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USACE / NAVFAC / AFCEA / NASA UFGS-02 56 15 (April 2006)  
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Preparing Activity: USACE Replacing without change  
UFGS-02376 (August 2004)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UML dated October 2007

Revised throughout - changes not indicated by CHG tags

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04/06

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### SECTION 02 56 15

#### GEOSYNTHETIC CLAY LINER (GCL) 04/06

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NOTE: This guide specification covers the requirements for geosynthetic clay liners.

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

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

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

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## PART 1 GENERAL

### 1.1 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 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.

ASTM INTERNATIONAL (ASTM)

ASTM D 1505	(2003) Density of Plastics by the Density-Gradient Technique
ASTM D 5199	(2001; R 2006) Measuring Nominal Thickness of Geosynthetics
ASTM D 5261	(1992; R 2003) Measuring Mass Per Unit Area of Geotextiles
ASTM D 5887	(2004) Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
ASTM D 5888	(2006) Storage and Handling of Geosynthetic Clay Liners
ASTM D 5889	(1997; R 2003) Quality Control of Geosynthetic Clay Liners
ASTM D 5890	(2006) Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
ASTM D 5891	(2002) Fluid Loss of Clay Component of Geosynthetic Clay Liners
ASTM D 5993	(1999; R 2004) Measuring Mass Per Unit of Geosynthetic Clay Liners
ASTM D 5994	(1998; R 2003) Measuring Core Thickness of Textured Geomembrane
ASTM D 6072	(1996; R 2002) Obtaining Samples of Geosynthetic Clay Liners
ASTM D 6243	(2006) Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method
ASTM D 6496	(2004a) Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
ASTM D 6768	(2004) Tensile Strength of Geosynthetic Clay Liners

ASTM D 792

(2000) Density and Specific Gravity  
(Relative Density) of Plastics by  
Displacement

## 1.2 UNIT PRICES

\*\*\*\*\*  
NOTE: Delete this paragraph when lump sum bidding  
is used.  
\*\*\*\*\*

Measurement will be made of the total surface area covered by GCL in square  
meters yards as shown on the contract drawings. Final quantities will be  
based on as-built conditions. Allowance will be made for GCL in anchor and  
drainage trenches; however, no allowance will be made for waste, overlap,  
repairs, or materials used for the convenience of the Contractor. GCL  
installed and accepted will be paid for at the respective contract unit  
price in the bidding schedule.

## 1.3 SUBMITTALS

\*\*\*\*\*  
NOTE: Review submittal description (SD) definitions  
in Section 01 33 00 SUBMITTAL PROCEDURES and edit  
the following list to reflect only the submittals  
required for the project. Submittals should be kept  
to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the  
submittal requires Government approval. Some  
submittals are already marked with a "G". Only  
delete an existing "G" if the submittal item is not  
complex and can be reviewed through the Contractor's  
Quality Control system. Only add a "G" if the  
submittal is sufficiently important or complex in  
context of the project.

For submittals requiring Government approval on Army  
projects, a code of up to three characters within  
the submittal tags may be used following the "G"  
designation 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,  
Air Force, and NASA projects.

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

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Government approval is required for submittals with a "G" designation;  
submittals not having a "G" designation are for [Contractor Quality Control  
approval.] [information only. When used, a designation following the "G"

designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

#### SD-02 Shop Drawings

##### Layout and Detail Drawings[; G][; G, [\_\_\_\_\_]]

GCL panel layout and penetration detail drawings, as specified.

#### SD-03 Product Data

##### GCL Properties

Manufacturer's certified raw and roll material data sheets. If needle punching or stitch bonding is used in construction of GCL, the certification shall indicate that the GCL has been continuously inspected for broken needles using an in-line metal detector and all broken needles have been removed. The certified data sheets shall be attested to by a person having legal authority to bind the GCL manufacturing company. Certified test results shall be submitted at least [14] [\_\_\_\_\_] working days prior to delivery of the GCL.

##### Warranty

Manufacturer's warranty statement.

##### Tests, Inspections, and Verifications

Manufacturer's quality control (QC) manual which describes testing procedures, frequency of testing and acceptance/rejection criteria for QC testing at least [14] [\_\_\_\_\_] days prior to delivery of the GCL.

##### Qualifications[; G][; G, [\_\_\_\_\_]]

Manufacturer's, installer's, QC inspector's, and QC laboratory's qualification statements including resumes of key personnel involved in this project.

#### SD-04 Samples

##### Samples

QC samples at the specified frequencies.

#### SD-06 Test Reports

##### Tests, Inspections, and Verifications

Mid-plane and interface shear strength test results at least [14] [\_\_\_\_\_] days prior to deployment.

##### Conformance Tests

Independent QC laboratory test results including description of equipment and test methods.

## Subgrade Preparation

Certificate of subgrade inspection.

### 1.4 QUALIFICATIONS

#### 1.4.1 Manufacturer

Geosynthetic clay liner shall be the product of a GCL Manufacturer who has produced the proposed GCL using the same bentonite, polyethylene geomembrane, geotextiles, sewing thread, and adhesive for at least 5 completed projects and shall have produced a minimum of [186,000] [\_\_\_\_\_] square meters [2,000,000] [\_\_\_\_\_] square feet of the proposed GCL.

#### 1.4.2 Installer

\*\*\*\*\*  
NOTE: Small projects may not require the use of a specialized GCL installer. If a specialized GCL installer will not be required, this paragraph should be omitted and the SD-03 requirements under SUBMITTALS edited accordingly.  
\*\*\*\*\*

The installer shall have installed GCL at a minimum of 5 projects of comparable scope and complexity and shall have installed a minimum of 186,000 [\_\_\_\_\_] square meters 2,000,000 [\_\_\_\_\_] square feet of the proposed GCL.

#### 1.4.3 QC Inspector

\*\*\*\*\*  
NOTE: An independent third party inspector should be considered based on the qualifications of the Government quality assurance personnel, the size and importance of the project, and impacts of a GCL failure. Delete this paragraph if a third party inspector will not be used.  
\*\*\*\*\*

An independent QC inspector is responsible for monitoring and documenting activities related to the QC of the GCL from manufacturing through installation. The QC inspector shall have provided QC and/or QA inspection during installation of GCL material for at least 5 projects and shall have performed QC and/or QA inspection on a minimum of [186,000] [\_\_\_\_\_] square meters [2] [\_\_\_\_\_] million square feet of GCL.

#### 1.4.4 QC Laboratory

An independent QC laboratory is responsible for QC GCL testing. The QC laboratory shall have provided QC and/or QA testing of GCL for at least 5 completed projects and shall have performed QC and or QA testing for a minimum of [186,000] [\_\_\_\_\_] square meters [2] [\_\_\_\_\_] million square feet of GCL. The QC laboratory shall be accredited via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP).

## 1.5 DELIVERY, STORAGE, AND HANDLING

### 1.5.1 Delivery

Delivery, storage, and handling of GCL shall be in accordance with **ASTM D 5888**. The Contracting Officer shall be present during unloading of the GCL. Rolls shall be packaged in an opaque, waterproof, protective covering and wrapped around a central core. Tears in the packaging shall be repaired to restore a waterproof protective barrier around the GCL. Unloading of rolls from the delivery vehicles shall be done in a manner that prevents damage to the GCL and its packaging.

### 1.5.2 Storage

Field storage shall be in flat dry areas where water cannot accumulate and the GCL rolls can be protected from damage. Storage of the rolls on blocks or pallets will not be allowed unless the GCL rolls are fully supported as approved by the Contracting Officer. Stacks of GCL rolls shall be no greater than three high. Rolls shall be covered with a water proof tarpaulin or plastic sheet if stored outdoors.

### 1.5.3 Handling

During handling, rolls shall not be dragged, lifted by one end, dropped to the ground, or otherwise damaged. A pipe or solid bar of sufficient strength to support the full weight of the roll without significant bending shall be used for all unloading and handling activities. If recommended by the manufacturer, a sling handling method utilizing appropriate loading straps may be used.

## 1.6 WARRANTY

\*\*\*\*\*  
NOTE: Several manufacturers should be contacted to determine what length of warranty is available for GCL materials and installation. Manufacturers provide prorated material warranties ranging from 1 to 30 years depending on the application. Installation warranties are generally specified as 1 to 2 years in length.  
\*\*\*\*\*

The manufacturer's warranty shall state that the GCL materials meet all requirements of the contract documents and that for the intended use, the GCL is warranted for [\_\_\_\_\_] years against deterioration. The installer's warranty shall state that the GCL shall not fail due to improper installation within [\_\_\_\_\_] years.

## 1.7 LAYOUT AND DETAIL DRAWINGS

The Contractor shall submit GCL panel layout and detail drawings, for approval, a minimum of [14] [\_\_\_\_\_] days prior to deployment.

## PART 2 PRODUCTS

### 2.1 GCL PROPERTIES

\*\*\*\*\*  
NOTE: Test method ASTM D 5887 is an index test used



to determine the flux rate of water through a GCL specimen. If a contaminated fluid will contact the GCL, compatibility testing should be considered during the design phase to ensure that the GCL can perform as desired. The following ASTM test methods should be referenced when performing compatibility testing:

ASTM D 6141 - Standard Guide for Screening the Clay Portion of a Geosynthetic Clay Liner (GCL) for chemical Compatibility to Liquids, and

ASTM D 6766 - Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Liquids.

Additional geomembrane or geotextile requirements can be added to Table 1 or placed in a separate section of the specification package and referenced here.

Remove geotextile and/or geomembrane requirements from Table 1 as required for the type of product being specified.

A normal stress equal to anticipated field conditions should be specified in Table 1 for mid-plane shear strength testing.

A residual mid-plane shear strength should never be specified. The designer must ensure that the design is configured such that the allowable peak mid-plane shear stress is not exceeded.

GCL constructed with nonwoven geotextiles on both sides should be considered for situations where increased frictional resistance is required.

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GCL shall be a manufactured product consisting of a sodium montmorillonite clay (bentonite) layer evenly [distributed between two geotextiles] [or] [attached to a polyethylene geomembrane. The exposed surface of the polyethylene membrane shall be [smooth] [textured]]. GCL shall conform to the property requirements listed in Table 1 and shall be free of tears, holes, or other defects that may affect its serviceability. Encapsulating geotextiles shall be mechanically bonded together using a needle punch or stitch bonding process. Needle punched and stitch bonded GCLs shall be continuously inspected for broken needles using an in-line metal detector and broken needles shall be removed. The minimum manufactured GCL sheet width shall be 4.1 m 13.5 feet and the minimum manufactured GCL sheet length shall be 30 m 98 feet.

TABLE 1 - GCL PROPERTIES

TEST METHOD	TEST VALUE
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BENTONITE	

TABLE 1 - GCL PROPERTIES

	TEST METHOD	TEST VALUE
Swell Index Test, minimum	ASTM D 5890	24 mL
Fluid Loss, maximum	ASTM D 5891	18 mL
UPPER GEOTEXTILE PROPERTIES		
Material Type		[Woven] [Nonwoven]
Mass per Unit Area, min.	ASTM D 5261	[204] [_____] g/sq m
LOWER GEOTEXTILE PROPERTIES		
Material Type		[Woven] [Nonwoven]
Mass per Unit Area, min.	ASTM D 5261	[204] [_____] g/sq m
GEOMEMBRANE		
Thickness, minimum	ASTM D 5199 ASTM D 5994	[_____]
Sheet Density, minimum	ASTM D 1505 ASTM D 792	0.92 g/cc
COMPOSITE		
Bentonite Mass/Unit Area, minimum, Note 1	ASTM D 5993	3700 g/sq m
Moisture Content, maximum	ASTM D 5993	40 percent
Tensile Strength, minimum, (MD and CD)	ASTM D 6768	[_____] kN/m
Peak Mid-Plane Shear Strength (hydrated), minimum at a normal stress of [_____] kPa	ASTM D 6243	[_____] kPa
[Peak] [Large Displacement] Interface Friction Angle (hydrated), minimum	ASTM D 6243	[_____] degrees
Index Flux, maximum	ASTM D 5887	0.00000001 cubic m/sq m-sec
Peel Strength, min. MD Note 2	ASTM D 6496	400 N/m

TABLE 1 - GCL PROPERTIES

	TEST METHOD	TEST VALUE
BENTONITE		
Swell Index Test, minimum	ASTM D 5890	24 mL
Fluid Loss, maximum	ASTM D 5891	18 mL
UPPER GEOTEXTILE PROPERTIES		
Material Type		[Woven] [Nonwoven]
Mass per Unit Area, min.	ASTM D 5261	[6] [____] ounces/square yard
LOWER GEOTEXTILE PROPERTIES		
Material Type		[Woven] [Nonwoven]
Mass per Unit Area, min.	ASTM D 5261	[6] [____] ounces/square yard
GEOMEMBRANE		
Thickness, minimum	ASTM D 5199 ASTM D 5994	[____]
Sheet Density, minimum	ASTM D 1505 ASTM D 792	0.92 g/cc
COMPOSITE		
Bentonite Mass/Unit Area, minimum, Note 1	ASTM D 5993	0.75 lbs/sq foot
Moisture Content, maximum	ASTM D 5993	40 percent
Tensile Strength, minimum, (MD and CD)	ASTM D 6768	[____] lbs/in
Peak Mid-Plane Shear Strength (hydrated), minimum at a normal stress of [____] psf	ASTM D 6243	[____] psf
[Peak] [Large Displacement] Interface Friction Angle (hydrated), minimum	ASTM D 6243	[____] degrees
Index Flux, maximum	ASTM D 5887	0.00000001 cubic m/sq m-sec
Peel Strength, MARV MD Note 2	ASTM D 6496	2.3 lbs/inch

Note 1: Bentonite mass/unit area shall be computed at 0 percent moisture content. Bentonite mass/unit area is exclusive of glues added to the bentonite.

Note 2: The peel test applies to geotextile backed GCL products only.

## 2.2 TESTS, INSPECTIONS, AND VERIFICATIONS

### 2.2.1 Manufacturing Sampling and Testing

GCL and its components shall be sampled and tested in accordance with the manufacturer's approved QC manual. The manufacturer's QC procedures shall be in accordance with ASTM D 5889. Test results not meeting the requirements specified in Table 1 shall result in the rejection of applicable rolls. The manufacturer's QC manual shall describe procedures used to determine rejection of applicable rolls. As a minimum, rolls produced immediately prior to and immediately after the failed roll shall be tested for the same failed parameter. Testing shall continue until a minimum of three successive rolls on both sides of the original failing roll pass the failed parameter.

### 2.2.2 Shear Strength Testing

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NOTE: Frictional resistance of GCL is highly dependent on the hydrating fluid, hydration state, confining stresses during saturation, confining stresses during shear, and strain rate. These parameters should be specified on a site specific basis. For interface shear strength testing, a set of direct shear tests should consist of a minimum of three tests performed at normal stresses bracketing the anticipated average normal field stresses.

The hydration state of the GCL can have a significant effect on its shear strength. The shear strength of bentonite decreases with increasing moisture content. In addition, hydration of bentonite may affect the properties of reinforced GCL by stretching the reinforcement as the bentonite swells. For geotextile backed GCLs, interface shear strength is reduced due to the bentonite extruding into the interface. As a preliminary guideline, minimum hydration time should be 24 hours for mid-plane and interface shear strength testing. However, it must be pointed out that research indicates these hydration times will probably not result in complete hydration of the GCL. Hydration times of up to 25 days are required to attain complete hydration.

The default strain rate of 1 mm/min is currently the predominant strain rate in use for both mid-plane and interface shear strength testing. Additional guidance on determining the appropriate strain rate to prevent the build-up of pore pressure is provided in ASTM D 6243.

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Mid-plane and interface shear strength testing shall be performed in accordance with **ASTM D 6243**. The hydration fluid to be used for both mid-plane and interface shear strength testing shall be [tap water] [\_\_\_\_\_]. The final moisture content of the GCL at the center of each specimen shall be included with the test results. GCL and adjacent geosynthetics shall be oriented such that the shear force is parallel to the down slope orientation of the geosynthetics in the field. Modifications to the test procedures described in this section shall be submitted and approved prior to use.

#### 2.2.2.1 Mid-Plane Shear Strength Testing

[One set] [[\_\_\_\_\_] sets] of mid-plane direct shear tests shall be performed. Specimens shall be allowed to hydrate prior to shearing for a minimum of [\_\_\_\_\_] hours. Free drainage shall be provided along both sides of the GCL to aid in hydration. Specimens shall be allowed to consolidate prior to shearing for a minimum of [\_\_\_\_\_] hours. A normal stress of [\_\_\_\_\_] **kPa psf** shall be used during hydration, consolidation, and shearing. The normal stresses shall not be relieved prior to or during shearing of the specimens. The shear rate shall be [\_\_\_\_\_]. Tests shall be run until peak strength is determined.

#### 2.2.2.2 Interface Shear Strength Testing

[One set] [[\_\_\_\_\_] sets] of interface direct shear tests shall be performed on both interfaces of the GCL. Specimens shall be allowed to hydrate prior to shearing for a minimum of [\_\_\_\_\_] hours. Free drainage shall be provided along the outside of the GCL to aid in hydration. The other side of the GCL shall be placed against the interface material on which the test will be run. This interface material shall remain in place during hydration, consolidation, and shearing. Specimens shall be allowed to consolidate prior to shearing for a minimum of [\_\_\_\_\_] hours. Normal stresses of [\_\_\_\_\_] , [\_\_\_\_\_] , and [\_\_\_\_\_] **kPa psf** shall be used during hydration, consolidation, and shearing. The normal stresses shall not be relieved prior to or during shearing of the specimens. The shear rate shall be [\_\_\_\_\_]. Tests shall be run until a minimum total displacement of **[50] [\_\_\_\_\_] mm [2] [\_\_\_\_\_] inches** is reached.

### PART 3 EXECUTION

#### 3.1 SAMPLES AND TESTS

\*\*\*\*\*  
**NOTE: The need for and amount of QC testing performed by the QC laboratory should be determined on a site specific basis. Permeability and tensile strength tests are often performed at a reduced frequency in comparison to the mass per unit area test referenced in this paragraph.**  
\*\*\*\*\*

##### 3.1.1 Samples

QC samples shall be collected by the Contractor at approved locations upon delivery to the site [at the request of the Contracting Officer] [at a frequency of one test sample per **[9,000] [\_\_\_\_\_] square meters [100,000] [\_\_\_\_\_] square feet**]. Samples shall be collected, packaged, and transported in accordance with **ASTM D 6072**. Samples shall be identified with a waterproof marker by manufacturer's name, product identification,

lot and roll number. The date, a unique sample number, the machine direction, and the top surface of the GCL shall also be noted on the sample. The outer layer of the GCL roll shall be discarded prior to sampling a roll. Samples shall then be collected by cutting the full-width of the GCL sheet a minimum of 1 meter 3 feet wide in the machine direction.

An additional [610 by 610] [\_\_\_\_\_] mm [24 by 24] [\_\_\_\_\_] inch QA sample shall be collected, labeled, and submitted to the Contracting Officer each time QC samples are collected.

### 3.1.2 Conformance Tests

The Contractor shall provide QC samples to the QC laboratory to determine bentonite mass per unit area (ASTM D 5993) peel strength (ASTM D 6496), flux (ASTM D 5887) and tensile strength (ASTM D 6768) [at the request of the Contracting Officer] [at a frequency of once per [\_\_\_\_\_] square meters square feet of GCL placed]. Tests not meeting the requirements specified in Table 1 shall result in the rejection of applicable rolls. Determination of applicable rolls shall be as described in paragraph Tests, Inspections and Verifications.

## 3.2 INSTALLATION

### 3.2.1 Subgrade Preparation

\*\*\*\*\*  
NOTE: Subgrade and anchor trench soils are typically compacted to a minimum of 90 percent of ASTM D 698 maximum density. The final subgrade surface should be rolled with a smooth drum roller. This paragraph will have to be removed or modified if the GCL subgrade will be another geosynthetic layer.  
\*\*\*\*\*

The subgrade shall be compacted in accordance with Section [\_\_\_\_\_] . The subgrade surface shall be smooth and free of vegetation, standing water, and angular stones or other foreign matter that could damage the GCL. At a minimum, the subgrade surface shall be rolled with a smooth-drum compactor of sufficient weight to remove any wheel ruts, footprints, or other abrupt grade changes. All protrusions extending more than [13] [\_\_\_\_\_] mm [0.5] [\_\_\_\_\_] inches from the subgrade surface (or less if recommended by the manufacturer) shall either be removed, crushed, or pushed into the surface with the smooth-drum compactor. Each day during placement, the Contracting Officer (or his authorized representative) and installer shall inspect the surface on which GCL is to be placed and certify in writing that the surface is acceptable.

### 3.2.2 Placement

GCL shall be installed as soon as practical after completion and approval of the subgrade. Rolls shall be delivered to the work area in their original packaging. Immediately prior to deployment, the packaging shall be carefully removed without damaging the GCL. GCL which has been hydrated prior to being covered by an overlying geomembrane or a minimum of 305 mm 12 inches of cover soil shall be removed and replaced. Hydrated GCL is defined as having become soft as determined by squeezing the material with finger pressure or material which has exhibited swelling. If the subgrade is soil, construction equipment may be used to deploy GCL. If the subgrade is a geosynthetic, GCL shall be deployed by hand or by use of approved

light weight equipment with pneumatic tires which will not damage the underlying geosynthetic. On side slopes, GCL shall be anchored at the top and deployed down the slope to minimize wrinkles. Dragging of GCL panels over the ground surface shall be minimized. The Contracting Officer has the option of requiring the use of a slip sheet. Deployed GCL panels shall lie flat on the subgrade surface, with no wrinkles or folds.

### 3.2.3 Anchor Trench

Where anchor trenches are required, they shall be placed a minimum of [610] [ ] mm [24] [ ] inches back from the edge of slopes to be covered. Anchor trenches shall be a minimum of [610] [ ] mm [24] [ ] inches deep and [457] [ ] mm [18] [ ] inches wide. The front edge of the trench shall be rounded so as to eliminate sharp corners that could damage the GCL. The GCL shall extend down the front wall and across the bottom of the anchor trench. Soils used for backfill shall have a maximum particle size of 25 mm 1.0 inch and shall be placed in two lifts. Compaction and testing requirements are described in Section [ ].

### 3.2.4 Seams

\*\*\*\*\*  
**NOTE: Geomembrane-backed GCLs may also be welded together. Refer to Section 02 56 13 WASTE CONTAINMENT GEOMEMBRANE for geomembrane seaming requirements.**  
\*\*\*\*\*

On side slopes, GCL shall be placed with seams oriented parallel to the line of maximum slope and shall be free of tension or stress upon completion of installation. Panels shall be positioned with the overlap recommended by the manufacturer, but not less than 150 mm 6 inches for panel sides or 450 mm 18 inches for panel ends. Soil or other foreign matter shall be removed from the overlap area immediately prior to seaming.

If recommended by the manufacturer, granular bentonite of the same type as the bentonite used for the GCL shall be placed along the entire overlap width at a minimum rate of 0.37 kg/linear meter 0.25 lbs/linear foot or as recommended by the manufacturer. Construction adhesive or other approved seaming methods recommended by the manufacturer shall be used for horizontal seams on slopes. Overlaps which occur on slopes shall be constructed with the up slope GCL shingled over the down slope GCL. Alternate seaming methods may be approved if recommended by the manufacturer.

### 3.2.5 Protection

Only those GCL panels which can be anchored and covered in the same day shall be unpackaged and installed. If exposed GCL cannot be permanently covered before the end of a working day, it shall be temporarily covered with plastic or other waterproof material to prevent hydration.

### 3.3 REPAIRS

Holes or tears in GCL shall be repaired by placing a patch of GCL extending a minimum of 305 mm 12 inches beyond the edges of the hole or tear on all sides. If recommended by the manufacturer, granular bentonite or bentonite mastic shall be applied in the overlap area. Patches shall be secured with a construction adhesive or other approved methods as recommended by the manufacturer.

### 3.4 PENETRATIONS

Penetration details shall be as recommended by the GCL manufacturer. As a minimum, pipe penetrations shall incorporate a collar of GCL wrapped around the pipe and securely fastened. Dry bentonite or bentonite paste shall be placed around the penetration as recommended by the GCL manufacturer.

### 3.5 COVERING

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NOTE: This paragraph should be modified or removed if the GCL will be covered by another geosynthetic layer.

Generally, cover soil should have a maximum particle size of 25 mm (1 inch) or less. The required maximum particle size should be based on manufacturer's recommendations.

In cases where a non-aqueous liquid (i.e. jet fuel, gasoline, etc.) is being contained by the GCL, it may be necessary to hydrate the GCL with water prior to use. Hydration may be accomplished by introducing water into the containment area either by flooding or by the use of sprinklers. The GCL supplier should be contacted for specific procedures if manual hydration is necessary.

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GCL shall not be covered prior to inspection and approval by the Contracting Officer. Cover soil shall be free of angular stones or other foreign matter which could damage the GCL. The maximum particle size of the cover soil shall be [25] [ ] mm [1] [ ] inch. Cover soil shall not be dropped directly onto the GCL from a height greater than 1 meter 3 feet. The soil shall be pushed out over the GCL in an upward tumbling motion. The direction of backfilling shall proceed in the direction of down gradient shingling of GCL overlaps; except that on side slopes, soil backfill shall be placed from the bottom of the slope upward. Cover soil shall be placed such that soil does not enter the GCL overlap zone and tensile stress are not mobilized in the GCL. No equipment shall be operated on the top surface of the GCL without permission from the Contracting Officer. The initial loose soil lift thickness shall be [305] [ ] mm [12] [ ] inches. Equipment with ground pressures less than 50 kPa 7.0 psi shall be used to place the first lift over the GCL. A minimum of [305] [610] [915] [ ] mm [12] [24] [36] [ ] inches of soil shall be maintained between construction equipment with ground pressures greater than 50 kPa 7 psi and the GCL during the covering process. Equipment placing cover soil shall not stop abruptly, make sharp turns, spin their wheels, or travel at speeds exceeding [2.2] [ ] m/s [5] [ ] mph. Cover soil compaction and testing requirements are described in Section [ ].

-- End of Section --