exceed **60 degrees C**.

2.5.3.3 Exposure

The Contractor shall limit the time composite drains are exposed to sunlight to a maximum 7 days. The period of exposure shall be measured from the time individual product rolls or panels are removed from their protective shipping wrappers until final coverage with backfill. If composite drains must be exposed for more than 7 days, the Contractor shall be required to protect the drains with an acceptable temporary cover for the duration of the delay, at no cost to the Government.

2.5.3.4 Maintenance

The Contractor shall protect the composite drains from damage or contamination from soil, mud, dust, or debris to mitigate any reduction in required strength and permeability of the product. The Contractor shall not operate equipment directly on the drains. The drains shall have no tears, punctures, or other defects which would adversely alter its physical properties. Damaged or otherwise defective drains shall be replaced with the same undamaged product, prior to installation, at no cost to the Government.

2.5.4 Installation Plan and Product Certification

2.5.4.1 Installation Plan

Before installing the composite drains, the Contractor shall submit the following to the Contracting Officer:

- a. Two samples of each drain product (at **0.3 meter**, 2 each);
- b. An installation plan detailing installation procedures for the composite drains;
- c. A certification signed by an authorized quality control employee of the Manufacturer stating that the products meet or exceed technical specifications as listed in paragraphs 2.5.3.1, 2.5.3.2, and 2.5.3.3 above; and
- d. Certified Manufacturer's laboratory test data for the following properties, at a minimum frequency of one test per **10,000 square meters** of product produced:
 - Compressive strength for drainage core;

- Grab tensile strength, puncture strength, mullen burst strength, trapezoidal tear strength, permeability, water flow rate, and AOS for the filter fabric; and
- In-plane flow capacity for the composite system.

2.5.4.2 Product Certification

The Contractor shall not purchase composite drains for the project until product samples have been examined and all certifications and supporting laboratory test data have been reviewed and approved by the Contracting Officer. The Contractor shall not proceed with installation of composite drains until approval of the Installation Plan by the Contracting Officer has been granted.

2.5.5 WEEP HOLES

Weep Holes unless otherwise indicated or approved shall be schedule 40 PVC pipe conforming to ASTM D1785 or KS M 3404. Drain pipes shall be plastic pipe containing ultraviolet inhibitor to provide protection from exposure to direct sunlight.

PART 3 EXECUTION

3.1 EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS

Excavate trenches, including the removal of rock and unstable material, in accordance with Section 31 00 00 EARTHWORK. Place bedding material in the trench as indicated or as required as replacement materials used in those areas where unstable materials were removed. Compact bedding material as specified for cohesionless material in Section 31 00 00 EARTHWORK.

3.2 MANHOLES AND FLUSHING AND OBSERVATION RISERS

NOTE: The details indicating size, shape, materials, thickness of various sections, the finish required, and amounts or reinforcing, if any, for headwalls, and manholes will be shown in the drawings. Also, the shape, size, thickness of sections, kind of materials, and weight for frames and covers for subdrain manholes will be indicated in the drawings. The covers will be designed to have ample strength for the traffic conditions to which they may be subjected. Fixed ladders or ladder rungs will be provided for manholes 3.6 m or deeper measured from top of grate to invert of outlet pipe.

3.2.1 Manholes

Install manholes complete with frames and covers or gratings at the locations and within the limits and sizes indicated. Construct manholes of one of the materials specified for manholes in paragraph DRAINAGE STRUCTURES. Completely fill precast concrete manhole joints so that they are smooth and free of surplus mortar or mastic on the inside of the structure. Use either precast or cast-in-place concrete manhole bases.

3.2.2 Flushing and Observation Risers

Install flushing and observation riser pipes with frames and covers at the locations indicated. Construct risers of non-perforated [plastic] [or] [galvanized] [bituminous coated] [corrugated metal] pipe. Join riser pipes to the subdrain system as indicated.

3.3 INSTALLATION OF GEOTEXTILE AND PIPE FOR SUBDRAINS

NOTE: Outlets for subdrains, if possible, within reasonable costs, will be designed so that severe rainstorms will neither submerge the drains nor back up water into the drains. Where outlets are not subject to backwater or flooding, the outlets will be provided with grates or heavy screens to prevent acts of vandalism or entrance by rodents. If suitable outlets for blind or french drains into pervious strata of gravel or sand with a lower water table are not obtainable, pipe outlets may be required. The perforated pipe will extend into the filter material of the blind or french drain a sufficient distance to provide ample waterway openings for the particular drain and non-perforated pipe will extend through the impervious material to a suitable outlet. Outlets subject to flooding will be provided with suitable and properly installed check valves or flap gates. If outlet pipes are necessary for blind or french drains, and are to be paid for as a separate item, such requirement will be clearly specified, giving the various kinds and sizes of pipe required.

3.3.1 Installation of Geotextile

NOTE: When geotextile is not used in the drainage system, the requirement for geotextile will be deleted from this specification.

3.3.1.1 Trench Lining and Overlaps

NOTE: The strength properties of most geotextiles composed of plastic materials are adversely affected by ultraviolet rays. Consequently, the geotextile should be exposed to sunlight as little as possible, and preferably should be covered the same day as installed. When geotextile is used to separate the drainage layer or filter material from the soil being drained, the gradation ratios of filter material to protected soil given in UFC 3-230-06A, do not apply; however, size the geotextile to filter the protected soil.

Grade trenches to be lined with geotextile to obtain smooth side and bottom surfaces so that the geotextile will not bridge cavities in the soil or be damaged by projecting rock. Lay the geotextile flat but not stretched on the soil, and secure it with anchor pins in accordance with manufacturer's instructions. Overlap at least 150 mm, and secure with anchor pins along the overlaps.

3.3.2 Installation of Pipe for Subdrains

3.3.2.1 Pipelaying

Install pipe in accordance with the manufacturer's recommendations. Thoroughly examine each section of pipe before being laid; do not use defective or damaged pipe. Do not lay pipe when the trench conditions or weather is unsuitable for such work. Remove water from trenches by sump pumping or other approved methods. Lay the pipe to the grades and alignment as indicated. Bed the pipe to the established gradeline. Center perforations on the bottom of the pipe. Lay bell-and-spigot type with the bell ends upstream. Approval of all in-place pipes by the Contracting Officer is required prior to backfilling.

3.3.2.2 Jointings

3.3.2.2.1 Perforated Corrugated Metal Pipe or Bituminous Coated, Perforated Corrugated Metal Pipe

Securely fasten together the sections of perforated corrugated metal pipe or bituminous coated, perforated corrugated metal pipe standard connecting bands furnished by the manufacturer of the pipe.

3.3.2.2.2 Bituminous Coated or Uncoated Corrugated Aluminum Pipe

If aluminum pipe is to be connected to dissimilar metal, insulate the connection by bituminous coating or other nonconductive material. Securely fasten standard joints between corrugated aluminum pipe with standard connecting bands furnished by the manufacturer of the pipe.

3.4 INSTALLATION OF FILTER MATERIAL AND BACKFILLING FOR PERFORATED SUBDRAINS

After perforated pipe for subdrains has been laid, inspected, and approved, place filter material around and over the pipe to the depth indicated. Place the filter material in layers not to exceed 200 mm thick. Thoroughly compact each layer using mechanical tampers or rammers.

3.5 INSTALLATION OF BEDDING AND BACKFILL FOR NON-PERFORATED SUBDRAIN OUTFALL PIPE

3.5.1 Plastic Pipe

Place and compact pipe embedment for plastic pipe in accordance with ASTM D2321. Use Class IB or II embedment materials.

3.5.2 Corrugated Metal Pipe

Place and compact bedding and structural backfill for corrugated metal pipe in accordance with ASTM A798/A798M. Use structural backfill materials classified by ASTM D2487 as either GW, GM, GP-GM, GW-GM, GC, GP-GC or SW.

3.6 INSTALLATION OF AND BACKFILLING FOR BLIND OR FRENCH DRAINS

Place filter material as indicated and compact as specified for cohesionless materials in Section 31 00 00 EARTHWORK. Extend filter material to a suitable outlet or to an outlet through a pipeline as indicated. Place and compact overlying backfill material as specified in Section 31 00 00 EARTHWORK.

-- End of Section --