Permit No.	Date	Document ID No.
20-02	August 6, 2015	24828

MSWLF FACILITY PERMIT TO CONSTRUCT PHASE 2

CHEROKEE COUNTY

MARBLE, NORTH CAROLINA

SECTION 4.0
CONSTRUCTION QUALITY ASSURANACE ONLY

Rev. December 2003
August 2003

Submitted by the Garner Office of:

Municipal Services **Engineering Company, P.A.**
P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393
P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767
LICENSE NUMBER: C-0281

SECTION 4.0

CONSTRUCTION QUALITY ASSURANCE PLAN

4.1 Introduction

The Division of Solid Waste Management requires that the Engineer certifies the constructed landfill is built according to approved plans and specifications. The Engineer that will accomplish this task is the one who did the planning and has written the specifications.

Before construction can begin a pre-construction meeting will be held and the responsibilities and duties of each party will be discussed.

The Contractor is responsible for following and meeting the requirements set forth in the contract documents. The Contractors will provide to the Owner of the landfill and the Engineer a completed landfill constructed by Division of Solid Waste approved plans and specifications. The Contractor will give the Engineer a schedule for completion of the landfill including dates for expected construction of the clay test pad, base liner system installation, installation of protective cover, installation of leachate collection system, and estimated time for project completion. The contractor is responsible for providing a foreman to remain on site at all times during construction, provide qualified personnel to conduct quality control, scheduling and coordinating the subcontractors, provide progress reports and as-built drawings, and coordinating construction activities with the Engineer. The foreman is responsible for supervising and coordinating with his crew, subcontractors, quality control personnel, attending all meetings and notifying the Engineer's Construction Observer when any discrepancies occur. The Contractor will meet with the Construction Observer on a daily basis to discuss the days construction activities. The results of all tests and any change in schedule shall be given to the Construction Observer as soon they are known by the contractor. The Contractor must be registered in the state of North Carolina.

Qualified liner installers, seamers, and the liner foreman shall meet a minimum requirement of 1,000,000 square feet of geomembrane installation. The Liner Foreman is responsible for coordinating the installation of the geomembrane liner. The Liner Forman will report to the Contractors Foreman, and Engineer's Construction Observer on a daily basis. The Liner Foreman is responsible for obtaining the geomembrane samples needed for field and laboratory testing as indicated in the plans and specifications.

The Engineer is responsible for providing the engineering design, drawings and specifications, contract documents and CQA needed for construction of the landfill. The Engineer is responsible for conduction of the pre-construction meeting, which will lay out the foundation for the project. The engineer will approve any design changes and certify to the Division of Solid Waste Management that the landfill was constructed according to the requirements of Rule .1621 Construction Quality Assurance Plan and .1624 Construction requirements for MSWLF Facilities, and Division approved plans and specifications. This will be accomplished by on site observation, independent laboratory soil testing to test site specific soil properties including permeability and independent material testing laboratories for destructive testing of the flexible membrane liner. The Engineer will be providing Quality Assurance by spot testing along side the contractor, who will be providing the Quality Control. The Engineer will certify that the construction was completed in accordance with the CQA manual. The Engineer must be a professional engineer registered in North Carolina

The Construction Observer (CO) is the Engineer's representative on-site. It is the CO's responsibility to know and interpret the plans and specifications of the project. On a daily basis the CO will coordinate with the Foreman to help ensure a quality product for the Owner. The CO will keep a daily log on the activities of the Contractor, keep notes on all meetings, and handle all quality assurance activities indicated in this document. The CO will keep a log of all material delivered on site and ensure the materials meets or exceeds the specifications indicated in this report. If the need arises additional meetings will be scheduled as seen fit by the CO.

4.2 Inspection Activities and Sampling Strategies

4.2.1. Base Liner System Subbase

The fill subgrade will be placed in 8" loose lifts and compacted to at least 95% of maximum dry density and near optimum moisture contents; as determined by Standard Proctor Compaction Test (ASTM D698) in 6" compacted lifts. No aggregate particles greater than 6" in any direction will be allowed in the subgrade or berm/embankment. Each compacted lift will be tested at one test per six inch (6") lift for each 200 lineal feet or fraction thereof of compacted berm(s) less than 50 feet in base width and one test per six (6) inch lift for each 10,000 square feet or fraction thereof of compacted mass fill. If an area fails, it shall be recompacted, reworked or replaced and retested.

Before beginning construction of the base liner system, the project engineer shall visually inspect the exposed surface to evaluate the suitability of the subgrade and document that the surface is properly prepared and that the elevations are consistent with the Division approved engineering plans. The elevations will be verified from survey data based on a 50 foot grid across the subbase.

At a minimum, the subgrade shall be proof-rolled at cut sections utilizing a fully loaded tandem dump truck or equivalent. If movement of the subbase is observed under the tires, the section of movement will be removed and replaced with suitable fill material. This newly placed fill material will then be tested for proper density and moisture.

4.2.2. Base Liner System Cohesive Soil Liner

All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications or shall be the product of the listed manufacturers or similar and equal thereto as approved by the Engineer.

Cohesive Soil Liner Borrow Material

Test Name	Test Method	Contractor/Engineer Frequency
Moisture/Density	ASTM D698/D1557	1 per 5000 c.y.
Remolded Permeability	ASTM D5084	1 per 5000 c.y.
Atterberg Limits	ASTM D4318	1 per 5000 c.y.
Visual Classification	ASTM D2488	1 per 5000 c.y.
Grain Size Distribution	ASTM D422	1 per 5000 c.y.

Cohesive Soil Liner Test Pad

Test Name	Test Method	Contractor/Engineer Frequency
Field Moisture/Density	ASTM D1556 (sand cone) ASTM D2922/D3017 (nuclear gauge) ASTM D2937 (drive cylinder)	3 per lift
Permeability	ASTM D5084	1 per lift
Remolded Permeability	ASTM D5084	1 per lift
Atterberg Limits	ASTM D4318	1 per lift
Visual Classification	ASTM D2488	1 per lift
Grain Size Distribution	ASTM D422	1 per lift

In-Place Cohesive Soil Liner

Test Name	Test Method	Contractor/Engineer Frequency
Field Moisture/Density	ASTM D1556 (sand cone) ASTM D2922/D3017 (nuclear gauge) ASTM D2937 (drive cylinder)	1 per lift per acre
Permeability	ASTM D5084	1 per lift per acre
Atterberg Limits	ASTM D4318	1 per lift per acre
Visual Classification	ASTM D2488	1 per lift per acre
Grain Size Distribution	ASTM D422	1 per lift per acre

(a) Suitable on-site and/or off-site soils may be used as cohesive soil liner if it can achieve an in-place permeability of 1.0×10^{-7} cm/sec or less for the base liner system or 1.0×10^{-5} cm/sec or less for the alternate base liner system and meets all testing requirements indicated in the material testing paragraph in this section. Wyoming bentonite or an approved equivalent may be blended with the soil to lower the soil's permeability.

(b) A permeability "window" shall be developed for each type of soil from the borrow material that will be used for construction of the cohesive soil liner. The window shall be plotted on a semi-log plot with moisture content versus density. Laboratory testing to develop the window shall include a series of remolded samples compacted to various dry densities and moisture contents utilizing the same compactive effort (ASTM D 698 or D 1557). The remolded samples shall be tested for permeability to determine whether or not the particular soil type will provide the maximum permeability (1.0×10^{-7} cm/sec or 1.0×10^{-5} cm/sec) at various dry densities and moisture contents. The window is then developed from the accepted remolded samples and moisture contents from the semi-log plot. A straight line is typically drawn between the acceptable points on the moisture-density curve to indicate a range of probable acceptable permeability results. The window will be used in the construction of the test strip to verify the laboratory remolded permeability results.

(c) Atterberg limits and grain size distribution shall also be conducted on the bulk samples used to prepare the permeability window ASTM D2488, D4318, D422. These tests can be used as indices on random samples collected from the borrow site during construction to verify the soil type is the same as was used to develop the "window". As a minimum, sufficient visual classifications and Atterberg limits shall be conducted in association with each permeability test to verify that the construction materials meet specifications.

(d) A test strip of compacted cohesive soil liner shall be prepared to verify the permeability "window" prior to general installation of the cohesive soil liner. The test strip will be used to verify the results from the remolded permeabilities from the borrow site utilizing the permeability window(s) for each soil type that is going to be used for construction of the cohesive soil liner. At a minimum, the verification will consist of three moisture density tests, one Atterberg limits test, one grain size distribution test (ASTM D698, ASTM D2488, D4318, and D422), and one Shelby Tube sample for each lift constructed in the test pad. Laboratory permeability tests shall be performed on tube (Shelby or drive tubes) samples of the cohesive soil liner after placement and compaction. The permeability must be a maximum of 1.0×10^{-7}cm/sec or 1.0×10^{-5} cm/sec for alternate liner systems. Tests shall be performed in accordance with the ASTM D5084. The test strip shall be approximately 2,500 sq. ft. in surface area and constructed to conform geometrically to the site topography with a minimum lateral dimension in any direction of 25 ft. The test strip shall consist of at least four compacted 6 inch lifts of cohesive soil liner(three compacted 6 inch lifts of cohesive soil liner for alternate base liner). Placement and testing of the test strip shall be in conformance with the construction specifications and requirements for general installation of the cohesive soil liner. Test results from the test strip shall be used to guide placement and

achievement of the required maximum permeabilities of the cohesive soil liners. The test strip may be used as an integral part of the overall cohesive soil liner if it meets the required specification for the liner. All results shall be given to the Construction Observer.

(e) The soils shall be placed to the total thickness shown on the plans in maximum 8-inch thick loose lifts with a maximum 6" compacted lift compacted preferably at a moisture content between 0 to 3% above optimum moisture content to 95% standard Proctor maximum dry density (ASTM Test Designation D698). A sheepsfoot roller or approved alternative may be used to compact the soil liner provided the compaction and permeability requirements can be achieved. Each lift shall be tested for permeability, moisture content, particle size distribution analysis, Atterberg limits, moisture-density-permeability relation, and if needed percent bentonite admixed with soil, prior to the placement of the succeeding lift and visually inspected to confirm that all soil clods have been broken and that the surface is sufficiently scarified so that adequate bonding can be achieved. Soils for cohesive soil liner shall be screened, disced, or prepared using any other approved method as necessary to obtain a homogeneous cohesive soil with clod sizes in a soil matrix no larger than about 1.5 inches in maximum diameter. After each lift, the surface shall be scarified prior to the placement of the next lift to provide good bonding from one lift to the next.

(f) The cohesive soil liner shall be tested to evaluate the coefficient of permeability. The coefficient of permeability of the soil liner shall be equal to or less than 1.0×10^{-7} cm/sec (1.0×10^{-5} cm/sec for alternate base liner) after placement and compaction. The soil liner must be a minimum of 2.0 feet thick (1.5 feet thick for alternate base liner).

(g) Laboratory permeability tests shall be performed on tube (Shelby or drive tubes) samples of the cohesive soil liner after placement and compaction. The permeability must be a maximum of 1.0×10^{-7} cm/sec (1.0×10^{-5} cm/sec for alternate base liner). Tests shall be performed in accordance with the ASTM D5084 with a hydraulic gradient of 20 and confining pressure of 10 psi.

(h) The soil liner shall be tested a minimum of one soil sample per lift per acre for laboratory permeability. All permeability testing will be on random samples judged by the Engineer to be representative of the most permeable soil conditions for the area being tested. The project engineer shall certify that the materials used in construction were tested according to the Division approved plans. If after placement of the soil liner it fails the required tests, the material will either be reworked or replaced. The soil liner must remain moist at all times, if any section becomes dry, rework the dry area and moisten.

(i) A minimum of two (2) inches of soil shall be removed prior to securing each sample for permeability testing. The sampling tube shall be advanced vertically into the soil with as little soil disturbance as possible and should be pushed using a uniform pressure. The sampling tube (Shelby tube), when extracted, shall be free of dents, and the ends shall not be distorted. A backhoe or approved alternative should be used to advance the sampling tube (Shelby tube) as long as disturbance is minimized. Drive tube samples of the liner may be obtained for permeability testings. If the Engineer judges the sample to be too disturbed, another sample shall be taken. Once an acceptable sample has been secured and properly prepared, all sample excavations shall be backfilled to grade with a 50% mixture of bentonite and similar soils in maximum 3-inch loose lifts and hand tamped with a blunt tool to achieve a tight seal equivalent to the original density.

(j) No additional construction shall proceed on the soil layers at the area being tested until the Engineer has reviewed the results of the tests and judged the desired permeability is being achieved.

(k) As a minimum, sufficient visual classifications (ASTM Test Designation D2488), gradation analyses (ASTM Test Designation D422) and Atterberg limits (ASTM Test Designation D4318)

shall be conducted in association with each permeability test to verify that the construction materials meet specifications. The minimum number of tests will be 1 per lift per acre.

(l) If the soil for the cohesive soil liner is incapable of achieving the required permeability when compacted, bentonite or approved alternative may be mixed with the soils to decrease the permeability. The amount of additive required must be determined in the laboratory. Where additives are required, the soil shall be placed in maximum 8-inch thick loose lifts and compacted preferably between 0 to +3% optimum moisture content to 95% standard Proctor maximum dry density (ASTM Test Designation D698) for the soil-additive mixture. All other compaction procedures for the soil apply.

(m) Surfaces to be lined shall be smooth and free of debris, roots, and angular or sharp rocks larger than three-eight (3/8) inches in diameter to a depth of six (6) inches. The cohesive soil liner shall have no sudden sharp or abrupt changes in grade.

(n) The Contractor shall protect the cohesive soil liner from desiccation, flooding and freezing. Protection, if required, may consists of a thin plastic protective cover, (or other material as approved by the engineer) installed over the completed cohesive soil liner until such time as the placement of flexible membrane liner begins. Areas found to have any desiccation cracks or which exhibit swelling, heaving or other similar conditions shall be replaced or reworked by the contractor to remove these defects.

(o) The thickness and grade of the soil liner will be verified by the surveyor before placement of the geomembrane liner. The soil liner will be surveyed at 50' grid points where the elevations of the subbase will be checked with the top of soil liner to verify 2.0 feet of soil liner (1.5 feet of soil liner for the alternate base liner). The grade will then be verified with the surveyed information. The survey will be performed by NC licensed surveyors.

(p) The anchor trench shall be excavated by the Contractor to lengths and widths shown on the design drawings prior to geomembrane placement. Anchor trenches excavated in cohesive soils susceptible to desiccation cracks should be excavated only the distance required for that days liner placement to minimize the potential of desiccation cracking of the cohesive soils. Corners in the anchor trench shall be slightly rounded where the geomembrane adjoins the trench to minimize sharp bends in the geomembrane.

(q) Surface Acceptance. Upon request, the Flexible Membrane Liner manufacturer installer shall provide the Engineer with a written acceptance of the surface prior to commencing installation. Subsequent repairs to the cohesive soil liner and the surface shall remain the responsibility of the contractor.

4.2.3 Alternate Base Liner System Specifications

(1.1) General

This specification covers the technical requirements for the furnishing and installation of the Geosynthetic Clay Liner (GCL) described herein. All materials used shall meet the requirements of this specification, and all work shall be performed in accordance with the procedures provided herein and the contract drawings.

The Contractor shall furnish all labor, materials, supervision and equipment to complete the installation of the GCL, including, but not limited to, liner layout, seaming, patching, and all necessary and incidental items required to complete the Work, in accordance with the Contract Drawings and these Specifications.

Sufficient liner material shall be furnished to cover all lined areas shown on the Drawings, including overlaps at field seams and anchor trenches.

It is the intent of these Specifications to ensure a quality finished product. It shall be the responsibility of the Contractor to ensure that this requirement is met.

(1.2) Definitions

For the purposes of this specification guideline, the following terms are defined below:

Geosynthetic Clay Liner (GCL) - A manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetics. The GCL may be reinforced or unreinforced as required by site conditions. This site will require reinforced GCL over the entire area.

Geomembrane - An essentially impermeable geosynthetic composed of one or more geosynthetic sheets.

Geotextile - Any permeable textile used with foundation, soil, rock, earth, or any other geotechnical engineering related material as an integral part of a human-made project, structure, or system.

Minimum Average Roll Value - The minimum average value of a particular physical property of a material, for 95 percent of all the material in the lot.

Overlap - Where two adjacent GCL panels contact, the distance measuring perpendicular from the overlying edge of one panel to the underlying edge of the other.

(1.3) Submittals/Qualifications

A. The GCL Manufacturer must have produced at least 10 million square feet (1 million square meters) of GCL, with at least 8 million square feet (800,000 square meters) installed. The manufacturer shall submit certification that GCL manufactured for the Project has been produced in accordance with these Specifications along with results from a quality control program. This information must be submitted for review prior to material delivery. The Engineer reserves the right to halt installation until proper certification is submitted and determined acceptable for use.

B. The Contractor shall submit to the Engineer, six (6) full sets of panel layout construction drawings. Drawings shall be submitted to the Engineer at least two (2) weeks prior to installation.

C. The manufacturer of the GCL used in this work shall approve all shop drawings and a proposed liner layout to cover the lined area shown on the Drawings.

D. Details shall be included to show the termination of the liner at the perimeter of lined areas, the methods of sealing around penetrations, and methods of anchoring. A specific anchor trench detail shall be provided.

E. The Contractor shall submit to the Engineer a physical sample of the liner to be used. The sample shall be labeled with the manufacturer's name, product identification, lot number and roll number.

F. Upon shipment, the Contractor shall furnish the GCL manufacturer's Quality Assurance/Quality Control (QA/QC) certifications to verify that the materials supplied for the project are in accordance with the requirements of this specification. The Contractor shall also submit to the Engineer inventory tickets, roll numbers or batch identifications, packing papers, and invoices for the liner used.

G. As installation proceeds, the Contractor shall submit certificates of subgrade acceptance to the Engineer, signed by the Contractor and the GCL Installer for each area that is covered by the GCL.

H. The Contractor shall provide personnel resumes demonstrating compliance with the following requirements.

1. A project reference list for the GCL(s) consisting of the principal details of at least ten projects totaling at least 10 million square feet (100,000 square meters) in size.

2. A minimum of one field superintendent per shift shall be designated by the Contractor and approved by the Engineer. Each field superintendent shall have a minimum of three years and five million square feet of field experience in installing GCL's. Any change or replacement of superintendent during the Project must be approved by the Engineer.

3. Liner placement technicians shall have a minimum of one year and one million square feet of GCL placement experience.

(1.4) Construction Quality Assurance (CQA)

A. The Project Engineer shall provide an inspector for CQA of the GCL installation. The inspector shall be responsible for observing and documenting activities related to the CQA of the GCL. The contractor shall not install any GCL on this project, at any time, in the absence of the CQA inspector.

B. Testing of the GCL, as necessary to support the CQA effort, shall be performed by a third party laboratory retained by the Engineer and independent from the GCL manufacturer and installer.

(2) Products

(2.1) General

A. The GCLs shall consist of a layer of natural sodium bentonite clay encapsulated between two geotextiles and shall comply with all of the criteria listed in this Section. Prior to using an alternate GCL, the Contractor must furnish independent test results demonstrating that the proposed alternate material meets all requirements of this specification. The Contractor also must obtain prior approval of the alternative GCL by the Project Engineer.

B. Reinforced GCL must be used on all areas of the site.

(2.2) Materials

A. An acceptable GCL product is Bentomat® ST as manufactured by CETCO or an engineer-approved equal.

B. All areas of the project requiring reinforced GCL will be furnished with Bentomat® ST or an engineer-approved equal.

C. The GCL(s) and their components shall have the properties shown in the attached CETCO's Technical Data Sheet (TR404bm).

D. The minimum acceptable dimensions of full-size GCL panels shall be 150 feet (45.7m) in length and 15 feet (4.6m) in width for Bentomat. Short rolls [(those manufactured to a length greater than 70 feet (21m) but less than a full-length roll)] may be supplied at a rate of no

greater than 3 per truckload or 3 rolls for every 36,000 square feet (3,500 square meters) of GCL, whichever is less.

E. A 6-inch (150mm) overlap guideline shall be imprinted on both edges of the upper geotextile component of the GCL as a means for providing assurance of the overlap dimension. Lines shall be printed in easily visible, non-toxic ink.

(2.3) Product Quality Documentation

The GCL manufacturer/Contractor shall provide the Engineer with manufacturing QA/QC certifications for each shipment of GCL, prior to the deployment of GCL. The certifications shall be signed by a responsible party employed by the GCL manufacturer, such as the QA/QC Manager, Production Manager, or Technical Services Manager, and shall include:

A. Certificates of analysis for the bentonite clay used in GCL production demonstrating compliance with the parameters swell index and fluid loss shown in CETCO's Technical Data Sheet TR404bm.

B. Manufacturer's test data for finished GCL products(s) of bentonite mass/area, GCL tensile strength, and GCL peel strength demonstrating compliance with the index parameters shown in CETCO's Technical Data Sheet TR404bm.

C. GCL lot and roll numbers supplied for the project (with corresponding shipping information).

CETCO
COLLOID ENVIRONMENTAL TECHNOLOGIES COMPANY

TECHNICAL DATA SHEET

BENTOMAT "ST" CERTIFIED PROPERTIES

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	REQUIRED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tonnes	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tonnes	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	90 lbs (400 N)
GCL Peel Strength[3]	ASTM D 4632	40,000 ft^2 (4,000 m^2)	15 lbs (65 N)
GCL Index Flux[4]	ASTM D 5887	Weekly	1×10^{-8} $m^3/m^2/sec$
GCL Permeability[4]	ASTM D 5084	Weekly	5×10^{-9} cm/sec
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf (24 kPa) typical

Bentomat "ST" is a reinforced GCL consisting of a layer of sodium bentonite between a woven and a non-woven geotextile which are needlepunched together.

Notes:

1. Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.
2. Bentonite mass/area reported at 0 percent moisture content..
3. All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.
4. Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-9} cm/sec for typical GCL thickness. This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.
5. Peak value measured at 200 psf (30 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

1350 W. Shure Drive • Arlington Heights, IL 60004 • USA • (847) 392-5800 • FAX (847) 506-6195
A wholly owned subsidiary of AMCOL International

The information and data contained herein are believed to be accurate and reliable. CETCO

D. Manufacturer's test data for finished GCL product(s) including GCL index flux, permeability, and hydrated internal shear strength data demonstrating compliance with the performance parameters shown in CETCO's Technical Data Sheet TR404bm.

(2.4) Material Conformance Testing

The CQA Engineer shall perform the material conformance tests listed in Table 1.

Table 1: QA Testing Program for GCL Material Conformance

PROPERTY	TEST METHOD	UNITS	VALUE[1]	TEST FREQUENCY
Hydraulic Conductivity	ASTM D5084[2]	cm/s	$\leq 5.0 \times 10^{-9}$	200,000 ft^2
Bentonite Content	ASTM D3776[3]	psf	0.75 (@0% moisture)	200,000 ft^2
Thickness	ASTM D1777	inch	0.20	200,000 ft^2
Grab Tensile Strength	ASTM D4632	lbs	90	200,000 ft^2
Interface Friction Test	ASTM D5321[6]	degrees	≥ 13.5[4]	1
Interface Friction Test	ASTM D5321[6]	degrees	≥ 13.0[5]	1
Shear Strength	ASTM D5321	psf	500	1

[1] Minimum Average Roll Values (MARV).
[2] Conduct test at 5 psi effective stress.
[3] Alternatively, use ASTM D5993 for measuring the mass per unit area of GCL.
[4] GCL against the soil liner (peak value).
[5] GCL (woven geotextile) against the textured FML (peak value).
[6] Conduct test at 3 psi effective stress and hydrate the GCL.

Samples for material conformance testing shall be obtained upon delivery of the GCL. Samples shall be taken across the entire width of the roll. Samples shall be 1 foot to 3 feet long by the roll width. All material conformance testing shall be performed by a third party Geosynthetics Laboratory retained by the Engineer. All test results must be available at the Engineer's office prior to the deployment of any GCL roll at the site. The CQA Engineer will examine all results from laboratory testing.

(2.5) Product Labeling

A. *Prior to shipment, the GCL manufacturer shall label each roll,* identifying:

1. Product identification information (Manufacturer's name and address, brand name, product code).
2. Lot number and roll number.
3. Roll length, width, and weight.

(2.6) Packaging

A. The GCL shall be wound around a rigid core whose diameter is sufficient to facilitate handling. The core is not necessarily intended to support the roll for lifting but should be sufficiently strong to prevent collapse during transit.

B. All rolls shall be labeled and bagged in packaging that is resistant to photodegradation by ultraviolet (UV) light.

(2.7) Accessory Bentonite

A. The granular bentonite or bentonite sealing compound used for seaming, penetration sealing, and repairs shall be made from the same natural sodium bentonite as used in the GCL and shall be as recommended by the GCL manufacturer.

(2.8) Equipment Requirements

A. CETCO GCLs are delivered in rolls weighing from 2,500 - 2,700 lbs (1,140-1,225 kg). It is necessary to support this weight using an appropriate core pipe. For any installation, the core pipe must not deflect more than 3 inches (75 mm) as measured from end to midpoint when a full GCL roll is lifted.

B. Lifting chains or straps rated for at least twice the load of the GCL should be used in combination with a spreader bar made from an I-beam. The spreader bar ensures that the lifting chains or straps do not chafe against the ends of the GCL roll, which must be able to rotate freely during installation.

C. A front end-loader, backhoe, dozer, or other equipment can be furnished with the spreader bar and core bar. Alternatively, a forklift with a "stinger" attachment may be used for on-site handling and, in certain cases, installation. **A forklift without a stinger attachment shall not be used to lift or handle the GCL rolls**.

D. When installing over certain geosynthetic materials, a 4-wheel all-terrain vehicle (ATV) can be used to deploy the GCL from behind. An ATV can be driven directly on the GCL provided that no sudden stops, starts, or turns are made.

E. Additional equipment needed for installation of CETCO's GCLs includes:

- Utility knife and spare blades (for cutting the GCL).
- Granular bentonite or bentonite mastic (for overlapped seams of GCLs with needle punched non-woven geotextiles and for sealing around structures and details).
- Waterproof tarpaulins (for temporary cover on installed material as well as or stockpiled rolls).

- Optional chalk line marker to simplify bentonite placement at seams (when installing a GCL with needle punched non-woven geotextile components).

- Optional flat-bladed vise grips (for positioning the GCL panel by hand).

(3) EXECUTION

(3.1) Shipping and Handling

A. The manufacturer assumes responsibility for initial loading the GCL. Shipping will be the responsibility of the party paying the freight. Unloading, on-site handling, and storage of the GCL are the responsibility of the Contractor, Installer, or other designated party.

B. A visual inspection of each roll should be made during unloading to identify if any packaging has been damaged. Rolls with damaged packaging should be marked and set aside for further inspection. The packaging should be repaired prior to being placed in storage.

The party responsible for unloading the GCL should contact the Manufacturer prior to shipment to ascertain the appropriateness of the proposed unloading methods and equipment.

(3.2) Storage

A. Storage of the GCL rolls shall be the responsibility of the installer. A dedicated storage area shall be selected at the job site that is away from high traffic areas and is level, dry, and well-drained.

B. Rolls should be stored in a manner that prevents sliding or rolling from the stacks and may be accomplished by the use of chock blocks or by use of the dunnage shipped between rolls. Rolls should be stacked at a height no higher than that at which the lifting apparatus can be safely handled (typically no higher than four). Rolls shall never be stacked on end.

C. All stored GCL materials and the accessory bentonite must be covered with a plastic sheet or tarpaulin until their installation.

D. The integrity and legibility of the labels shall be preserved during storage.

(3.3) Earthwork/Subgrade Preparation

A. Any surface upon which the GCL is installed shall be prepared and compacted in accordance with the project specifications and drawings. The surface shall be smooth, firm, and unyielding, and free of vegetation, any debris, sticks, sharp rocks, void spaces, ice, abrupt elevation changes, standing water, cracks larger than one-quarter inch (6mm) in width, and any other foreign matter that could contact the GCL.

B. Subgrade surfaces consisting of granular soils or gravel may not be acceptable due to their large void fraction and puncture potential. Subgrade soils should possess a particle size distribution such that at least 80 percent of the soil is finer than a No. 60 sieve (0.250 mm).

C. Immediately prior to GCL deployment, the subgrade shall be final-graded to fill in all voids or cracks and then smooth-rolled to provide the best practicable surface for the GCL. At completion of this activity, no wheel ruts, footprints or other irregularities shall exist in the subgrade. Furthermore, all protrusions extending more than one-half inch (12mm) from the surface shall either be removed, crushed or pushed into the surface with a smooth-drum compactor.

D. On a continuing basis, the Contractor/GCL Installer shall submit certifications of subgrade acceptance to the Engineer, and the project CQA inspector shall verify acceptance of the subgrade before GCL placement.

E. It shall be the installer's responsibility thereafter to indicate to the Engineer any change in the condition of the subgrade that could cause the subgrade to be out of compliance with any of the requirements listed in this Section.

F. At the top of sloped areas of the job site, an anchor trench for the GCL shall be excavated in accordance with the project plans and specifications. The excavated trench shall be verified by the CQA Inspector prior to GCL placement. No loose soil shall be allowed at the bottom of the trench and no sharp corners or protrusions shall exist anywhere within the trench.

(3.4) <u>GCL Placement</u>

Placement of the GCL shall be conducted in accordance with the manufacturer's recommendations and with the direction provided herein. Any deviations from these procedures must be pre-approved by the CQA Engineer.

A. The contractor shall not install any GCL on this project, at any time, in the absence of the CQA inspector. During start-up of the GCL installation, an agent or representative of the Manufacturer shall provide on-site assistance and instruction to the Contractor and CQA Engineer regarding the appropriate installation techniques.

B. The CQA Inspector/Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. All defects and deficiencies shall be properly documented by the GCL Installer and CQA Inspector. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Inspector/Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the Engineer. The CQA Inspector shall observe and verify all repaired defects.

C. Reinforced GCL shall be placed on all areas of the site.

D. GCL rolls should be delivered to the working area of the site in their original packaging. Immediately prior to deployment, the packaging should be carefully removed without damaging the GCL. The orientation of the GCL (i.e., which side faces up) may be important if the GCL has two different geotextiles. Unless otherwise specified, however, the GCL shall be placed with the white side (non-woven) geotextile facing down.

E. The GCL shall be properly weighted to avoid uplift due to wind.

F. Equipment which could damage the GCL shall not be allowed to travel directly on it. Acceptable installation, therefore, may be accomplished such that the GCL is unrolled in front of the backwards-moving equipment. If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues. Equipment necessary to perform the installation (generators, compressors, etc.) shall have a scrap GCL sheet placed underneath to protect the installed GCL from possible damage.

G. The GCL shall be kept free of debris, unnecessary tools and materials. In general, the GCL area shall remain neat in appearance. All damage shall be recorded and located in the record drawings.

H. Care must be taken to minimize the extent to which the GCL is dragged across the subgrade in order to avoid damage to the bottom surface of the GCL. A temporary geosynthetic

subgrade covering commonly known as a slip sheet or rub sheet may be used to reduce friction damage during placement.

I. The GCL shall be placed so that seams are parallel to the direction of the slope. End-of-roll seams should be located at least 3 feet (1m) from the toe and crest of slopes steeper than 4H:1V. GCL rolls shall **not** be released on the slope and allowed to unroll freely by gravity.

J. All GCL panels shall be placed free of tension or stress and lie flat on the underlying surface, with no wrinkles or fold, especially at the exposed edges of the panels. Similarly, the geomembrane placed over GCL shall lie flat and in contact with the underlying GCL with no wrinkles or fold.

K. The GCL shall not be installed in standing/ponded water, during rainy weather/precipitation, excessive moisture, and during extremely/excessive high wind. Only as much GCL shall be deployed as can be covered at the end of the working day with the geomembrane. In no case shall the GCL be exposed to the elements at the end of the day. The GCL shall not be left uncovered overnight. If the GCL is hydrated when no confining stress is present, it will be necessary to remove and replace the hydrated material. The project Engineer, CQA inspector, and GCL supplier should be consulted for specific guidance if premature hydration occurs.

L. The GCL shall not get wet before or during installation. The GCL mat shall not be installed during periods of any precipitation. If a precipitation event occurs after the installation of a GCL panel, but prior to covering with the geomembrane panel, a thin film plastic sheeting may be used to cover and to temporarily protect the GCL from moisture, if approved by the Project Engineer.

M. Panels shall be placed from the highest elevation to the lowest within the area to be lined, to facilitate drainage in the event of precipitation.

N. It is not permissible to stretch the GCL in order to fit a designated area. Panels shall not be dragged across the subgrade into position except where necessary to obtain the correct overlap for adjacent panels.

(3.5) <u>Anchorage</u>

A. As directed by the project drawings and specifications, the end of the GCL roll shall be placed in an anchor trench at the top of the slope. The front edge of the trench should be rounded so as to eliminate any sharp corners. The GCL should cover the entire trench floor but does not extend up the rear trench wall.

B. The amount of trench open at any time shall be limited to one day of GCL installation capacity. The anchor trench shall be adequately drained to prevent water ponding and softening the adjacent soils. Loose soil shall be removed from the floor of the trench. The soil backfill should be placed in the trench to provide resistance against pullout. The size and shape of the trench, as well as the appropriate backfill procedures, should be in accordance with the project drawings and specifications.

(3.6) <u>Seaming</u>

A. The GCL seams are constructed by overlapping their adjacent edges. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris. Supplemental bentonite is required for Bentomat® ST.

B. The minimum dimension of the longitudinal overlap should be 6 inches (150 mm). End-of-roll overlapped seams should be similarly constructed, but the minimum overlap should measure

24 inches (600 mm). In the opinion of the CQA Engineer/Inspector, any seam, or edge of GCL material exposed for more than 24 hours or considered partially hydrated when seaming occurs shall receive a 3-foot overlap (rainlap) from the adjoining GCL panel.

C. All seams shall have a seam number that corresponds with the panel layout numbers. The numbering system shall be used in the development of the record drawings. Seam numbers shall be derived from the combination of the two panel numbers that are to be seamed.

D. Seam areas or runs shall also be flat and clear of any large rocks, debris, or ruts. Contacting surfaces shall be clean and clear of dirt or native soil with all edges pulled tight to maximize contact and to smooth out any wrinkles or creases.

E. All seams constructed on sloped surface shall be vertical seams.

F. Seams at the ends of the panels should be constructed such that they are shingled in the direction of the grade to prevent the potential for runoff flow to enter the overlap zone.

G. Bentonite-enhanced seams are constructed between the overlapping adjacent panels described above. The underlying edge of the longitudinal overlap is exposed and then a continuous bead of granular sodium bentonite is applied along a zone defined by the edge of the underlying panel and the 6 inch (150 mm) line. A similar bead of granular sodium bentonite is applied at the end-of-roll overlap. The bentonite shall be applied at a minimum application rate of one quarter pound per lineal foot (0.4 kg/m).

(3.7) <u>Detail Work/Sealing Around Penetration and Structures</u>

A. Cutting the GCL should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid irregular tearing of the geotextile components of the GCL during the cutting process. The GCL shall be sealed around penetrations and structures embedded in the subgrade. Granular bentonite or a bentonite mastic shall be used liberally (approximately 2 lbs/in ft or 3 kg/m) to seal the GCL to these structures.

B. When the GCL is placed over an earthen subgrade, a "notch" (approximately 3 inches wide and 8 inches deep) shall be cut against the edge of the subgrade area around the penetration. The mat shall be brought up to the edge of the structure and trimmed to fit into the notch. The Contractor shall then hand apply a pure bead of bentonite into half the notch. The mat shall then be inserted into the notch, with the remaining volume of the notch refilled with the pure bentonite and compacted.

C. A secondary collar of GCL should be placed around the penetration. It is helpful to first trace an outline of the penetration on the GCL and then cut a "star" pattern in the collar to enhance the collar's fit to the penetration.

D. Vertical penetrations are prepared by notching into the subgrade. The penetration is completed with two separate pieces of GCL. A secondary collar is option in this case.

E. When the GCL is terminated at a structure or wall that is embedded into the subgrade, the subgrade should be notched as described in Items B and D above. The notch is filled with granular bentonite, and the GCL should be placed over the notch and up against the structure. The connection to the structure can be accomplished by placement of soil or stone backfill in this area.

(3.8) <u>Damage Repair</u>

A. If the GCL is damaged (torn, punctured, perforated, etc.) during installation, it may be possible to repair it by cutting a patch to fit over the damaged area. The patch shall be

obtained from a new GCL roll and shall be cut to size such that minimum overlap of 12 inches (300 mm) is achieved around all of the damaged area. Dry bentonite or bentonite mastic should be applied around the damaged area at the rate of one-half pound per lineal foot prior to placement of the patch. Any epoxy-based adhesives shall be used to keep the patch in position during backfill operations.

(3.9) Placement of Overlaying Materials

A. Although direct vehicular contact with the GCL is to be avoided, lightweight, low ground pressure vehicles [such as 4-wheel all-terrain vehicles (ATV)] may be used to facilitate the installation of any geosynthetic material placed over the GCL, provided the ATV makes no sudden stops, starts, or turns. The GCL supplier or CQA engineer should be contacted with specific recommendations on the appropriate procedures in this situation.

B. When a textured geomembrane is installed over the GCL, a temporary geosynthetic covering known as a slip sheet or rub sheet should be used to minimize friction during placement and to allow the textured geomembrane to be more easily moved into its final position.

C. Any leading edge of panels left uncovered shall be protected at the end of the working day with a waterproof sheet which is adequately secured with sandbags or other ballast.

D. Soil cover shall be placed over the GCL/geomembrane using low ground pressure construction equipment that minimizes stresses on the GCL/geomembrane, according to the existing project specification requirements for protective cover soil installation over geomembrane liner.

4.2.4 Base Liner System Flexible Membrane Liner Method of Deployment

All materials and equipment shall be furnished by an established and reputable manufacturer or supplier. All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications or shall be the product of the listed manufacturers or similar and equal thereto as approved by the Engineer.

Flexible Membrane Liner Tests

Test Name	Description	Test Method	Frequency
Air Test	Air Test Seams		Every Seam
Vacuum Test	Every welded area		Where air test impossible
Destructive Tests	Seam Strength	ASTM D4437	Every 500' of seam

Qualified liner installers, seamers, and the liner foreman shall meet a minimum requirement of 1,000,000 square feet of geomembrane installation. There are no other minimum qualifications needed by other parties.

60 mil High Density Polyethylene (HDPE) - Geosynthetic Research Institute (GRI) GM13 - Is to be placed in direct contact with moist cohesive soil liner. The Landfill itself is single lined and will only have a single Textured Geomembrane. The extrusion rods and/or brads used in seaming the rolls together shall be derived from the same base resin as the liner and shall meet the following minimum properties:

ENGLISH UNITS

Table 2(a) - High Density Polyethylene (HDPE) Geomembrane - Textured

Property	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height (min. ave.) *(1)*	GM 12	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	every 2nd roll *(2)*
Density (min. ave.)	D 1505/D792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (min. ave.) *(3)* • yield stress • break stress • yield elongation • break elongation	D 638 Type IV	63 lb/in. 45 lb/in. 12% 100%	84 lb/in. 60 lb/in. 12% 100%	105 lb/in. 75 lb/in. 12% 100%	126 lb/in. 90 lb/in. 12% 100%	168 lb/in. 120 lb/in. 12% 100%	210 lb/in. 150 lb/in. 12% 100%	252 lb/in. 180 lb/in. 12% 100%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	45 lb	60 lb	75 lb	90 lb	120 lb	150 lb	180 lb	45,000 lb
Stress Crack Resistance *(4)*	D 5397 (App.)	200 hr.	200 hr.	200 hr.	200 hr.	200 hr.	200 hr.	200 hr.	per GRI-GM 10
Carbon Black Content (range)	D 1603 *(5)*	2.0 - 3.0%	2.0 - 3.0%	2.0 - 3.0%	2.0 - 3.0%	2.0 - 3.0%	2.0 - 3.0%	2.0 - 3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note*(6)*	note*(6)*	note*(6)*	note *(6)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(7)* (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	200,000 lb
Oven Aging at 85°C *(7), (8)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	per each formulation
UV Resistance *(9)* (a) Standard OIT — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	GM11 D 3895 D 5885	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 7 mil, and lowest individual reading must be ≥ 5 mil
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
(6) Carbon black dispersion for 10 different views:
• all 10 in Categories 1 or 2
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8 It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Preparation for Geomembrane Deployment

(a) Panel Layout

Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and location of seams for the project.

(b) Identification

Each panel used for the installation shall be given a numeric or alpha-numeric identification number consistent with the layout drawing. This identification number shall be related to manufacturing roll number that identifies the resin type, batch number and date of manufacture.

(c) Verification

The manufacturers certification will be given to the construction observer. The construction observer will inspect all certifications. If the certification does not meet specifications, it will be rejected. Adequate laboratory QA/QC conformance testing shall be performed by the contractor/engineer to verify minimum requirements outlined on Table 2(a) of GM13-9 of 12. QC testing information is for each roll of material delivered to the site. A third party QA lab will test for thickness, density, carbon black content, carbon black dispersion and tensile properties for one roll out of four delivered to the site.

(2) Field Panel Placement

(a) Location

The Flexible Membrane Liner Manufacturer/Installer shall install field panels at the location indicated on the layout drawing. If the panels are deployed in a location other than that indicated on the layout drawings, the revised location shall be noted in the field on a layout drawing which will be modified at the completion of the project to reflect actual panel locations.

(b) Weather Conditions

Geomembrane deployment shall not be carried out during any precipitation, nor in the presence of excessive moisture (i.e. fog, dew), in an area of standing water, or during high winds.

(c) Method of Deployment

(1) The method and equipment used to deploy the panels must not damage the geomembrane or the supporting subgrade surface.

(2) No personnel working on the geomembrane will smoke, wear shoes that can damage the geomembrane, or engage in actions which could result in damage to the geomembrane.

(3) Adequate temporary loading and/or anchoring, (i.e. sandbags, tires), which will not damage the geomembrane, will be placed to prevent uplift of the geomembrane by wind. If uplift occurs, additional sandbags will be placed in necessary areas.

(4) The geomembrane will be deployed in a manner to minimize wrinkles. The geomembrane will have no fold overs.

(5) Any damage to a panel of the geomembrane will be repaired. Any area of a panel seriously damaged (torn, twisted, or crimped) will be marked, cut out and removed from the work area with resulting seaming and/or repairs performed.

(3) Field Seaming

(a) Layout

In general, seams shall be oriented parallel to the slope, i.e., oriented along, not across the slope. Whenever possible, horizontal seams should be located not less than five (5) feet from the toe of the slope. Each seam made in the field shall be numbered in a manner that is compatible with the panel layout drawing for documentation of seam testing results.

(b) Personnel

All personnel performing seaming operations shall be trained in the operation of the specific seaming equipment being used and will qualify by successfully welding a test seam. The project foreman will provide direct supervision of all personnel seaming to verify proper welding procedures are followed. Qualified liner installers, seamers, and the liner foreman shall meet a minimum requirement of 1,000,000 square feet of geomembrane installation. There are no other minimum qualifications needed by other parties.

(c) Equipment

(1) Fusion Welding

Fusion Welding consists of placing a heated wedge, mounted on a self propelled vehicular unit, between two (2) overlapped sheets such that the surface of both sheets are heated above the polyethylene's melting point. After being heated by the wedge, the overlapped panels pass through a set of preset pressure wheels which compress the two (2) panels together so that a continuous homogeneous fusion weld is formed. The fusion welder is equipped with a temperature readout device which continuously monitors the temperature of the wedge.

(2) Extrusion Fillet Welding

Extrusion fillet welding consists of introducing a ribbon of molten resin along the edge of the seam overlap of the two (2) sheets to be welded. The molten polymer causes some of the material of each sheet to be liquefied resulting in a homogeneous bond between the molten weld bead and the surfaces of the sheets. The extrusion welder is equipped with gauges giving the temperature in the apparatus and the preheat temperature at the nozzle.

(d) Weather Conditions

The Flexible Membrane Liner Manufacturer/Installer will rely on the experience of the Project Superintendent and the results of test seams to determine seaming restrictions by weather. Many factors, such as ambient temperature, humidity, wind, sunshine, etc., can effect the integrity of field seams and must be taken into account when deciding whether or not seaming should proceed. Responsibility for monitoring these conditions shall lie with the Project Superintendent; however, the Engineer may suspend any seaming operation which is, in his opinion, at the risk of providing the Owner with a quality product. Test seams are required prior to daily production seaming to determine if the weather conditions will effect the Flexible Membrane Liner System's ability to produce quality seams. Additional non-destructive and destructive testing of production seams substantiate the decision made by the Project Superintendent to seam on any given day.

(4) Seam Preparation

(a) Fusion Welding

(1) Overlap the panels of geomembrane approximately four (4) inches.

(2) Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, debris of any kind. No grinding is required for fusion welding.

(3) Adjust the panels so that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

(4) A movable protective layer may be used, at the discretion of the Flexible Geomembrane Liner System Project Superintendent, directly below the overlap of geomembrane that is to be seamed to prevent build-up of moisture between the panels.

(b) Extrusion Welding

(1) Overlap the panels of geomembrane a minimum of three (3) inches.

(2) Temporarily bond the panels of geomembrane to be welded taking care not to damage the geomembrane.

(3) Grind seam overlap prior to welding within one (1) hour of welding operation in a manner that does not damage the geomembrane. Limit grinding to ¼" outside of the extrusion weld area.

(4) Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, and debris of any kind.

(5) Purge the extruder prior to beginning the seam to remove all heat-degraded extrudate from the barrel.

(6) Keep welding rod clean and off the ground.

(5) Test Seams

Test seams shall be performed at the beginning of each seaming period and at approximately every 4-working hour intervals for each seaming apparatus used that day. Test seams shall be made on fragment pieces of the geomembrane liner and under the same conditions as actual seams.

(a) Test Seam Length

The test seam shall be at least three (3) feet long and should be made by joining two (2) pieces of geomembrane at least 9" in width.

(b) Sample Procedure

(1) Visually inspect the seam for squeeze out, footprint, pressure and general appearance.

(2) Two random samples one (1) inch wide shall be cut from the test seam. The specimens shall then be tested in peel using a field tensiometer and shall not fail in the seam. If a specimen fails the entire procedure shall be repeated.

(3) If any of the second set of specimens fail, the seaming apparatus shall not be accepted and shall not be used for seaming until the deficiencies are corrected and a passing test seam is achieved.

(4) After completion of these tests, the remaining portion of test seam can be discarded. Documentation of the test seams will be maintained listing seam identification number, welder's name, temperature control setting and test results.

(5) Passing test results records shall be maintained.

(6) General Seaming Procedures

(a) Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

(b) While welding a seam, monitor and maintain the proper overlap.

(c) Inspect seam area to assure area is clean and free of moisture, dust, dirt, debris of any kind.

(d) While welding a seam, monitor temperature gauges to assure proper settings are maintained and that the seaming apparatus is operating properly.

(e) Align wrinkles at the seam overlap to allow welding through the wrinkle.

(f) Fishmouths or wrinkles at seam and overlaps that cannot be welded through shall be cut along the ridge in order to achieve a flat overlap. The cut fishmouth or wrinkle shall be seamed. Any portion where the overlap is inadequate shall be patched with an oval or round patch of the same geomembrane extending a minimum of six (6) inches beyond the cut in all directions.

(g) All cross/butt seams between two (2) rows of seamed panels shall be welded during the coolest time of the day to allow for contraction of the geomembrane.

(h) All "T" joints shall have the overlap from the wedge welder seam trimmed back to allow an extrusion fillet weld. Then grind ¼ of an inch minimum on either side of the wedge seam, then extrusion weld all of the area prepared by grinding.

4.2.5 Base Liner System Flexible Membrane Liner Tests

The installation crews will non-destructively test all field seams over their full length using air pressure testing, vacuum testing or other approved methods, to verify the continuity and integrity of the seams.

(a) Air Pressure Testing

The welded seam created by double hot-wedge fusion welding process is composed of two distinct welded seams separated by an unwelded channel approximately 3/8 of an inch between the two welded seams permits the double hot-wedge fusion seams to be tested by inflating the sealed channel with air to a predetermined pressure, and observing the stability of the pressurized channel over time.

(1) Equipment for Air Testing

An air pump (manual or motor driven) capable of generating and sustaining a pressure between 25 to 30 psi.

A rubber hose with fittings and connections.

A sharp hollow needle, or other approved pressure feed device with a pressure gauge capable of reading and sustaining a pressure between 25 to 30 psi.

(2) Procedure for Air Testing

Seal both ends of the seam to be tested.

Insert needle or other approved pressure feed device into the sealed channel created by the fusion weld.

Inflate the test channel to a pressure between 25 to 30 psi, in accordance with the following schedule, close valve, and observe initial pressure after approximately 2 minutes.

INITIAL PRESSURE SCHEDULE *

Material (Mil)	Min. Psi	Max. Psi
40	25	30
60	27	30
80	30	30
100	30	30

* Initial pressure settings are read after a two minute "relaxing period". The purpose of this "relaxing period" is to permit the air temperature and pressure to stabilize.

Observe and record the air pressure five (5) minutes after "relaxing period" ends and when initial pressure setting is used. If loss of pressure exceeds the following or if the pressure does not stabilize, locate faulty area and repair.

MAXIMUM PERMISSIBLE PRESSURE DIFFERENTIAL AFTER 5 MINUTES - HDPE

Material (Mil)	Pressure Diff.
40	4 psi
60	3 psi
80	3 psi
100	3 psi

At the conclusion of the pressure test the end of the seam opposite the pressure gauge is cut. A decrease in gauge pressure must be observed or the air channel will be considered "blocked" and the test will have to be repeated after the blockage is corrected.

Remove needle or other approved pressure feed device and seal resulting hole by extrusion welding.

(3) In the event of a Non-Complying Air Pressure Test, the following procedure shall be followed:

Check seam end seals and retest seams.

If non-compliance with specified maximum pressure differential re-occurs, repair the seam. Capping or removal/reseam of the non-complying seam are the only two (2) acceptable methods of repairing failed seams.

Non-destruct test the entire length of the repaired seam.

(b) Vacuum Testing

This test is used when the geometry of the weld makes air pressure testing impossible or impractical or when attempting to locate the precise location of a defect believed to exist after air pressure testing. The penetration will be tested using this method.

(1) Equipment for Vacuum Testing

Vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.

Vacuum pump assembly equipped with a pressure controller and pipe connection.

A rubber pressure/vacuum hose with fittings and connections.

A bucket and means to apply a soapy solution.

A soapy solution.

(2) Procedure for Vacuum Testing

Trim excess overlap from seam, if any.

Turn on the vacuum pump to reduce the vacuum box to approximately 5 inch of mercury, i.e., 5 psi gauge.

Apply a generous amount of a solution of strong liquid detergent and water to the area to be tested.

Place the vacuum box over the area to be tested and apply sufficient downward pressure to "seat" the seal strip against the liner.

Close the bleed valve and open the vacuum valve.

Apply a minimum of 5 in. Hg vacuum to the area as indicated by the gauge on the vacuum box.

Ensure that a leak tight seal is created.

For a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.
If no bubbles appear after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in. overlap, and repeat the process.

(3) Procedure for Non-Complying Test

Mark all areas where soap bubbles appear and repair the marked areas.

Retest repaired areas.

(c) Destructive Testing

(1) Concept

The purpose of destructive testing is to determine and evaluate seam strength. These tests require direct sampling and thus subsequent patching. Therefore destructive testing should be held to a minimum to reduce the amount of repairs to the geomembrane.

(2) Procedure for Destructive Testing

All Destructive tests will be done according to ASTM D4437. Destructive test samples shall be marked and cut out randomly at a minimum average frequency of one test location every 500 feet of seam length.

Additional destructive tests may be taken in areas of contamination, offset welds, visible crystallinity or other potential cause of faulty welds at the descretion of the Project Superintendent and Engineer.

Sample Size

The sample should be twelve (12) inches wide with a seam fourteen (14) inches long centered lengthwise in the sample. The sample may be increased in size to accommodate independent laboratory testing by the owner at the owner's request or by specific project specifications.

A one (1) inch sample shall be cut from each end of the test seam for field testing.

The two (2), one (1) inch wide samples shall be tested in the field in a tensiometer for peel ASTM D4437. Tensile strength is essentially a measurement of the greatest tension stress a substance can bear without tearing. If the liner tears before any part of the seam does the test is successful. If any field sample fails to pass, it will be assumed the sample fails destructive testing. The passing destructive test requirements for a 60-mil liner seam is: minimum peel adhesion of 78 ppi, minimum shear strength of 120 ppi, and Film Tear Bond (FTB).

(3) Procedure in the event of Destructive Test Failure

Cut additional field samples for testing. In the case of a field production seam, the samples must lie a minimum of ten (10) feet in each direction from the location of the failed sample. Perform a field test for peel strength. If these field samples pass, then laboratory samples can be cut and forwarded to the laboratory for full testing.

If the laboratory samples pass then repair the seam between the two (2) passing samples locations.

Capping or removal of the failed seam are the only two (2) acceptable methods for repairing failed seams.

All destructive seam samples sent to the Flexible Membrane Liner System's laboratory shall be numbered.

(d) Quality Assurance Laboratory Testing

(1) Destructive samples sent to the laboratory will be tested for "shear strength" and "peel adhesion" (ASTM D4437 as modified by NSF). Five (5) specimens shall be tested for each test method with data recorded. Four (4) out of the five (5) specimens must pass for each test in order for the seam to pass the destructive test.

(2) Defects and Repairs

(a) The Project Superintendent shall conduct a detailed walk through and visually check all seams and non-seam areas of the geomembrane for defects, holes, blisters and signs of damage during installation.

(b) All other installation personnel shall, at all times, be on the lookout for any damaged areas. Damaged areas shall be marked and repaired.

(c) Repair Procedures

Any portion of the geomembrane showing a flaw or failing a destructive or non-destructive test shall be repaired. Several procedures exist for repair and the decision as to the appropriate repair procedure shall be made by the Project Superintendent. Repairs need to be made in a timely manner to protect the moist cohesive soil liner and flexible membrane liner. If inclement weather is approaching, steps need to be made to protect the cohesive soil liner such as a temporary cover. If cohesive soil liner is damaged, it must be reworked. Procedures available for liner repair:

Patching - used to repair large holes, tears and destructive sample locations. All patches shall extend at least six (6) inches beyond the edges of the defect and all corners of patches shall be rounded.

Grinding and welding - used to repair sections of extruded seams.

Spot welding or seaming - used to repair small tears, pinholes or other minor localized flaws.

Capping - used to repair lengths of failed seams.

Removal of a bad seam and replacement with a strip of new material seamed into place.

(d) Verification of Repairs

Every repair shall be non-destructively tested. Repairs which pass the non-destructive test shall be deemed adequate. Large repairs may require a destructive test. Repair test results shall be logged. The repair location shall be recorded on an as-built drawing.

4.2.6 Protective Cover for Landfill Construction

HPDE Geocomposite Drainage Netting manufactured by SKAPS Industries, or approved equal. Q/C testing information/certification for each property on geocomposite will be provided by the contractor/manufacture for the rolls delivered.

GEOCOMPOSITE PROPERTIES

PROPERTY	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Thickness	ASTM D 5199	inch	0.305
Transmissivity[1] (15,000 psf)	ASTM D 4716	m^2/sec	$3x10^{-5}$
Ply Adhesion	ASTM D 413 or F 904	lb/in	2.0

COMPONENT PROPERTIES

GEONET	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Polymer Density	ASTM D 1505	g/cm^3	0.94
Carbon Black Content	ASTM D 4218	%	2.0
Thickness	ASTM D 5199	inches	0.200
Mass per unit area	ASTM D 5261	lbs/ft^2	0.162
Transmissivity[1]	ASTM D 4716	m^2/sec	$1x10^{-3}$@ 15,000 psf
Tensile Strength	ASTM D 5035	lbs/in	45

GEOTEXTILE	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Fabric Weight	ASTM D 5261	oz/yd^2	7.1
Thickness	ASTM D 5199	mils	95
Grab Strength	ASTM D 4632	lbs	210
Water Flow Rate	ASTM D 4491	gpm/ft^2	110
Apparent opening size (AOS)	ASTM D 4751	mm (Sieve Size)	0.150 (100)

1. Measured using water @ 20° C (68° F) with a gradient of one, between two steel plates, after one hour. Value may vary, based on dimensions of the transmissivity specimen and specific laboratory.
2. Component properties are tested prior to the lamination process. They cannot be tested on the final product.

The geocompsite will be handled in such a manner as to ensure the geocomposite are not damaged in any way. On slopes, the geocomposite will be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite will be positioned by hand after being unrolled to minimize wrinkles. Geocomposite can be placed in the horizontal direction (i.e., across the slope) in some special locations (e.g., where extra layers are required or where slope is less than 10:1).

Geocomposite will not be welded to the geomembrane. Geocomposite will be cut using approved cutters,(i.e., hook blade, scissors, etc.) Care should be taken to prevent damage to underlying layers. Care must be taken not to entrap dirt in the geocomposite that could cause clogging of the drainage system, and or stones that could damage the adjacent geomembrane.

Adjacent rolls of geocomposite will be overlapped by at least four inches and securely tied. Tying can be achieved by plastic fasteners. Tying devices will be white or yellow for easy inspection. Metallic devices are not allowed. Tying will be five to ten feet along the bottom of the slope. Tying will be every five feet along the slope, every two feet across the slope and at the top of the berm. Tying in the

anchor trench will be done in one foot intervals. In the corners of the side slopes where overlaps between perpendicular geocomposite strips are required, an extra layer of geocomposite will be unrolled along the slope, on top of the previously installed geocomposite, from the top to bottom of the slope.

Any holes or tears in the geocomposite will be repaired by placing a patch extending two feet beyond edges of the hole or tear. The patch will be secured to the original geocomposite by tying every twelve inches. If the hole or tear width across the roll is more than 50% the width of the roll, the damaged area will be cut out and the two portions of the geocomposite will be joined.

The engineer will visually inspect the drainage layer before placement of the protective soil, if any defects are detected they will be repaired before placement of protective soil.

Select Backfill

The soil for the select backfill shall consist of suitable soil free of debris, roots, rocks and organics. The soil shall contain no particles or objects greater than 3/4 inch in largest dimension, which has been screened. There are no permeability, grain size, or any other test required for this material. This material is not being used as a drainage media; leachate collection lines are installed and designed to collect water flowing on top of the protective cover.

Backfill

The soil for backfill shall consist of suitable soil free of debris, roots, rocks, and organics. There are no permeability, grain size, or any other test required for this material. This material is not being used as a drainage media; leachate collection lines are installed and designed to collect water flowing on top of the protective cover.

Protective Soil Cover

Installation of the protective cover shall be the responsibility of the contractor. Before proceeding with placement of the protective cover over the liner, the Contractor shall furnish to the Engineer with the manufacturer's certification that the lining has been satisfactorily installed in accordance with the manufacturer's recommendations.

The protective cover shall be composed of select backfill and backfill. The cover shall be installed using low ground pressure equipment such as a Caterpillar D6H LGP, or approved equal, with ground pressure not exceeding 4.71 psi until the depth of cover exceeds three feet.

When installing the cover, the contractor shall adhere to the following guidelines:

(1) A minimum of 12 inches of cover between low ground pressure equipment such as the Caterpillar D6H LGP, or approved equal, and the liner is required at all times. Roadways for entering and for transporting material over slopes and floor shall have a minimum depth of four feet.

(2) Avoid undue stress on the liner at all times. Cover material must be pushed up side slopes, never down to help minimize wrinkles. Material must be placed to minimize wrinkles, wrinkles in excess of two feet in height are unacceptable. If a wrinkle is more than two feet in height, soil will be placed on top of the wrinkle to decrease the height. Fold over of the liner will not be allowed. A worker must walk along side earth moving equipment and remove all rocks, stones, roots or other debris that could cause damage to the liner. Equipment operators must avoid sharp turns or quick stops that could pinch and tear the liner.

(3) If damage does occur, report it to the Project Manager immediately so that repairs can be performed without needless delay.

(4) Cover shall be placed and maintained in a uniform thickness, free of ruts and i Irregularities.

(5) Do not work wet cover material that cannot support equipment.

(6) Equipment operators and all other personnel must be qualified and must exercise good judgment and common sense at all times.

4.2.7 Leachate Collection System

All materials and equipment shall be furnished by an established and reputable manufacturer or supplier. All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications, or shall be the product of the listed manufacturers, or similar and equal; thereto, as approved by the Engineer.

(1) High Density Polyethylene Pipe

The polyethylene pipe shall be high performance, ultra-high molecular weight, high density polyethylene pipe, conforming to ASTM D1248 (Type III, Class C, Category 5, Grade P34). Minimum cell classification values shall be 335434C as referenced in ASTM D3350. The pipe shall be SDR 17. The pipe shall contain 2 percent carbon black. The pipe shall be "Driscopipe," as manufactured by Phillips Products Company, or equal.

(2) Stone Surrounding Perforated Collection Piping

Stone for leachate collection system shall meet the requirements of NC DOT aggregate, standard size No. 5 and shall contain no fines. Stone must pass the sieve analysis test for No. 5 stone performed at the quarry.

(3) Geotextile Filter Fabric

Filter fabric surrounding the stone/collection piping shall be non-woven needle punched drainage fabric with the following minimum properties:

1) Weight	4.5 oz/yd^2	ASTM D-5261
2) Thickness	60 mils	ASTM D-1777
3) Grab Strength	125 lbs.	ASTM D-4632
4) Grab Elongation	60%	ASTM D-4632
5) Trapezoidal Tear Strength	60 lbs.	ASTM D-4533
6) Puncture Strength	65 lbs.	ASTM D-4833
7) Mullen Burst Strength	185 psi	ASTM D-3786
8) Permittivity	1.8 sec^{-1}	ASTM D-4491
9) Apparent Opening Size (AOS)	0.212 mm (US sieve size 70)	ASTM D-4751

Filter fabric shall be manufactured by Polyfelt, Mirafi, or approved equal.

(4) Knife Gate Valves

Knife Gate Valves shall be bonnetless, wafer type made with a cast iron body, with several support ribs for a strong flanged connection. All sizes shall have a fabricated stainless steel liner. Standard flange holes will be drilled and tapped. Flange drilling dimensions will meet M.S.C. SP-81 and A.N.S.I. B16.5, Class 125/150 requirements. The raised face flange shall meet M.S.S. SP-81 face-to-face dimensions. Valves shall have all wetted parts of stainless steel. Stainless steel liner shall extend through the valve chest to the top of the packing gland. Both sides of the gate shall be finished ground. The stem shall be stainless steel and shall have double pitch threads. The yoke nut shall be acid-resisting bronze. The valve shall have a raised seat with a relieved area around the seat to prevent jamming. The valve gate shall be suitable for 125 psi pressure differential. Packing gland shall have three (3) layers of fiber packing with a 4th elastomer seal. Resilient seated knife gate valves shall have a round port with a replaceable resilient seat interlocked by a metal retaining ring. The metal ring shall act as a wiper blade to clean the gate before it passes over the seat. The resilient seat shall be captured and locked in place on three (3) sides only exposing one surface for sealing which prevents blowout. Knife gate valves shall be a series 304G as manufactured by Red Valve or equal.

(5) Polyethylene Manholes

Polyethylene manholes shall be produced using polyethylene compounds conforming to the requirement of Type III, Category "3", Class B, as defined and described in ASTM D-1248. Clean reworked material or reprocessed material may be use din the manufacture provided that the manhole components meet all the requirements of the product specification.

Polyethylene manholes shall be produced in the rotational molding process. The manhole will consist of an appropriate combination of base, elevation, and top section based on project requirements. Interior access to all manholes shall be designed so that a portable ladder or permanent step system can be supported by the installed manhole. Manholes may be supplied with factory molded steps. Manway reducers shall be concentric with respect to the larger portion of the manhole. The manhole shall be designed to accept and shall be furnished with concrete filled polyethylene manhole lids weighing not less than 190 pounds and must be compatible with a Dewey Brothers RCR-2001 standard cast iron frame. Manhole segment joints shall be designed to function as a full tongue and grove with the groove portion no less than 2.75 inches in depth, and shall include water tight gaskets and/or sealing compounds as recommended by the manufacturer.

Polyethylene manholes shall have a nominal cylinder internal diameter of 48 inches. The manway reducer nominal inside diameter shall be 27.75 inches. Wall thickness of all components shall be determined in accordance with ASTM D-2122 and shall be a minimum of .330 inches.

(6) Trenching for Leachate Piping

The Engineer shall provide on the Contract Drawings a horizontal layout for the proposed leachate collection system along with a minimum of two (2) bench marks. The Contractor shall be responsible for verifying the accuracy of any and all bench marks prior to use. No claim for extra work will be allowed for alleged inaccuracy for any bench mark. It shall be the Contractor's responsibility to protect the original line and bench marks set by the Engineer. Should this information become destroyed or damaged, the cost of the replacement will be borne by the Contractor.

Excavation for the leachate collection shall be done only after the three foot of protective cover has been installed over the flexible membrane liner.

Mechanical equipment can be used for the first two and one-half feet of excavation. The remaining one-half foot or whatever protective cover remains above the flexible membrane liner shall be excavated by hand so as to not damage the liner. If damage occurs to the liner the Engineer or Owner shall be notified immediately and the repair shall take place shortly thereafter.

(7) Installation of Geotextile Filter Fabric

Geotextile filter fabric shall be installed along the entire length of the trenching or as required by Project Specifications on top of the exposed flexible membrane liner/geocomposite net. This fabric is intended to protect the liner/net from the stone that surrounds the perforated collection piping.

In addition, the fabric shall be installed up the walls of the trench with enough excess at the top so that the stone can be completely covered with filter fabric.

4.2.8 Closure Cap System

All materials and equipment shall be furnished by an established and reputable manufacturer or supplier. All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications or shall be the product of the listed manufacturers or similar and equal thereto as approved by the Engineer.

4.2.9 Closure Cohesive Soil Cap

All materials and equipment shall be furnished by an established and reputable manufacturer or supplier. All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications or shall be the product of the listed manufacturers or similar and equal thereto as approved by the Engineer.

Cohesive Soil Cap Borrow Material

Test Name	Test Method	Contractor/Engineer Frequency
Moisture/Density	ASTM D698/D1557	1 per 5000 c.y.
Remolded Permeability	ASTM D5084	1 per 5000 c.y.
Atterberg Limits	ASTM D4318	1 per 5000 c.y.
Visual Classification	ASTM D2488	1 per 5000 c.y.
Grain Size Distribution	ASTM D422	1 per 5000 c.y.

Cohesive Soil Cap Test Pad

Test Name	Test Method	Contractor/Engineer Frequency
Field Moisture/Density	ASTM D1556 (sand cone) ASTM D2922/D3017 (nuclear gauge) ASTM D2937 (drive cylinder)	3 per lift
Permeability	ASTM D5084	1 per lift
Remolded Permeability	ASTM D5084	1 per lift
Atterberg Limits	ASTM D4318	1 per lift
Visual Classification	ASTM D2488	1 per lift
Grain Size Distribution	ASTM D422	1 per lift

In-Place Cohesive Soil Cap

Test Name	Test Method	Contractor/Engineer Frequency
Field Moisture/Density	ASTM D1556 (sand cone) ASTM D2922/D3017 (nuclear gauge) ASTM D2937 (drive cylinder)	1 per lift per acre
Permeability	ASTM D5084	1 per lift per acre
Atterberg Limits	ASTM D4318	1 per lift per acre
Visual Classification	ASTM D2488	1 per lift per acre
Grain Size Distribution	ASTM D422	1 per lift per acre

(a) Suitable on-site and/or off-site soils may be used as cohesive soil cap if it can achieve an in-place permeability of 1.0×10^{-5} cm/sec or less and meets all testing requirements indicated in the material testing paragraph in this section. Wyoming bentonite or an approved equivalent may be blended with the soil to lower the soil's permeability.

(b) A permeability "window" shall be developed for each type of soil from the borrow material that will be used for construction of the cohesive soil cap. The window shall be plotted on a semi-log plot with moisture content versus density. Laboratory testing to develop the window shall include a series of remolded samples compacted to various dry densities and moisture contents utilizing the same compactive effort (ASTM D 698 or D 1557). The remolded samples shall be tested for permeability to determine whether or not the particular soil type will provide the maximum permeability (1.0×10^{-5} cm/sec) at various dry densities and moisture contents. The window is then developed from the accepted remolded samples and moisture contents from the semi-log plot. A straight line is typically drawn between the acceptable points on the moisture-density curve to indicate a range of probable acceptable permeability results. The window will be used in the construction of the test strip to verify the laboratory remolded permeability results.

(c) Atterberg limits and grain size distribution shall also be conducted on the bulk samples used to prepare the permeability window ASTM D2488, D4318, D422. These tests can be used as indices on random samples collected from the borrow site during construction to verify the soil type is the same as was used to develop the "window". As a minimum, sufficient visual classifications and Atterberg limits shall be conducted in association with each permeability test to verify that the construction materials meet specifications.

(d) A test strip of compacted cohesive soil cap shall be prepared to verify the permeability "window" prior to general installation of the cohesive soil cap. The test strip will be used to verify the results from the remolded permeabilities from the borrow site utilizing the permeability window(s) for each soil type that is going to be used for construction of the cohesive soil cap. At a minimum, the verification will consist of three moisture density tests, one Atterberg limits test, one grain size distribution test (ASTM D2488, D4318, and D422), and one Shelby Tube sample for each lift constructed in the test pad. Laboratory permeability tests shall be performed on tube (Shelby or drive tubes) samples of the cohesive soil cap after placement and compaction. The permeability must be a maximum of 1.0×10^{-5}cm/sec. Tests shall be performed in accordance with the ASTM D5084. The test strip shall be approximately 2,500 sq. ft. in surface area and constructed to conform geometrically to the site topography with a minimum lateral dimension in any direction of 25 ft. The test strip shall consist of at least three compacted 6 inch lifts of cohesive soil cap. Placement and testing of the test strip shall be in conformance with the construction specifications and requirements for general installation of the cohesive soil cap. Test results from the test strip shall be used to guide placement and achievement of the required maximum permeability of 1.0×10^{-5} cm/sec of the cohesive soil cap. The test strip may be used as an integral part of the overall cohesive soil cap if it meets the required specification for the cap. All results shall be given to the Construction Observer.

(e) The soils shall be placed to the total thickness shown on the plans in maximum 8-inch thick loose lifts with a maximum 6" compacted lift compacted preferably at a moisture content between 0 to 3% above optimum moisture content to 95% standard Proctor maximum dry density (ASTM Test Designation D698). A sheepsfoot roller or approved alternative may be used to compact the soil cap provided the compaction and permeability requirements can be achieved. Each lift shall be tested for permeability, moisture content, particle size distribution analysis, Atterberg limits, moisture-density-permeability relation, and if needed percent bentonite admixed with soil, prior to the placement of the succeeding lift and visually inspected to confirm that all soil clods have been broken and that the surface is sufficiently scarified so that adequate bonding can be achieved. Soils for cohesive soil cap shall be screened, disced, or prepared using any other approved method as necessary to obtain a homogeneous cohesive soil with clod sizes in a soil matrix no larger than about 1.5 inches in maximum diameter. After each lift, the surface shall be scarified prior to the placement of the next lift to provide good bonding from one lift to the next.

(f) The cohesive soil cap shall be tested to evaluate the coefficient of permeability. The coefficient of permeability of the soil cap shall be equal to or less than 1.0×10^{-5} cm/sec after placement and compaction. The soil cap must be a minimum of 1.5 feet thick.

(g) Laboratory permeability tests shall be performed on tube (Shelby or drive tubes) samples of the cohesive soil cap after placement and compaction. The permeability must be a maximum of 1.0×10^{-5} cm/sec. Tests shall be performed in accordance with ASTM D5084.

(h) The soil cap shall be tested a minimum of one soil sample per lift per acre for laboratory permeability. All permeability testing will be on random samples judged by the Engineer to be representative of the most permeable soil conditions for the area being tested. The project engineer shall certify that the materials used in construction were tested according to the Division approved plans. If after placement of the soil cap it fails the required tests, the material will either be reworked or replaced. The soil cap must remain moist at all times, if any section becomes dry, rework the dry area and moisten.

(i) A minimum of two (2) inches of soil shall be removed prior to securing each sample for permeability testing. The sampling tube shall be advanced vertically into the soil with as little soil disturbance as possible and should be pushed using a uniform pressure. The sampling tube (Shelby tube), when extracted, shall be free of dents, and the ends shall not be distorted. A backhoe or approved alternative should be used to advance the sampling tube (Shelby tube) as long as disturbance is minimized. Drive tube samples of the cap may be obtained for permeability testings. If the Engineer judges the sample to be too disturbed, another sample shall be taken. Once an acceptable sample has been secured and properly prepared, all sample excavations shall be backfilled to grade with a 50% mixture of bentonite and similar soils in maximum 3-inch loose lifts and hand tamped with a blunt tool to achieve a tight seal equivalent to the original density.

(j) No additional construction shall proceed on the soil layers at the area being tested until the Engineer has reviewed the results of the tests and judged the desired permeability is being achieved.
(k) As a minimum, sufficient visual classifications (ASTM Test Designation D2488) , analyses (ASTM Test Designation D422) and Atterberg limits (ASTM Test Designation D4318) shall be conducted in association with each permeability test to verify that the construction materials meet specifications. The minimum number of tests will be 1 per lift per acre.

(l) If the soil for the cohesive soil cap is incapable of achieving the required permeability when compacted, bentonite or approved alternative may be mixed with the soils to decrease the permeability. The amount of additive required must be determined in the laboratory. Where additives are required, the soil shall be placed in maximum 8-inch thick loose lifts and compacted preferably between 0 to +3% optimum moisture content to 95% standard Proctor maximum dry density (ASTM Test Designation D698) for the soil-additive mixture. All other compaction procedures for the soil apply.

(m) Surfaces to be lined shall be smooth and free of debris, roots, and angular or sharp rocks larger than three-eight (3/8) inches in diameter to a depth of six (6) inches. The cohesive soil cap shall have no sudden sharp or abrupt changes in grade.

(n) The Contractor shall protect the cohesive soil cap from desiccation, flooding and freezing. Protection, if required, may consists of a thin plastic protective cover, (or other material as approved by the engineer) installed over the completed cohesive soil cap until such time as the placement of flexible membrane liner begins. Areas found to have any desiccation cracks or which exhibit swelling, heaving or other similar conditions shall be replaced or reworked by the contractor to remove these defects.

(o) The thickness and grade of the soil cap will be verified by the surveyor before placement of the geomembrane liner. The soil cap will be surveyed at 100' grid points where the elevations of the top of landfill will be checked with the top of soil cap to verify 1.5 feet of soil cap. The grade will then be verified with the surveyed information. The survey will be performed by NC licensed surveyors.

(p) Surface Acceptance. Upon request, the Flexible Membrane Liner manufacturer installer shall provide the Engineer with a written acceptance of the surface prior to commencing installation. Subsequent repairs to the cohesive soil cap and the surface shall remain the responsibility of the contractor.

4.2.10 Closure Flexible Membrane Liner Method of Deployment

All materials and equipment shall be furnished by an established and reputable manufacturer or supplier. All materials and equipment shall be new and shall be of first class ingredients and construction, designed and guaranteed to perform the service required and shall conform with the following standard specifications or shall be the product of the listed manufacturers or similar and equal thereto as approved by the Engineer.

Flexible Membrane Liner Tests

Test Name	Description	Test Method	Frequency
Air Test	Air Test Seams		Every Seam
Vacuum Test	Every welded area		Where air test impossible
Destructive Tests	Seam Strength	ASTM D4437	Every 500' of seam

Qualified liner installers, seamers, and the liner foreman shall meet a minimum requirement of 1,000,000 square feet of geomembrane installation. There are no other minimum qualifications needed by other parties.

40 mil Linear Low Density Polyethylene (LLDPE) is to be placed in direct contact with moist cohesive soil cap. The extrusion rods and/or brads used in seaming the rolls together shall be derived from the same base resin as the liner and shall meet the following minimum properties:

Smooth 40 mil LLDPE Liner Specifications

Property	Test Method	Test Value	Contractor/Engineer Test Frequency
Thickness (min. avg.)	D5199	nom. (mil)	Per roll
- lowest individual for 8 out of 10 values		-10%.	
Density (max.)	D1505/D792	0.939	200,000 lb
Tensile Properties (1)(min. avg.)	D638 Type IV		20,000 lb
- yield stress lb/in		64	

- break stress lb/in		152	
- yield strain %		13	
- break strain %		800	
2% Modulus - psi (max.)	D5323	30,000	20,000 lb
Tear Resistance- lb/in (min avg.)	D1004	22	45,000 lb
Puncture Resistance- lb/in (min avg.)	D4833	56	45,000 lb
Axi-Symmetric Break Strain- % (min)	D5617	30	200,000 lb
Stress Crack Resistance- hr (2)	D5397 (App.)	n/a	per GRI-GM10
Carbon Black Content- %	D1603 (3)	2.0-3.0	20,000 lb
Carbon Black Dispersion	D5597	note (4)	45,000 lb
Oxidative Induction Time (OIT) (min ave,) (5)			
(a) Standard OIT	D3895	120 min.	
-or-			200,000 lb
(b) High Pressure OIT	D5885	500 min.	
Oven Aging at 85°C (6)	D5721		
(a) Standard OIT (min. ave) -% retained after 90 days	D3895	55	per each formulation
-or-			
(b) High Pressure OIT (min ave) -% retained after 90 days	D5885	80	
UV Resistance (7)			
(a) Standard OIT (min avg.)	D3890	N.R. (8)	
-or-			per each formulation
High Pressure OIT (min avg.) -% retained after 1600 hrs (9)	D5885	50	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction yield elongation is calculated using a gage length of 33 mm Break elongation is calculated using a gage length of 50 mm
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D4128 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
(4) Carbon black dispersion for 10 different views: - all 10 in Categories 1 or 2
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr UV cycle at 75°C followed by 4hr condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

(1) Preparation for Geomembrane Deployment

(a) Panel Layout

Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and location of seams for the project.

(b) Identification

Each panel used for the installation shall be given a numeric or alpha-numeric identification number consistent with the layout drawing. This identification number shall be related to manufacturing roll number that identifies the resin type, batch number and date of manufacture.

(c) Verification

The manufacturers certification will be given to the construction observer. The construction observer will inspect all certifications. If the certification does not meet specifications, it will be rejected. Adequate laboratory QA/QC conformance testing shall be performed by contractor/engineer to verify minimum requirements.

(2) Field Panel Placement

(a) Location

The Flexible Membrane Liner Manufacturer/Installer shall install field panels at the location indicated on the layout drawing. If the panels are deployed in a location other than that indicated on the layout drawings, the revised location shall be noted in the field on a layout drawing which will be modified at the completion of the project to reflect actual panel locations.

(b) Weather Conditions

Geomembrane deployment shall not be carried out during any precipitation, nor in the presence of excessive moisture (i.e. fog, dew), in an area of standing water, or during high winds.

(c) Method of Deployment

(1) The method and equipment used to deploy the panels must not damage the geomembrane or the supporting subgrade surface.

(2) No personnel working on the geomembrane will smoke, wear shoes that can damage the geomembrane, or engage in actions which could result in damage to the geomembrane.

(3) Adequate temporary loading and/or anchoring, (i.e. sandbags, tires), which will not damage the geomembrane, will be placed to prevent uplift of the geomembrane by wind. If uplift occurs, additional sandbags will be placed in necessary areas.

(4) The geomembrane will be deployed in a manner to minimize wrinkles. The geomembrane will have no fold overs.

(5) Any damage to a panel of the geomembrane will be repaired. Any area of a panel seriously damaged (torn, twisted, or crimped) will be marked, cut out and removed from the work area with resulting seaming and/or repairs performed.

(3) Field Seaming

(a) Layout

In general, seams shall be oriented parallel to the slope, i.e., oriented along, not across the slope. Whenever possible, horizontal seams should be located not less than five (5) feet from the toe of the slope. Each seam made in the field shall be numbered in a manner that is compatible with the panel layout drawing for documentation of seam testing results.

(b) Personnel

All personnel performing seaming operations shall be trained in the operation of the specific seaming equipment being used and will qualify by successfully welding a test seam. The project foreman will provide direct supervision of all personnel seaming to verify proper welding procedures are followed. Qualified liner installers, seamers, and the liner foreman shall meet a

minimum requirement of 1,000,000 square feet of geomembrane installation. There are no other minimum qualifications needed by other parties.

(c) Equipment

(1) Fusion Welding

Fusion Welding consists of placing a heated wedge, mounted on a self propelled vehicular unit, between two (2) overlapped sheets such that the surface of both sheets are heated above the polyethylene's melting point. After being heated by the wedge, the overlapped panels pass through a set of preset pressure wheels which compress the two (2) panels together so that a continuous homogeneous fusion weld is formed. The fusion welder is equipped with a temperature readout device which continuously monitors the temperature of the wedge.

(2) Extrusion Fillet Welding

Extrusion fillet welding consists of introducing a ribbon of molten resin along the edge of the seam overlap of the two (2) sheets to be welded. The molten polymer causes some of the material of each sheet to be liquefied resulting in a homogeneous bond between the molten weld bead and the surfaces of the sheets. The extrusion welder is equipped with gauges giving the temperature in the apparatus and the preheat temperature at the nozzle.

(d) Weather Conditions

The Flexible Membrane Liner Manufacturer/Installer will rely on the experience of the Project Superintendent and the results of test seams to determine seaming restrictions by weather. Many factors, such as ambient temperature, humidity, wind, sunshine, etc., can effect the integrity of field seams and must be taken into account when deciding whether or not seaming should proceed. Responsibility for monitoring these conditions shall lie with the Project Superintendent; however, the Engineer may suspend any seaming operation which is, in his opinion, at the risk of providing the Owner with a quality product. Test seams are required prior to daily production seaming to determine if the weather conditions will effect the Flexible Membrane Liner System's ability to produce quality seams. Additional non-destructive and destructive testing of production seams substantiate the decision made by the Project Superintendent to seam on any given day.

(4) Seam Preparation

(a) Fusion Welding

(1) Overlap the panels of geomembrane approximately four (4) inches.

(2) Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, debris of any kind. No grinding is required for fusion welding.

(3) Adjust the panels so that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

(4) A *movable protective layer may be used, at the discretion of the Flexible* Geomembrane Liner System Project Superintendent, directly below the overlap of geomembrane that is to be seamed to prevent build-up of moisture between the panels.

(b) Extrusion Welding

(1) Overlap the panels of geomembrane a minimum of three (3) inches.

(2) Temporarily bond the panels of geomembrane to be welded taking care not to damage the geomembrane.

(3) Grind seam overlap prior to welding within one (1) hour of welding operation in a manner that does not damage the geomembrane. Limit grinding to ¼" outside of the extrusion weld area.

(4) Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, and debris of any kind.

(5) Purge the extruder prior to beginning the seam to remove all heat-degraded extrudate from the barrel.

(6) Keep welding rod clean and off the ground.

(5) Test Seams

Test seams shall be performed at the beginning of each seaming period and at approximately every 4-working hour intervals for each seaming apparatus used that day. Test seams shall be made on fragment pieces of the geomembrane liner and under the same conditions as actual seams.

(a) Test Seam Length

The test seam shall be at least three (3) feet long and should be made by joining two (2) pieces of geomembrane at least 9" in width.

(b) Sample Procedure

(1) Visually inspect the seam for squeeze out, footprint, pressure and general appearance.

(2) Two random samples one (1) inch wide shall be cut from the test seam. The specimens shall then be tested in peel using a field tensiometer and shall not fail in the seam. If a specimen fails the entire procedure shall be repeated.

(3) If any of the second set of specimens fail, the seaming apparatus shall not be accepted and shall not be used for seaming until the deficiencies are corrected and a passing test seam is achieved.

(4) After completion of these tests, the remaining portion of test seam can be discarded. Documentation of the test seams will be maintained listing seam identification number, welder's name, temperature control setting and test results.

(5) Passing test results records shall be maintained.

(6) General Seaming Procedures

(a) Seaming shall extend to the outside edge of panels to be anchored.

(b) While welding a seam, monitor and maintain the proper overlap.

(c) Inspect seam area to assure area is clean and free of moisture, dust, dirt, debris of any kind.

(d) While welding a seam, monitor temperature gauges to assure proper settings are maintained and that the seaming apparatus is operating properly.

(e) Align wrinkles at the seam overlap to allow welding through the wrinkle.

(f) Fishmouths or wrinkles at seam and overlaps that cannot be welded through shall be cut along the ridge in order to achieve a flat overlap. The cut fishmouth or wrinkle shall be seamed. Any portion where the overlap is inadequate shall be patched with an oval or round patch of the same geomembrane extending a minimum of six (6) inches beyond the cut in all directions.

(g) All cross/butt seams between two (2) rows of seamed panels shall be welded during the coolest time of the day to allow for contraction of the geomembrane.

(h) All "T" joints shall have the overlap from the wedge welder seam trimmed back to allow an extrusion fillet weld. Then grind ¼ of an inch minimum on either side of the wedge seam, then extrusion weld all of the area prepared by grinding.

4.2.11 Closure Flexible Membrane Liner Tests

The installation crews will non-destructively test all field seams over their full length using air pressure testing, vacuum testing or other approved methods, to verify the continuity and integrity of the seams.

(a) Air Pressure Testing

The welded seam created by double hot-wedge fusion welding process is composed of two distinct welded seams separated by an unwelded channel approximately 3/8 of an inch between the two welded seams permits the double hot-wedge fusion seams to be tested by inflating the sealed channel with air to a predetermined pressure, and observing the stability of the pressurized channel over time.

(1) Equipment for Air Testing

An air pump (manual or motor driven) capable of generating and sustaining a pressure between 25 to 30 psi.

A rubber hose with fittings and connections.

A sharp hollow needle, or other approved pressure feed device with a pressure gauge capable of reading and sustaining a pressure between 25 to 30 psi.

(2) Procedure for Air Testing

Seal both ends of the seam to be tested.

Insert needle or other approved pressure feed device into the sealed channel created by the fusion weld.

Inflate the test channel to a pressure between 25 to 30 psi, in accordance with the following schedule, close valve, and observe initial pressure after approximately 2 minutes.

INITIAL PRESSURE SCHEDULE *

Material (Mil)	Min. Psi	Max. Psi
40	25	30
60	27	30
80	30	30
100	30	30

* Initial pressure settings are read after a two minute "relaxing period". The purpose of this "relaxing period" is to permit the air temperature and pressure to stabilize.

Observe and record the air pressure five (5) minutes after "relaxing period" ends and when initial pressure setting is used. If loss of pressure exceeds the following or if the pressure does not stabilize, locate faulty area and repair.

MAXIMUM PERMISSIBLE PRESSURE DIFFERENTIAL AFTER 5 MINUTES - LLDPE

Material (Mil)	Pressure Diff.
40	4 psi
60	3 psi
80	3 psi
100	3 psi

At the conclusion of the pressure test the end of the seam opposite the pressure gauge is cut. A decrease in gauge pressure must be observed or the air channel will be considered "blocked" and the test will have to be repeated after the blockage is corrected.

Remove needle or other approved pressure feed device and seal resulting hole by extrusion welding.

(3) In the event of a Non-Complying Air Pressure Test, the following procedure shall be followed:

Check seam end seals and retest seams.

If non-compliance with specified maximum pressure differential re-occurs, repair the seam. Capping or removal/reseam of the non-complying seam are the only two (2) acceptable methods for repairing failed seams. Non-destruct test the entire length of the repaired seam.

(b) Vacuum Testing

This test is used when the geometry of the weld makes air pressure testing impossible or impractical or when attempting to locate the precise location of a defect believed to exist after air pressure testing. The penetration will be tested using this method.

(1) Equipment for Vacuum Testing

Vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.

Vacuum pump assembly equipped with a pressure controller and pipe connection.

A rubber pressure/vacuum hose with fittings and connections.

A bucket and means to apply a soapy solution.

A soapy solution.

(2) Procedure for Vacuum Testing

Trim excess overlap from seam, if any.

Turn on the vacuum pump to reduce the vacuum box to approximately 5 inch of mercury, i.e., 5 psi gauge.

Apply a generous amount of a solution of strong liquid detergent and water to the area to be tested.

Place the vacuum box over the area to be tested and apply sufficient downward pressure to "seat" the seal strip against the liner.

Close the bleed valve and open the vacuum valve.

Apply a minimum of 5 in. Hg vacuum to the area as indicated by the gauge on the vacuum box.

Ensure that a leak tight seal is created.

For a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.

If no bubbles appear after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in. overlap, and repeat the process.

(3) Procedure for Non-Complying Test

Mark all areas where soap bubbles appear and repair the marked areas.
Retest repaired areas.

(c) Destructive Testing

(1) Concept

The purpose of destructive testing is to determine and evaluate seam strength. These tests require direct sampling and thus subsequent patching. Therefore destructive testing should be held to a minimum to reduce the amount of repairs to the geomembrane.

(2) Procedure for Destructive Testing

All Destructive tests will be done according to ASTM D4437. Destructive test samples shall be marked and cut out randomly at a minimum average frequency of one test location every 500 feet of seam length.

Additional destructive tests may be taken in areas of contamination, offset welds, visible crystallinity or other potential cause of faulty welds at the descretion of the Project Superintendent and Engineer.

Sample Size

The sample should be twelve (12) inches wide with a seam fourteen (14) inches long centered lengthwise in the sample. The sample may be increased in size to accommodate independent laboratory testing by the owner at the owner's request or by specific project specifications.

A one (1) inch sample shall be cut from each end of the test seam for field testing.

The two (2), one (1) inch wide samples shall be tested in the field in a tensiometer for peel ASTM D4437. Tensile strength is essentially a measurement of the greatest tension stress a substance can bear without tearing. If the liner tears before any part of the seam does the test is successful. If any field sample fails to pass, it will be assumed the sample fails destructive testing. The passing destructive test requirements for 40-mil liner seam is: minimum peel adhesion of 52 ppi, minimum shear strength of 80 ppi, and Film Tear Bond (FTB).

(3) Procedure in the event of Destructive Test Failure

Cut additional field samples for testing. In the case of a field production seam, the samples must lie a minimum of ten (10) feet in each direction from the location of the failed sample. Perform a field test for peel strength. If these field samples pass, then laboratory samples can be cut and forwarded to the laboratory for full testing.

If the laboratory samples pass then repair the seam between the two (2) passing samples locations.

Capping or removal/reseam of the non-complying seam are the only two (2) acceptable methods for repairing failed seams.

All destructive seam samples sent to the Flexible Membrane Liner System's laboratory shall be numbered.

(d) Quality Assurance Laboratory Testing

(1) Destructive samples sent to the laboratory will be tested for "shear strength" and "peel adhesion" (ASTM D4437 as modified by NSF). Five (5) specimens shall be tested for each test method with data recorded. Four (4) out of the five (5) specimens must pass for each test in order for the seam to pass the destructive test.

(2) Defects and Repairs

(a) The Project Superintendent shall conduct a detailed walk through and visually check all seams and non-seam areas of the geomembrane for defects, holes, blisters and signs of damage during installation.

(b) All other installation personnel shall, at all times, be on the lookout for any damaged areas. Damaged areas shall be marked and repaired.

(c) Repair Procedures

Any portion of the geomembrane showing a flaw or failing a destructive or non-destructive test shall be repaired. Several procedures exist for repair and the decision as to the appropriate repair procedure shall be made by the Project Superintendent. Repairs need to be made in a timely manner to protect the moist

cohesive soil liner and flexible membrane liner. If inclement weather is approaching, steps need to be made to protect the cohesive soil cap such as a temporary cover. If cohesive soil cap is damaged, it must be reworked. Procedures available for liner repair:

Patching - used to repair large holes, tears and destructive sample locations. All patches shall extend at least six (6) inches beyond the edges of the defect and all corners of patches shall be rounded.

Grinding and welding - used to repair sections of extruded seams.

Spot welding or seaming - used to repair small tears, pinholes or other minor localized flaws.

Capping - used to repair lengths of failed seams.

Removal of a bad seam and replacement with a strip of new material seamed into place.

(d) Verification of Repairs

Every repair shall be non-destructively tested. Repairs which pass the non-destructive test shall be deemed adequate. Large repairs may require a destructive test. Repair test results shall be logged. The repair location shall be recorded on an as-built drawing.

4.2.12 Closure Protective Cover

(1) HPDE Geocomposite Drainage Netting manufactured by SKAPS Industries, or approved equal.

GEOCOMPOSITE PROPERTIES

PROPERTY	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Thickness	ASTM D 5199	inch	0.305
Transmissivity[1] (15,000 psf)	ASTM D 4716	m^2/sec	$3x10^{-5}$
Ply Adhesion	ASTM D 413 or F 904	lb/in	2.0

COMPONENT PROPERTIES

GEONET	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Polymer Density	ASTM D 1505	g/cm^3	0.94
Carbon Black Content	ASTM D 4218	%	2.0
Thickness	ASTM D 5199	inches	0.200
Mass per unit area	ASTM D 5261	lbs/ft^2	0.162
Transmissivity[1]	ASTM D 4716	m^2/sec	$1x10^{-3}$@ 15,000 psf
Tensile Strength	ASTM D 5035	lbs/in	45

GEOTEXTILE	TEST	UNITS	MINIMUM AVERAGE ROLL VALUE
Fabric Weight	ASTM D 5261	oz/yd^2	7.1
Thickness	ASTM D 5199	mils	95
Grab Strength	ASTM D 4632	lbs	210
Water Flow Rate	ASTM D 4491	gpm/ft^2	110
Apparent opening size (AOS)	ASTM D 4751	mm (Sieve Size)	0.150 (100)

1. Measured using water @ 20° C (68° F) with a gradient of one, between two steel plates, after one hour. Value may vary, based on dimensions of the transmissivity specimen and specific laboratory.
2. Component properties are tested prior to the lamination process. They cannot be tested on the final product.

The geocompsite will be handled in such a manner as to ensure the geocomposite are not damaged in any way. On slopes, the geocomposite will be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite will be positioned by hand after being unrolled to minimize wrinkles. Geocomposite can be placed in the horizontal direction (i.e., across the slope) in some special locations (e.g., where extra layers are required or where slope is less than 10:1).

Geocomposite will not be welded to the geomembrane. Geocomposite will be cut using approved cutters,(i.e., hook blade, scissors, etc.) Care should be taken to prevent damage to underlying layers. Care must be taken not to entrap dirt in the geocomposite that could cause clogging of the drainage system, and or stones that could damage the adjacent geomembrane.

Adjacent rolls of geocomposite will be overlapped by at least four inches and securely tied. Tying can be achieved by plastic fasteners. Tying devices will be white or yellow for easy inspection. Metallic devices are not allowed. Tying will be five to ten feet along the bottom of the slope. Tying will be every five feet along the slope, every two feet across the slope and at the top of the berm. Tying in the anchor trench will be done in one foot intervals. In the corners of the side slopes where overlaps between perpendicular geocomposite strips are required, an extra layer of geocomposite will be unrolled along the slope, on top of the previously installed geocomposite, from the top to bottom of the slope.
Any holes or tears in the geocomposite will be repaired by placing a patch extending two feet beyond edges of the hole or tear. The patch will be secured to the original geocomposite by tying every

twelve inches. If the hole or tear width across the roll is more than 50% the width of the roll, the damaged area will be cut out and the two portions of the geocomposite will be joined.

The engineer will visually inspect the drainage layer before placement of the erosive layer, if any defects are detected they will be repaired before placement of erosive layer.

(2) Erosive Layer

The soil for the erosive layer shall consist of any soils suitable of supporting vegetative growth. The erosive layer shall be installed using low ground pressure equipment such as a Caterpillar D6H LGP, or approved equal, with ground pressure not exceeding 4.71 psi. When installing the erosive layer, the contractor shall adhere to the following guidelines:

(a) A minimum of twelve inches (12") of cover between low ground pressure equipment and the liner is required at all times. Roadways for entering and for transporting material over slopes and capped/lined areas shall have a minimum depth of four feet (4').

(b) Avoid undue stress on the liner at all times. Cover material must be pushed up slopes, never down to help minimize wrinkles. Material must be placed to minimize wrinkles, wrinkles in excess of two feet in height are unacceptable. If a wrinkle is more than two feet in height, soil will be placed on top of the wrinkle to decrease the height. Fold over of the liner will not be allowed. A worker must walk along side earth moving equipment and remove all rocks, stones, roots or other debris that could cause damage to the liner. Equipment operators must avoid sharp turns or quick stops that could pinch and tear the liner.

(c) If damage does occur, report it to the Project Manager immediately so that repairs can be performed without needless delay.

(d) Do not work wet cover material that cannot support equipment.

(e) Equipment operators and all other personnel must be qualified and must exercise good judgment and common sense at all times.

(3) Vegetative Layer

Native vegetation will be used as approved by the Erosion Control Plan.

4.2.13 Closure Methane Venting System

NC.D.O.T. No.5 stone, Geotextile fabric, and 8" and 10" plastic pipes will be used in the construction of the gas venting system.

(1) Stone in Trenches and Surrounding Perforated Collection Piping

Stone for methane collection system shall meet the requirements of NC DOT aggregate, standard size No. 5 and shall contain no fines. Stone must pass the sieve analysis test for No. 5 stone performed at the quarry.

(2) Geotextile Fabric

Geotextile fabric surrounding the stone/piping shall be non-woven needle punched fabric with the following minimum properties:

1)	Weight	8.0 oz/yd^2	ASTM D-3776
2)	Grab Strength	205 lbs.	ASTM D-4632
3)	Grab Elongation	50%	ASTM D-4632
4)	Trapezoidal Tear Strength	85 lbs.	ASTM D-4533
5)	Puncture Strength	100 lbs.	ASTM D-4833
6)	Mullen Burst Strength	320 psi	ASTM D-3786
7)	Permittivity	1.4 sec^{-1}	ASTM D-4491

Geotextile fabric shall be manufactured by Polyfelt , TNS Advanced Technologies, or approved equal.

(3) Plastic Pipe

Plastic gravity sewer pipe and fittings used for methane vent shall be unplasticized polyvinyl chloride (PVC) and conform to the requirements of ASTM Designation D-3034 on ASTM F679, Type PSM, Class 12454-B, SDR-35 with elastomeric gasket joints. PVC pipe and fittings shall be as manufactured by J-M Pipe, Certainteed, H&W Industries or equal. The methane riser pipe shall be a 10 inch solid wall PVC pipe.

4.3 Documentation

At the completion of the contract, it is the Engineer's responsibility to provide to the Owner and eventually to the Division of Solid Waste Management the following:

1. As-built drawings of the subgrade, liner system, leachate collection.
2. Documentation of all subbase standard Proctor tests.
3. Documentation of all cohesive soil liner tests including test pads, permeability, standard Proctor and Atterberg limits.
4. Documentation of all destructive and non-destructive tests, methods and results and repairs.
5. Geomembrane panel layout with test locations and repairs illustrated.
6. Summary from the Project Engineer.
7. Any other pertinent documentation.

The CQA report shall be sealed by the Project Engineer and a certification that construction was completed an accordance with the CQA plan, Conditions of the permit to construct, The requirements of rule .1624 Construction Requirements for MSWLF Facilities, and acceptable engineering practices.

Shop Drawings

Contractor is required to submit to the Engineer a descriptive detail and any shop and setting drawings. On composite liner system, such submission shall include the following:

(1) Flexible Membrane Liner Panel Layout Drawings,
(2) Flexible Membrane Liner Penetration Details,
(3) Flexible Membrane Liner Anchoring Detail,
(4) Flexible Membrane Liner Seaming Detail,
(5) Single Flexible Membrane Liner Anchoring to Structure Detail,
(6) Flexible Membrane Liner Extension Detail, and
(7) Certified experience records for manufacturer, fabricator and installer, listing installations of Flexible Membrane Liners.

SEAM TESTING

Project Name _____ Project Number _____ Superintendent _____

NSC FIELD SEAM NO.	SEAM DATE	SHOP DWGN SEAM NO.	WELDER AND SEAMER ID. NO.	TEST DATE	START _____		END _____		AIR TEST RESULTS	COMMENTS	REPAIR DATE	WELDER AND GUN ID. NO.	REPAIR VACUUM TEST DATE	SEAM (INITIAL) (DATE)
					PRESS.	TIME	PRESS.	TIME						

Page _____ of _____

DESTRUCTIVE TEST SAMPLES

Project Name _____ Project Number _____ Supervisor _____

DATE	WELDER ID.	SEAMER	SEAM NO.	LOCATION	SAMPLE ID.

Page _____ of _____

TEST SEAM RECORDS

Project Name _____ Project Number _____ Supervisor _____

TEST DATE	TIME	LBS./IN.	PASS/FAIL	MACHINE NUMBER	TEMP. SETTING	OPERATOR

Page _____ of _____

REPAIR REPORT

Project Name _____ Project Number _____ Supervisor _____

FIELD SEAM #	PANEL #	REPAIR DATE	WELDER AND SEAMER ID. #	LOCATION OF REPAIR	REPAIR VACUUM TEST DATE	REPAIR ACCEPTED (INITIAL) (DATE)

Page _____ of _____