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**USACE / NAVFAC / AFCEC** **UFGS-02 56 13.19 (February 2025)**

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**Preparing Activity: USACE** **Superseding**
**UFGS-02 56 13.19 (February 2021)**

**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

**References are in agreement with UMRL dated January 2026**
**********

SECTION TABLE OF CONTENTS

DIVISION 02 - EXISTING CONDITIONS

SECTION 02 56 13.19

GEOSYNTHETIC CLAY LINER WASTE CONTAINMENT

**02/25**

-- End of Section Table of Contents --

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SECTION 02 56 13.19

GEOSYNTHETIC CLAY LINER WASTE CONTAINMENT
**02/25**

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

**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

**********

**NOTE: These paragraphs should be edited based on whether the contract will use a single job price or unit prices. If there is a separate Measurement and Payment section, edited versions of these paragraphs should be inserted in that section.**

**********

#### 1.1.1 Measurement

Complete a survey to measure the total surface area covered by geosynthetic clay liner (GCL) in square meters square yards. 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.

1.1.2 Payment

GCL installed and accepted by the Contracting Officer will be paid for at the respective Contract unit price in the bidding schedule. This unit price will include the costs of materials, equipment, installation, testing, and other costs associated with placement of the GCL.

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.

ASTM INTERNATIONAL (ASTM)

| | |
|---|---|
| ASTM D698 | (2012; R 2021) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.)) |
| ASTM D1557 | (2012; E 2015) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3) (2700 kN-m/m3) |
| ASTM D5887/D5887M | (2020) Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter |
| ASTM D5888 | (2006; R 2016) Standard Guide for Storage and Handling of Geosynthetic Clay Liners |
| ASTM D5890 | (2011) Swell Index of Clay Mineral Component of Geosynthetic Clay Liners |

| | |
|---|---|
| ASTM D5993 | (2014) Measuring Mass Per Unit of Geosynthetic Clay Liners |
| ASTM D6072/D6072M | (2019) Standard Practice for Obtaining Samples of Geosynthetic Clay Liners |
| ASTM D6243/D6243M | (2020) Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method |
| ASTM D6496/D6496M | (2020) Standard Test Method for Determining Average Bonding Peel Strength Between Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners |
| ASTM D6768/D6768M | (2020) Standard Test Method for Tensile Strength of Geosynthetic Clay Liners |

GEOSYNTHETIC INSTITUTE (GSI)

| | |
|---|---|
| GSI GRI GCL3 | (2005; R2019) Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs) |

## 1.3 DEFINITIONS

**********
**NOTE: NOTE: These definitions are adapted from Waste Containment Facilities, Guidance for Construction Quality Assurance and Construction Quality Control of Liner and Cover Systems, Daniel and Koerner, 2nd Edition.**
**********

a. Construction Quality Assurance (CQA): CQA includes inspections, audits, and evaluations of materials and workmanship to determine and document the quality of the constructed facility. CQA is performed by a party independent from the Contractor.

b. Construction Quality Control (CQC): A planned system of inspections that is used to directly monitor and control the quality of the geomembrane installation project. CQC is normally performed by the GCL installation [contractor][subcontractor], and is necessary to achieve quality in the geomembrane system. CQC refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project.

c. Manufacturing Quality Control (MQC): A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of the geomembrane material and is necessary to ensure minimum (or maximum) specified values in the geomembrane. MQC refers to the measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and Contract specifications.

1.4 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.**

**********

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. 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-02 Shop Drawings

Layout and Detail Drawings; G, [_____]

As-Built Drawings; G, [_____]

SD-03 Product Data

Manufacturer's Quality Control Manual

Installer's Quality Control Manual

GCL

Accessory Bentonite

Adhesive

Installer's Warranty

Manufacturer's Warranty

SD-04 Samples

CQA Product Acceptance Sample

Interface Shear Testing Soil Sample

SD-06 Test Reports

Product Acceptance Tests

Visual Inspection and Evaluation

Manufacturer's Certified Raw And Roll Material Data Sheets

Mid-Plane And Interface Shear Strength Test Results

SD-07 Certificates

Certificates of Subgrade Acceptance

Qualifications; G, [_____]

SD-08 Manufacturer's Instructions

GCL Manufacturer's Installation Instructions

## 1.5 QUALITY CONTROL

### 1.5.1 Manufacturer's Quality Control Manual

Submit the manufacturer's quality control manual which describes testing procedures, frequency of testing and acceptance/rejection criteria for MQC testing at least [14][_____] days prior to delivery of the GCL.

### 1.5.2 Installer's Quality Control Manual

Submit the installer's quality control manual a minimum of [7][_____] calendar days prior to GCL placement.

### 1.5.3 Qualifications

Submit manufacturer qualification statements a minimum of [7][_____] calendar days prior to GCL shipment. Also submit installer, CQC inspector, [MQC][CQC] laboratory, and Licensed Surveyor qualification statements including resumes of key personnel involved in the project a minimum of [7][_____] calendar days prior to GCL placement.

#### 1.5.3.1 Manufacturer

Provide GCL that is the product of a GCL Manufacturer who has produced the proposed GCL using the same bentonite,[ geotextiles,][ polyethylene geomembrane,][ polymer,][ sewing thread,][ and ][adhesive] for at least [5][_____] completed projects and has produced a minimum of

[186,000][_____] square meters [2][_____] million square feet of the proposed GCL.

1.5.3.2 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 submittal requirements above edited accordingly.**

**********

The installer is responsible for field handling, deploying, seaming, and anchoring the GCL. The installer will have installed GCL at a minimum of [5][_____] projects of comparable scope and complexity and will have installed a minimum of [186,000][_____] square meters[2][_____] million square feet of the proposed GCL.

1.5.3.3 CQC Inspector

**********

**NOTE: A separate third party CQA contract should be considered based on the qualifications of the Government CQA personnel, the size and importance of the project, and impacts of a GCL failure. CQC inspectors are still considered necessary even if the Government provides independent third-party CQA inspection.**

**********

The CQC inspector is the person or corporation hired by the Contractor, who is responsible for monitoring and documenting activities related to the CQC of the GCL from manufacturing through installation. The CQC inspector will have provided CQC [and][or] CQA inspection during installation of GCL material for at least [5][_____] projects and performed CQC [and][or] CQA inspection on a minimum of [186,000][_____] square meters [2][_____] million square feet of GCL.

1.5.3.4 [MQC][CQC] Laboratory

The [MQC][CQC] laboratory will have provided [MQC][CQC] [and][or] CQA testing of GCL for at least [5][_____] completed projects and performed [MQC][CQC] [and][or] CQA testing for a minimum of [186,000][_____] square meters [2][_____] million square feet of GCL. The [MQC][CQC] laboratory must be accredited via the [Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP)][_____] for the tests the [MQC][CQC] laboratory are required to perform.

1.5.3.5 Licensed Surveyor

Perform all survey work under the supervision of a Surveyor licensed in the [applicable jurisdiction][State of [_____]].[ Perform surveys in accordance with Section [_____].]

1.5.4 Construction Quality Assurance

**********

**NOTE: Although independent CQA by the Government is**

**strongly recommended, this paragraph should be deleted if CQA will not be performed and only CQC will be performed. If CQA is not performed, references to CQA throughout the specification should be deleted. Note that the specification section uses the term Contracting Officer as a blanket term that would include CQA personnel acting under the Contracting Officer. Activities specified for the CQA personnel acting under the Contracting Officer would also need to be removed.**

**Depending on the project, the Government may also elect to implement Manufacturing Quality Assurance (MQA) activities, which include manufacturing facility inspections, verifications, audits, and evaluation of the raw materials and finished products (Daniel and Koerner, 2007). MQA is done in addition to MQC. The Contractor does not have an active role in MQA, but must be aware if MQA will occur on a project.**

**********

All work will be constructed, monitored, and tested in accordance with the requirements of a CQA [and MQA] Plan. Be aware of all activities outlined in the CQA [and MQA] Plan and account for these activities in the construction schedule. If CQA inspections or testing indicate work which does not meet the requirements of the specifications, the Contracting Officer will establish the extent of the nonconforming area. Repair the nonconforming area in accordance with paragraph DEFECTS AND REPAIRS.[ If MQA inspections indicate products do not meet the requirements of this specification, applicable portions of the product will be rejected.]

1.6 DELIVERY, STORAGE, AND HANDLING

**********

**NOTE: ASTM D5888 provides guidance on delivery, storage, and handling of GCL materials. The designer should be familiar with the requirements of that ASTM standard; in some cases the ASTM standard provides options or suggestions as opposed to strict requirements. The designer can edit this paragraph to include stricter or more specific requirements than allowed in ASTM D5888.**

**********

Perform delivery, storage, and handling of GCL in accordance with ASTM D5888 and this Section. Deliver only approved GCL materials to the project site.[ Deliver the GCL materials to the project site at least [14][_____] calendar days prior to installation to allow sufficient time for testing in accordance with paragraph PRODUCT ACCEPTANCE.] Deliver and unload the geomembrane with the CQC inspector [and Contracting Officer] present. Confirm the presence of a label on each GCL [roll][panel] with the manufacturer's name, product identification number, [roll][panel] number, and roll dimensions. Reject GCL rolls which are not labeled upon delivery to the project site.

1.7 PROJECT/SITE CONDITIONS

**********

**NOTE: The primary concern associated with weather conditions and GCL placement is exposure of the GCL to moisture that can result in premature hydration. GCL should be covered relatively quickly after it is placed, but a competing interest is the need to allow adequate time for CQC and CQA inspections of the GCL before covering it with the subsequent layer of the waste containment system. Temporary covering (aka tarping) can be considered, but temporary covers may not be effective on relatively flat areas where rain/snow can penetrate seams in temporary covers. The designer should consider the site specific design, speed at which CQC/CQA can be completed, and temporary/permanent covering methods when specifying buffer time between GCL placement and forecasted precipitation.**

**********

Consider present and forecasted weather conditions prior to GCL placement. Do not place GCL during periods of rain or snow or if rain or snow is forecasted within [4][_____] hours after placement will end.

1.8 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.**

**********

Provide manufacturer's warranty stating that the GCL materials meet all requirements of the Contract and that for the intended use, the GCL is warranted for [_____] years against deterioration. Provide installer's warranty stating that the GCL will not fail due to improper installation within [_____] years.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

2.1.1 Design Requirements

2.1.1.1 Layout and Detail Drawings

**********

**NOTE: The proposed GCL panel layout should be reviewed by the project engineer for compliance with the design conditions and best practices in laying-out panels. On slopes, panels should be installed with the long dimension of the panel parallel to the maximum slope. If end-of-panel seams (i.e. seams are perpendicular to the direction**

**of maximum slope) are proposed, the designer must confirm that the GCL is not expected to be in tension.**

**Minimize the number of penetrations and show their locations on the drawings. Referencing the manufacturer's typical penetration details is generally acceptable. When reviewing submitted penetration details, Designer's and others involved in a project such as CQA personnel may wish to consult the penetration examples in ASTM D6102 Standard Guide for Installation of Geosynthetic Clay Liners.**

**********

Submit GCL panel layout and detail drawings, for approval, a minimum of [seven][_____] calendar days prior to placement. Provide GCL penetration details [as indicated][as recommended by the GCL manufacturer]. At a minimum, pipe penetrations must incorporate a collar of GCL wrapped around the pipe and securely fastened.

## 2.2 MATERIALS

### 2.2.1 GCL

**********

**NOTE: GRI-GCL3 is used as the basis for specifying the properties of the GCL components (bentonite, geosynthetic bonding components) and the finished GCL. GRI-GCL3 provides material properties, minimum/maximum acceptable values, testing methods, and testing frequencies. Depending on the specific application of the GCL, the designer may wish to modify the specific requirements of GRI-GCL3. Any modifications to the material property requirements in GRI-GCL3 should be specified in this paragraph. ASTM D5889 is an alternative to GRI-GCL3. The primary difference is that GRI-GCL3 provides minimum/maximum property values for the GCL; ASTM D5889 only provides the testing methods and frequencies. Apart from this difference the two standards are overall very similar. If the Designer wishes to use the ASTM standard instead, replace the references to GRI-GCL3 in this paragraph and in paragraph MANUFACTURING SAMPLING AND TESTING. Provide minimum/maximum tested properties for the GCL.**

**Test method ASTM D5887 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 D6141 - Standard Guide for Screening Clay Portion and Index Flux of Geosynthetic Clay Liner**

**(GCL) for Chemical Compatibility to Liquids, and**

**ASTM D6766 REV A - Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Aqueous Solutions.**

**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.**

**Certain aggressive leachates may interfere with the performance of traditional sodium bentonite GCLs. GCLs made with polymer-modified bentonite or other bentonite additives may provide improved performance. If the designer determines that a polymer (or other additive) modified bentonite is needed, this paragraph and the paragraph MANUFACTURER QUALIFICATIONS should be modified to reflect that requirement.**

**GCL constructed with nonwoven geotextiles on both sides should be considered for situations where increased frictional resistance is required. Required values for internal friction and interface friction must be based on site-specific conditions including, but not limited to, normal stresses, saturation conditions, liquid type, consolidate time, shearing rate, shearing distance, etc.**

**********

Provide a GCL that is a manufactured product consisting of a [sodium montmorillonite clay (bentonite) layer][_____]. Provide a GCL that meets the requirements in Table 1 and is free of tears, holes, or other defects that may affect its serviceability. Provide a GCL with overlap lines printed onto the GCL [in accordance with GSI GRI GCL3][_____]. Mechanically bond encapsulating geotextiles together using a needle punch or stitch bonding process. If needle punching or stitch bonding is used for construction of the GCL, provide a GCL that has been continuously inspected for broken needles using an in-line metal detector, and all broken needles have been removed.

| TABLE 1 - GCL PROPERTIES | |
|---|---|
| Tested Properties | As defined in [GSI GRI GCL3][_____] |
| GCL Category | [Reinforced][Nonreinforced] |
| GCL Joining | [geotextile][polymer-coated geotextile][smooth geomembrane/geofilm][textured geomembrane/geofilm] |
| Minimum Peak Internal Friction Angle | [_____] degrees |
| Minimum [Peak][Residual] Interface Friction Angle | [_____] degrees |

| TABLE 1 - GCL PROPERTIES | |
|---|---|
| Minimum Manufactured Sheet Width | [4.1][_____] meters [13.5][_____] feet |
| Minimum Manufactured Sheet Length | [30][_____] meters [98][_____] feet |
| Note 1: GCL which is [capped][carried] by geotextile is identified as "Geotextile Related" in GSI GRI GCL3; GCL which is [capped][carried] by polymer coated geotextile is identified as "Geotextile Polymer Coated" in GSI GRI GCL3; GCL which is attached to a geomembrane or geofilm is identified as "Geomembrane/Geofilm Related" in GSI GRI GCL3. | |

2.2.2 Accessory Bentonite

Provide accessory bentonite used for sealing seams, penetrations, or repairs that is produced by the same manufacturer as the GCL and confirmed by the manufacturer to be compatible for use in sealing seams. Submit manufacturer documentation demonstrating compatibility.

[2.2.3 Interface Shear Testing Soil Sample

**********

**NOTE: This paragraph can be deleted if the GCL interface is not against a soil layer, but rather another geosynthetic. An optional requirement is included for the contractor to test the soil that will be used in the interface shear testing, to demonstrate that the soil meets project requirements. This demonstration testing would not be necessary if the borrow source has already been adequately investigated, or if the soil used for interface testing is collected at the same time that other borrow source sampling is conducted.**

**To reduce the overall risk to the Government, it is strongly advised that the Contractor is required to collect samples for interface shear testing unless the nature of the site prevents the Contractor to do so. Depending on site conditions and project needs (e.g. site security, access issues, etc.), the Government may provide samples to the Contractor to conduct interface shear testing.**

**********

[The Contracting Officer will provide][Obtain] soil to be used for interface shear testing from [the proposed borrow source][_____].[ Conduct one set of tests and submit testing results demonstrating that the soils to be used for interface shear testing meet the material requirements in accordance with [_____].]

]2.2.4 Adhesive

Provide adhesives used for securing repair patches that is approved for use by the GCL manufacturer. Submit manufacturer documentation demonstrating compatibility.

## 2.3 ACCESSORIES

### 2.3.1 Temporary Ballast

Provide temporary ballast used during GCL installation including sandbags, tires, or other material as recommended by the GCL manufacturer. Use non-abrasive material, free of sharp edges or other features that may damage the GCL.

## 2.4 TESTS, INSPECTIONS, AND VERIFICATIONS

### 2.4.1 Manufacturing Sampling and Testing

**********

**NOTE: The testing required in this paragraph and subparagraphs occurs at the manufacturing facility. Additional testing is required once materials are delivered to the site, as defined in paragraph PRODUCT ACCEPTANCE. GRI-GCL3 provides testing frequencies, test methods, and minimum/maximum required properties. If paragraph GCL provides any required properties for the GCL that differ from GRI-GCL3, this paragraph must indicate the testing methods and frequencies associated with those properties.**

**********

Sample and test GCL and its components in accordance with the Manufacturer's Quality Control Manual and GSI GRI GCL3; sample and test according to the stricter requirement if there are deviations. Test results not meeting the requirements specified in paragraph GCL will result in the rejection of applicable rolls. Describe procedures used to determine rejection of applicable rolls in the Manufacturer's Quality Control Manual. As a minimum, test rolls produced immediately prior to and immediately after the failed roll tested for the same failed parameter. Continue testing until a minimum of three successive rolls on both sides of the original failing roll pass the failed parameter. Submit manufacturer's certified raw and roll material data sheets. The certified data sheets must be attested to by a person having legal authority to bind the GCL manufacturing company. If needle punching or stitch bonding is used in construction of GCL, indicate that the GCL has been continuously inspected for broken needles using an in-line metal detector and all broken needles have been removed in the certification.

### 2.4.2 Shear Strength Testing

**********

**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. For additional discussion on the significance of GCL shear strength and design, see GRI-GCL5 Design Considerations for Geosynthetic Clay Liners (GCLs)**

**in Various Applications.**

**Tables 2 and 3 are from ASTM D6243/6243M; the Designer should verify that the tables are current if ASTM D6243/6243M is updated.**

**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.**

**ASTM D6243/6243M indicates that strain/shear rates of 1 mm/min 0.04 in/min for interface shear and 0.1 mm/min 0.004 in/min for internal shear provide appropriate shear strengths for design when hydrated under normal stress of at least 7 kPa 1 psi and consolidated under normal stress of 70 kPa 10 psi. However, other conditions can require different hydrating/consolidation/strain parameters. Additional guidance on determining the appropriate strain rate to prevent the build-up of pore pressure is provided in ASTM D6243/D6243M.**

**********

Perform mid-plane and interface shear strength testing in accordance with ASTM D6243/D6243M. Submit mid-plane and interface shear strength test results at least [14][_____] calendar days prior to GCL shipment. Include the final moisture content of the GCL at the center of each specimen with the test results. Submit modifications to the test procedures described in this Section for approval prior to use.

2.4.2.1 Internal Shear Strength Testing

Perform [one set][[_____] sets] of internal shear tests. Conduct tests using the conditions specified in Table 2.

TABLE 2 - Internal Shear Strength Testing

| | |
|---|---|
| Material(s) for which shear will be tested | 1 - [_____]<br>2 - [_____] |
| Side or characteristics for the side of material to be tested at the interface | 1 - [_____]<br>2 - [_____] |

| TABLE 2 - Internal Shear Strength Testing | |
|---|---|
| Orientation of material | 1 - [Machine Direction][Cross Direction][N/A]<br>2 - [Machine Direction][Cross Direction][N/A] |
| Soil Interface Compaction Density and Moisture Content (MC) (Note 1) | [Lightly Compacted]<br><br>[Specified Density = [_____] kN/m3 [_____] lb/ft3]<br><br>[As-received MC][Specified MC = [_____] percent]<br><br>[Based on ASTM D698 test results: Maximum Dry Density = [_____] kN/m3 [_____] lb/ft3, Optimum MC = [_____] percent]<br><br>[Based on ASTM D1557 test results: Maximum Dry Density = [_____] kN/m3 [_____] lb/ft3, Optimum MC = [_____] percent]<br><br>If compaction unit weight and moisture content for soil placement based on ASTM D698 or ASTM D1557 test results, compaction [_____] percent of maximum dry unit weight and Moisture Content [optimum water content][plus [_____] percent relative to optimum][minus [_____] percent relative to optimum] |
| Conditioning of GCL | [Hydrated]<br>[Partially hydrated to [_____] percent Water Content]<br>[Wetted by pouring water over entire specimen]<br>[Wetted by spraying water over entire specimen]<br>[As-received] |
| If GCL hydrated under applied normal load other than test normal load prior to application of test normal load | Normal load = [_____] kPa [_____] psi<br>Minimum duration = [_____] hours |
| Conditioning of Other Geosynthetic Materials | [Wetted by pouring water over entire specimen]<br>[Wetted by spraying water over entire specimen]<br>[As-received] |
| Shear Test Normal Loads (Note 2) | [_____], [_____],[_____], [_____], [_____] kPa [_____], [_____],[_____], [_____], [_____] psi |
| List if there is a specified Normal Load Application Sequencey to be applied: | [_____] hours |
| Interface saturation condition | [Inundated with Water - Interface is submerged in water prior to consolidation and through duration of shear][Spray Wetted - The interface is wetted using a spray bottle during placement of specimens, but not submerged in water][Dry - No addition of water during placement of specimens or shear] |
| Settling/Consolidation time under test normal load prior to shearing | [_____] |

| TABLE 2 - Internal Shear Strength Testing | |
|---|---|
| Shear displacement rate | [0.1][_____] mm per minute [0.004][_____] inches per minute |
| Other test instructions | Provide free drainage along both sides of the GCL to aid in hydration. Do not relieve the normal stresses prior to or during shearing of the specimens. Run tests until peak strength is determined. Use [tap water][_____] for testing. [_____] |
| Note 1: Over-sized corrected test values from ASTM D698 and ASTM D1557 are typically not applied in calculating compaction density and moisture content as gradations minus 19.5 mm 0.75 in sieve of soil sample are used due to dimensions of most shear boxes. If requesting use of rock correction values to be applied, indicate so.<br>Note 2: The normal loads selected should bracket the design normal loads being evaluated. | |

2.4.2.2 Interface Shear Strength Testing

Perform [one set][[_____] sets] of interface direct shear tests on both interfaces of the GCL. Conduct tests using the conditions specified in Table 3. Place the other side of the GCL against the interface material on which the test will be run. Keep the interface material in place during hydration, consolidation, and shearing.

| TABLE 3 - Interface Shear Strength Testing Properties | |
|---|---|
| Material(s) for which shear will be tested | 1 - [_____]<br>2 - [_____] |
| Side or characteristics for the side of material to be tested at the interface | 1 - [_____]<br>2 - [_____] |
| Orientation of material | 1 - [Machine Direction][Cross Direction][N/A]<br>2 - [Machine Direction][Cross Direction][N/A] |

| TABLE 3 - Interface Shear Strength Testing Properties | |
|---|---|
| Soil Interface Compaction Density and Moisture Content (MC) (Note 1) | [Lightly Compacted]<br><br>[Specified Density = [_____] kN/m3 [_____] lb/ft3]<br><br>[As-received MC][Specified MC = [_____] percent]<br><br>[Based on ASTM D698 test results: Maximum Dry Density = [_____] kN/m3 [_____] lb/ft3, Optimum MC = [_____]percent]<br><br>[Based on ASTM D1557 test results: Maximum Dry Density = [_____] kN/m3 [_____] lb/ft3, Optimum MC = [_____]percent]<br><br>If compaction unit weight and moisture content for soil placement based on ASTM D698 or ASTM D1557 test results, compaction [_____] percent of maximum dry unit weight and Moisture Content [optimum water content][plus [_____] percent relative to optimum][minus [_____] percent relative to optimum] |
| Conditioning of GCL | [Hydrated]<br>[Partially hydrated to [_____] percent Water Content]<br>[Wetted by pouring water over entire specimen]<br>[Wetted by spraying water over entire specimen]<br>[As-received] |
| If GCL hydrated under applied normal load other than test normal load prior to application of test normal load | Normal load = [_____] kPa [_____] psi<br>Minimum duration = [_____] hours |
| Conditioning of Other Geosynthetic Materials | [Wetted by pouring water over entire specimen]<br>[Wetted by spraying water over entire specimen]<br>[As-received] |
| Shear Test Normal Loads (Note 2) | [_____], [_____],[_____], [_____], [_____] kPa [_____], [_____],[_____], [_____], [_____] psi |
| List if there is a specified Normal Load Application Sequence to be applied: | [_____] |
| Interface saturation condition | [Inundated with Water - Interface is submerged in water prior to consolidation and through duration of shear][Spray Wetted - The interface is wetted using a spray bottle during placement of specimens, but not submerged in water][Dry - No addition of water during placement of specimens or shear] |
| Settling/Consolidation time under test normal load prior to shearing | [_____] hours |
| Shear displacement rate | [1][_____] mm per minute [0.04][_____] inches per minute |

| TABLE 3 - Interface Shear Strength Testing Properties | |
|---|---|
| Other test instructions | Provide free drainage along both sides of the GCL to aid in hydration. Do not relieve the normal stresses prior to or during shearing of the specimens. Run tests until a minimum total displacement of [50][_____] mm [2][_____] inches is reached. Use [tap water][_____] for testing. [_____] |
| Note 1: Over-sized corrected test values from ASTM D698 and D1557 are typically not applied in calculating compaction density and moisture content as gradations minus 19.5 mm 0.75 in sieve of soil sample are used due to dimensions of most shear boxes. If requesting use of rock correction values to be applied, indicate so.<br>Note 2: The normal loads selected should bracket the design normal loads being evaluated. | |

### 2.4.3 Product Acceptance

**********

**NOTE: The testing required in this paragraph and subparagraphs occurs at the project site. Some technical documents refer to this type of testing as "conformance testing". The need for and amount of CQC testing performed by the CQC 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. Daniel and Koerner (2007) presents an alternative approach to specifying testing frequencies on the basis of amount of GCL received.**

**********

#### 2.4.3.1 Product Acceptance Samples

Collect CQC Product Acceptance samples at approved locations upon delivery to the site. Collect, package, and transport samples in accordance with ASTM D6072/D6072M and this paragraph. Identify samples with a waterproof marker; include the date and other information as specified in ASTM D6072/D6072M. Collect samples by cutting the full-width of the GCL sheet a minimum of 1 meter 3 feet wide in the machine direction. Collect and label an additional [610 by 610][_____] mm [24 by 24][_____] inch CQA Product Acceptance Sample and submit to the Contracting Officer each time CQC Product Acceptance samples are collected.[ Collect all CQC and CQA Product Acceptance samples with the [Contracting Officer][_____] present].

#### 2.4.3.2 Product Acceptance Tests

Provide CQC Product Acceptance samples to the CQC laboratory for testing as required in Table 4. Based on testing results, reject rolls and complete supplemental testing as described in paragraph MANUFACTURING SAMPLING AND TESTING.

| TABLE 4 - PRODUCT ACCEPTANCE TESTS | | |
|---|---|---|
| Property | Test Method | Test Frequency |
| Bentonite Mass per Unit Area | ASTM D5993 | [once per [10,000][_____] square meters [100,000][_____] square feet] [_____] |
| Swell Index | ASTM D5890 | [once per [10,000][_____] square meters [100,000][_____] square feet] [_____] |
| Flux | ASTM D5887/D5887M | [once per [10,000][_____] square meters [100,000][_____] square feet] [_____] |
| Internal Shear Strength | ASTM D6243/D6243M | [once per [10,000][_____] square meters [100,000][_____] square feet] [_____] |
| Peel Strength (1) | ASTM D6496/D6496M | [once per [4,000][_____] square meters [45,000][_____] square feet ] [_____] |
| Tensile Strength, MD | ASTM D6768/D6768M | [once per [10,000][_____] square meters [100,000][_____] square feet] [_____] |
| [_____] | [_____] | [_____] |
| (1) Peel Strength testing is not applicable for a non-reinforced GCL. | | |

## PART 3 EXECUTION

**********

**NOTE: Designers may wish to consult ASTM D6102 Standard Guide for Installation of Geosynthetic Clay Liners when using this UFGS section. ASTM D6102 is not written in a way that it can wholly replace a project specification, but it does provide useful information and refences as well as example GCL penetration details and CQA checklists. The execution concepts discussed in the 2023 version of that ASTM are substantially addressed in this UFGS section.**

**********

### 3.1 CERTIFICATES OF SUBGRADE ACCEPTANCE

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**NOTE: An example Certificate of Subgrade Acceptance can be found in the USACE Engineering Manual EM 1110-1-4011 Construction Quality Assurance (CQA) Plan - Requirements for Hazardous Waste Landfills. The list of subgrade conditions in this paragraph is written assuming that the GCL is underlain by soil;**

**if a different subgrade is used such as a geosynthetic, the examination items specified below should be revised (e.g. requirements related to rutting, soil surfaces, etc. will not be necessary).**

**Guidance from GCL manufacturers indicates that in applications where a GCL is the sole barrier providing containment, subgrade surfaces consisting of granular soils or gravel may not be appropriate due to large void content. Minimum recommended properties of subgrade in this application are greater than 80% of soil finer than 0.25 mm #60 sieve and no particles larger than 25 mm 1 inch. This requirement should be included in a specification section for subgrade preparation, but could also be included in this specification section at the discretion of the Designer.**

**********

Each day during placement of GCL, the CQC Inspector [and Contracting Officer] and installer must inspect the surface on which GCL is to be placed and certify in writing on a Certificate of Subgrade Acceptance that the surface is acceptable. Examine the subgrade for compliance with the items in the list below. Perform repairs to the subgrade in accordance with paragraph PREPARATION, and at no additional cost to the Government.

a. A project-qualified land surveyor has verified the lines and grades of the subgrade meet project design.

b. All CQC and CQA of the underlying soils or geosynthetics has been completed and results have been accepted by the Contracting Officer.

c. The subgrade is free of irregularities, protrusions, loose soil, ice, standing water, and abrupt changes in grade.

d. The subgrade is not excessively deformed or rutted by construction equipment used to deploy GCL rolls. Ruts should not exceed [25][_____] mm [1][_____] inch in depth.

e. The underlying soil surface (if present) does not contain stones, litter, or organic matter which may be damaging to the GCL. Rocks larger than [13][_____] mm [0.5][_____] inch in diameter and any other material which could damage the GCL must be removed from the surface to be covered with the GCL.

f. If installed on soil, no area of the underlying soil surface is excessively softened by high water content.

g. If installed on soil, no area of the underlying soil surface contains desiccation cracks which may damage the GCL.

## 3.2 PREPARATION

### 3.2.1 Subgrade Repair

**********

**NOTE: Ensure other sections of the specification package adequately address compaction requirements for soil subgrade layers. If the geomembrane is**

**placed directly on top of a compacted clay layer, reference Section 02 56 13.16 CLAY WASTE CONTAINMENT for repairs/preparation. If the GCL is placed onto a geomembrane, reference Section 02 56 13.13 GEOMEMBRANE WASTE CONTAINMENT.**

**********

For any subgrade found deficient in accordance with paragraph EXAMINATION, perform repairs in accordance with [Section 31 00 00 EARTHWORK][Section 02 56 13.16 CLAY WASTE CONTAINMENT][Section 02 56 13.13 GEOMEMBRANE WASTE CONTAINMENT][_____].

3.2.2 Anchor Trench

**********

**NOTE: Anchor trench dimensions are often site-specific and are therefore defined in the project drawings. If that is the case, replace the dimensioning sentences with a reference to the project drawings/plans. Dimensions for a 90 degree anchor trench are included in the paragraph; if other standard anchor trench designs such as a "V" trench or horizontal runout are used instead, replace the dimensions as appropriate.**

**********

Where anchor trenches are required, place them a minimum of [610][_____] mm [24][_____] inches back from the edge of slopes to be covered. Make anchor trenches a minimum of [610][_____] mm [24][_____] inches deep and [457][_____] mm [18][_____] inches wide. If the anchor trench is excavated in cohesive soil susceptible to desiccation, excavate only the quantity of anchor trench required for placement of GCL in a single day. Remove ponded water from the anchor trench while the trench is open. Round the front edge of the trench so as to eliminate sharp corners that could damage the GCL. Remove loose soil, rocks larger than [13][_____] mm [0.5][_____] inch in diameter, and any other material which could damage the GCL from the surfaces of the trench. Extend the GCL down the front wall and across the bottom of the anchor trench. Use soils for backfill with a maximum particle size of 25 mm 1.0 inch. Compaction and testing requirements are described in [Section 31 00 00 EARTHWORK][_____].

3.3 GCL INSTALLATION

3.3.1 CGL Placement

**********

**NOTE: An optional requirement is provided for using a rub/slip sheet when placing the GCL. Rub sheets are thin sheets of plastic placed between the GCL and another surface. Rub sheets facilitate movement/placement of the GCL, particularly when the GCL is in contact with a textured geomembrane or other geosynthetic.**

**********

At least [seven][_____] calendar days prior to placement, submit GCL manufacturer's installation instructions detailing the following:

a. Penetration completion methods.

b. Acceptable temporary ballasting methods.

c. Seam overlap dimensions.

d. Accessory bentonite placement rates.

e. Method(s) of securing repair patches to underlying GCL.

Complete GCL placement in accordance with the GCL manufacturer's installation instructions and this paragraph. Install GCL as soon as practical after completion and approval of the subgrade. Deliver rolls to the work area in their original packaging. Immediately prior to deployment, carefully remove the packaging without damaging the GCL. If the subgrade is soil, construction equipment may be used to deploy GCL. If the subgrade is a geosynthetic, deploy GCL by hand or by use of approved light weight equipment with pneumatic tires which will not damage the underlying geosynthetic. Do not operate equipment on the top surface of the GCL. On side slopes, anchor GCL at the top and deploy down the slope to minimize wrinkles. Minimize dragging of GCL panels over the ground surface.[ Deploy a [rub][slip] sheet (e.g. 0.50 mm 20 -mil smooth HDPE) when placing the GCL and carefully remove the rub sheet to avoid shifting the geomembrane once the geomembrane is in place.] Lay deployed GCL panels flat on the subgrade surface, with no wrinkles or folds.

### 3.3.2 Seams

**********

**NOTE: The geomembrane portion of geomembrane-backed GCLs may be seamed/welded together. Refer to Section 02 56 13.13 GEOMEMBRANE WASTE CONTAINMENT for geomembrane seaming requirements. The Designer may wish to consult GSI GRI GCL6 Practice for Field Seaming of Overlapped Geosynthetic Clay Liners (GCLs).**

**********

Completely unroll and layout adjacent GCL [panels][sheets] before performing field seaming. On side slopes, place GCL with seams oriented parallel to the line of maximum slope and free of tension or stress upon completion of installation. Position panels with the overlap recommended by the manufacturer, but not less than 150 mm 6 inches for panel sides or 500 mm 20 inches for panel ends. Remove soil or other foreign matter from the overlap area immediately prior to seaming. If recommended by the manufacturer, place accessory bentonite 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. Use construction adhesive or other approved seaming methods recommended by the manufacturer for horizontal seams on slopes. Construct overlaps which occur on slopes with the up slope GCL shingled over the down slope GCL. Alternate seaming methods approved by the manufacturer may be proposed.

### 3.3.3 Penetrations

Install penetrations (e.g., pipe vents, boots, sleeves) as shown on the drawings and in accordance with any manufacturer's recommendations. Place dry bentonite or bentonite paste around the penetration as recommended by the GCL manufacturer.

### 3.3.4 Defects and Repairs

Repair holes, tears, or other defects in GCL by placing a patch of the same 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, apply accessory bentonite in the overlap area. Secure patches to the underlying GCL with a construction adhesive or other approved methods as recommended by the manufacturer. Remove and replace GCL which has been hydrated prior to being covered by an overlying geomembrane or a minimum of 305 mm 12 inches of cover soil.

## 3.4 FIELD QUALITY CONTROL

### 3.4.1 Visual Inspection and Evaluation

Immediately prior to covering or at the end of each day GCL is installed (whichever comes first), the CQC inspector[ and Contracting Officer] must[ will] visually inspect the GCL, seams, and non-seam areas for defects, holes, evidence of hydrated GCL, proper orientation of the GCL (top and bottom sides), seaming practices, or damage due to weather conditions or construction activities. Hydrated GCL is defined as having become soft as determined by squeezing the material with finger pressure or material which has exhibited swelling. At the Contracting Officer's or the CQC inspector's discretion, the surface of the GCL must be brushed or blown by the installer if the quantity of dust, mud, or foreign material inhibits inspection or functioning of the overlying material. Repair each location where defects are identified in accordance with paragraph DEFECTS AND REPAIRS. Submit a Visual Inspection and Evaluation report for each day that GCL is installed.

## 3.5 PROTECTION AND COVERING

### 3.5.1 Protection

Unpack and install only those GCL panels which can be anchored and covered in the same day. If exposed GCL cannot be permanently covered before the end of a working day, temporarily cover with plastic or other waterproof material to prevent hydration. Ballast the temporary cover and ensure that water cannot enter from the sides. Do not leave any tools or equipment on the GCL after active work ceases in the area.

### 3.5.2 Covering

**********

**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 mm1 inch or less. The required maximum particle size should be based on design and compatible with the manufacturer's recommendations. Final thickness of cover soil is typically at least 305 mm1 foot thick to provide confining stress, eliminate the potential for seam separation, and prevent damage from equipment, soil erosion, etc.**

**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.**

**********

Do not cover GCL prior to inspection and approval by the CQC Inspector [and Contracting Officer]. Use cover soil that is free of angular stones or other foreign matter which could damage the GCL. A maximum particle size of the cover soil greater than [25][_____] mm [1][_____] inch is unacceptable. Do not drop cover soil directly onto the GCL from a height greater than 1 meter 3 feet. Push the soil out over the GCL in an upward tumbling motion. The direction of backfilling must proceed in the direction of down gradient shingling of GCL overlaps; except that on side slopes, place soil backfill from the bottom of the slope upward. Place cover soil such that soil does not enter the GCL overlap zone and tensile stress are not mobilized in the GCL. Do not operate equipment on the top surface of the GCL. The initial loose soil lift thickness must be [305][_____] mm [12][_____] inches. Use equipment with ground pressures less than 50 kPa 7.0 psi to place the first lift over the GCL. Maintain a minimum of [305][610][915][_____] mm [12][24][36][_____] inches of soil between construction equipment with ground pressures greater than 50 kPa 7 psi and the GCL during the covering process. While placing cover soil do not operate equipment by stopping abruptly, making sharp turns, spinning their wheels, or traveling at speeds exceeding [2.2][_____] m/s [5][_____] mph. Cover soil compaction and testing requirements are described in [Section 31 00 00 EARTHWORK][_____].

## 3.6 AS-BUILT DRAWINGS

Submit final as-built drawings of the GCL installation. Include panel numbers with a unique identifier that can be linked to the roll number/factory panel number, location of repairs, and penetrations in these drawings.

-- End of Section --