Polyethylene Geomembrane Product Specifications

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PART I
PURPOSE

This manual addresses the quality assurance and quality control of the installation of High Density Polyethylene (HDPE) geomembrane liners used by Colorado Lining Construction (CLC) in hazardous waste disposal landfills, surface impoundments or other installations as specified by the owner and/or engineer. This manual delineates the quality procedures and standards for installation.

1.1.0 Scope of Quality Assurance

The scope of this manual includes the quality assurance applicable to shipment, handling, and installation of High Density Polyethylene (HDPE) geomembrane liners also referred to Flexible Membrane Liners (FML's).

1.2.0 Units

In this manual, all properties and dimensions are expressed in English units, with "equivalent" Système International (SI)/metric units in parentheses. It should be noted that the conversion is typically only accurate within ten percent. In cases of conflict or clarifications, the U.S. units shall be deemed to govern. Since most field geomembrane testing equipment manufactured in the United States are equipped to measure in English units, required test result data are tabulated herein with such units.

1.3.0 References

The manual includes references to test procedures of the American Society for Testing and Materials (ASTM), the Federal Test Method Standards (FTMS) and the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF).

PART II
DELIVERY

2.1.0 Transportation and Handling

CLC through its own transportation or an independent trucking firm or other party as agreed upon by the Owner will perform transportation of the geomembrane. If the geomembrane arrives on site prior to CLC project personnel, the Owner is responsible for off-loading roll goods and any ancillary items shipped. The material received shall be matched against the freight bill of lading. Any discrepancies shall be immediately reported to CLC before the shipment is signed for. When off-loaded, geomembrane and any ancillary items should be placed on a smooth, well drained surface, free of rocks or any other protrusions which may damage the material. No special covering is necessary for geomembrane.

The following should be verified prior to and during off-loading geomembrane:

> Handling equipment used on the site is adequate and does not pose any risk or damage to the geomembrane and that personnel handle the geomembrane with care. If slings are provided, the material should be lifted with such. In any event, materials shall be offloaded in a safe manner whereby the rolls are properly balanced and no personnel or property are at risk of being injured/damaged should loss of control of any roll(s) of material occur.

Upon arrival at the site, CLC shall conduct a surface observation of all rolls for

defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. CLC shall indicate any damage to the Owner's Representative. The Owner shall immediately report to CLC any damage known to exist prior to delivery or that may have occurred during off-loading/handling.

2.2.0 Storage

The Owner shall provide storage in location (or several locations) such that on-site transportation and handling are minimized. Storage space should be protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined.

2.2.1 Special Consideration for Welding Rod or GCL Liner

Should any welding rod or geoclay (GCL) liner be delivered to the site prior to CLC arrival, such materials shall be immediately secured in a sheltered/dry condition and maintained in such condition until deployed by CLC personnel.

PART III
SITE PREPARATION & INSPECTION

3.1.0 Anchor Trench Systems

All Anchor Trench Systems shall be excavated by others (unless otherwise specified) to the lines and widths shown on the design drawings, prior to geomembrane placement.

3.2.0 Site Inspection

Immediately prior to installation, the subgrade shall be jointly inspection walked by the Owner's Representative and CLC personnel to determine it's worthiness to accept the specified lining system. The decision to repair cracks, if any, should be made only by the Owner's Representative. Once properly prepared, CLC will sign acceptance of the surface condition of the subgrade. The integrity of the underlying soil shall remain the responsibility of the owner/earthwork contractor.

Subgrade Preparation Recommendations:

No liner shall be placed on surfaces not previously found acceptable by the CLC supervisor or his agent.

Surfaces to be lined shall be compacted, smooth, and free of all rocks greater than 3/8" in diameter, sharp angular stones, sticks, vegetation, roots, sharp objects, gravel, or debris of any kind. The surface shall provide a firm, unyielding foundation for the lining system with no sudden, sharp or abrupt changes or breaks in grade or geometry.

Part IV
PANEL DEPOLYMENT AND TRACKING

4.1.0 Weather and Site Conditions

Panel placement shall not take place during precipitation, or in the presence of excessive winds (unless wind barriers are provided). In addition, deployment shall not take place in any areas of ponded water.

4.2.0 Panel Identification

Panels are portions of roll stock membrane that are field cut to size as required for

fitment and overlapped/welded in situ. In larger projects, a panel may consist of an entire uncut roll.

At the time of installation, the CLC Field Supervisor shall give each field panel an "identification code" (Number or letter-number). This field panel identification code shall be as simple and logical as possible.

4.3.0 Panel Placement

Panels are located by the CLC Field Supervisor in a manner consistent with the specification and best suited to existing site conditions. Field Panels shall be placed one at a time and each shall be seamed immediately after its placement for protection against wind action or rainwater infiltration.

CLC shall record the identification code, location, and date of installation of each geomembrane field panel.

4.4.0 Precautions During Panel Placement

CLC shall ensure that:

Any equipment used will not damage the geomembrane by handling, trafficking, excessive heat, leakage of fluids, or other means.

The prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately prior to liner placement.

Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.

All personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane.

Methods used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil.

Methods used to place the panels minimize wrinkles (especially differential wrinkles between adjacent panels).

Adequate temporary ballast is placed over deployed lining panel edges to prevent wind uplift and is not likely to damage the geomembrane. In the event of high winds, continuous loading such as sandbags shall be placed end to end along edges of panels to minimize risk of wind effects.

Direct contact with the geomembrane is minimized. Geotextiles, extra liner or other suitable materials shall be used as protective buffers in areas where excessive traffic may be expected.

4.5.0 Damaged Material

CLC shall inspect the geomembrane after placement and prior to seaming for damage. Any damaged membrane that cannot be reasonably repaired shall be removed and replaced. Repairs to geomembrane shall be made according to procedures described in section 8.2.0.

PART IV
SEAMING

5.1.0 Required Weather Conditions for Seaming

No seaming shall be conducted during periods of excessive moisture, blowing dust, or in the presence of excessive winds (unless wind barriers are provided). Seaming shall not take place in an areas of ponded water.

High temperature limits for welding are dependent upon crew safety and membrane material limits. Elevated temperatures can create conditions whereby seam strength may be compromised and an inferior installation may result. When elevated temperature conditions exist over 95° F/35° C, weld quality shall be closely monitored during seaming operations.

No seaming shall be conducted during rain or snow, unless the seam is covered with an enclosure permitting favorable seaming conditions.

No seaming shall be attempted at ambient temperatures below 5° F without proper pre-heating of material promoting favorable seaming conditions.

In all cases, geomembrane shall be dry and protected from wind.

CLC shall verify that favorable weather conditions exist and advise the Owner's Representative if they are not favorable.

5.2.0 Seaming and Related Equipment

Unless otherwise specified, all field seaming procedures shall be limited to two methods: extrusion welding and fusion (via hot wedge/"wedge welding"). The bulk of all panel to panel seaming shall be performed using the wedge weld technique. Extrusion welding shall limited to areas where wedge welders cannot practically be deployed such as patching and pipe penetration sealing. These machines typically require gas or diesel fueled generators as power sources.

Each extrusion welding apparatus shall be equipped with gauges giving the temperature of the apparatus at the nozzle and extruder barrel.

Each wedge welding apparatus shall be equipped with gauges giving the applicable temperatures.

Although welding over a frozen, wet or muddy subgrade is generally not encouraged, fusion welding may be possible under such conditions by deployment of a movable plastic slip-sheet placed directly below the overlapped membranes being seamed. Properly designed and deployed slip-sheets serve to prevent moisture buildup between the sheets being welded while providing conditions whereby wedge welding machines may be propelled at an uninterrupted rate of speed.

5.2.1 Equipment Preparation

Generator(s) shall be fueled outside the extents of the lining system and be inspected for fluid leakage and mechanical damage that may result in damage to the lining system. Should it be necessary to place the generator over the lining system a suitable buffer strip shall be placed between the tires and the membrane. Generators without inflated rubber tires shall not be introduced over the lining system. Tires shall be pre-inspected to be free of foreign matter that may damage the membrane. Generators shall be positioned within close proximity of the seaming region and have adequate extension cords to complete an entire seam without the necessity to move the machine.

Wedge welders shall be calibrated for ambient conditions and the material type/thickness to be welded. The front part of the seaming device should be inspected for sharp corners and irregular details, which may damage the liner. The major point for inspection is that no sharp edges should exist where FML sheet surfaces must pass over the heated wedge element. If a dual, or split, hot wedge seam is being made, the recessed space for the air track should be examined. Knurled pressure rollers shall be inspected for sharp surfaces. All wedge welder adjustments shall be checked daily. Cleaning of machine should be done at least daily.

Extrusion welders shall have an initial inspection before warm up to confirm that the insulation and covers are in good condition and that the welding nozzles (or Teflon shoes) are correct for the FML to be seamed. Teflon shoes should be checked for proper weld bead geometry and excessive wear and replaced if necessary. They shall then be heated to the correct welding temperature for thickness of the material to be welded and then purged of all heat-degraded resin from within the barrel. During the purge process temperature controllers shall be monitored for proper function and that the welding rod feed systems and rotating tips are operating properly.

5.2.2 Trial Seams

Before any welding is performed by either method on the actual membrane lining system, trial seam welds must first be performed yielding passing results.

CLC shall prepare trial seams made with test strips of the actual membrane being installed to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period (start of the day and midday) for each seaming apparatus used. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be approximately 3 feet/1.0 m long by 1 foot/0.3 m wide (after seaming) with the seam centered lengthwise. Seam overlap shall be nominally 4 inches/10.2 cm, 3 inches/7.6 cm minimum.

Unless otherwise specified, five (5) seam sample coupons each measuring 1"/25mm wide x 6"/150mm long shall be cut from the trial seam sample in increments to span its length. The specimens shall be tested in peel (3 ea.) and shear (2 ea.) modes using a field tensiometer. No seaming apparatus shall be used for seaming until deficiencies are corrected and two consecutive trial welds are successfully achieved.

5.3.0 Seam Layout

In general, seams should be oriented parallel to the line of maximum slope, in the direction of slope, not across the slope (horizontal to slopes). Horizontal to slope seams should be no less than 5 feet (1.5 m) from the toe of the slope or areas of potential

stress concentrations unless otherwise approved by The Owner's Representative. When full roll lengths do not extend past the toe of the slope, panel ends may be seamed provided the panel end is cut at an angle greater than 45° to minimize seam stress. In corners and areas of irregular geometry, the number of seams should be minimized.

A seam numbering system compatible with a panel numbering system shall be employed.

5.4.0 Panel Overlap for Seaming

Controlled overlapping of adjacent sheets shall produce approximately 3 inches of overlap for extrusion welds and 4 inches of overlap between sheets for wedge welded seams.

5.5.0 Seam Preparation

CLC shall verify that:

Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material, and seams are aligned with the fewest possible number of wrinkles or "fishmouths".

All areas to receive extrusion welds shall first be lightly/evenly ground with a hand held grinder with a 60 or 80 grit disc to roughen the surface while removing all surface shine. The grinding is performed parallel to the seam and controlled such that grinding marks do not extend more than 0.25 inches outside the area of the weld bead area. Sixty mil or thicker liners should have the edge of the top sheet beveled by grinding to approximately a 45° angle. This grinding preparation shall be completed no more than one (1) hour prior to extrusion welding. Grinding preparation does not apply to wedge welding.

5.6.0 Wedge Welder Seaming Procedure

A smooth insulating plate or fabric is shall be placed beneath the hot welding apparatus both before and after usage.

Unless otherwise specified, the general seaming procedure used by CLC shall be as follows:

The rolls of geomembrane shall be overlapped by approximately four inches (100 mm) for fusion welding and three inches for extrusion welding.

Welding can occur once the panels to be joined have been brought into their exact plan position for final installation.

"Fishmouths" or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut "fishmouths" or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions.

Power to the drive motor shall remain switched-off off when positioning the machine to make a seam.

When starting a new weld, the machine shall be manually placed into the overlapped sheet of material. The sheets shall then be guided between the idlers and the wedge element, and into the drive/nip rollers.

When starting a weld in the middle of two sheets, the material must be loaded from the sides. The machine is to be picked up a few inches, loading the bottom sheet first and top sheet second.

As soon as the wedge is in position and the nip rollers are engaged, the drive motor should be energized and the hot wedge moved into position and locked.

Welder alignment and temperature shall be monitored during the seaming process and any adjustments be made as necessary.

Should the machine tend to bulldoze the subgrade due to soil conditions, the operator shall take some of the weight off the front of the machine by lifting it slightly. Alternatively, a base for the machine to travel on could be provided consisting of strips of geotextile or geomembrane.

To avoid damaging membrane material, once the end of a seam is reached the drive and/or pressure rollers shall be immediately disengaged before the material runs completely out of the machine. The machine shall be withdrawn as quickly as possible to avoid damaging the membrane.

Seaming shall span the full panel length extend well into the anchor trench.

All cross seams or "T" intersections are to be extrusion welded where they intersect. The top flap of geomembrane shall be removed in the area to be extrusion welded and the weld area is ground prior to welding.

5.7.0 Extrusion Welder Seaming Procedure

A smooth insulating plate or fabric is shall be placed beneath the hot welding apparatus both before and after usage.

Using a hot air welders or hand held heat guns with seam rollers the overlapping materials to be welded must first be pre-bonded to hold the materials in place before actual extruding.
Welding operations should be observed to assure that the machines are properly aligned resulting in weld beads that are centered over the edges of the top FML sheets and that weld bead appearances are smooth and uniform.

PART VI
Non-Destructive Seam Continuity Testing

CLC shall non-destructively test all field seams over their full length using a vacuum test unit, air pressure testing, or other approved method. The purpose of non-destructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

6.1.0 Vacuum Box Testing

This test method is almost exclusively used for evaluating extrusion weld bead quality. In areas where vacuum boxes cannot practically be deployed, the welds shall be visually inspected and manually probed over their full length to check adhesion.

The equipment shall be comprised of the following:

A vacuum box assembly constructed from clear transparent plastic with a soft neoprene gasket attached to the bottom and a gauge to indicate vacuum chamber pressure.

A vacuum motor capable of creating a vacuum of 2.5 to 3 psi.

A bucket and wide brush, mop or spray assembly.

A soapy solution.

Procedure:

Wet a strip of geomembrane approximately 12 inches by 48 inches (0.3 m by 1.2 m) with the soapy solution;

Place the box over the wetted area.

Energize the vacuum apparatus; confirm 2.5 to 3psi.

Ensure that a leak tight seal is created.

For a period of approximately 5 to 10 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.

All areas where soap bubbles appear shall be marked and repaired in accordance with Section 3.4.

If no bubbles appear, the vacuum shall be disengaged and the box indexed to the next test area with a minimum 6" overlap between indexes, and the process repeated.

Vacuum tested seams are recorded on Daily Progress Reports.

6.2.0 Air Channel Pressure Testing

This method is only applicable to seam continuity testing of air channels produced using dual track hot wedge welding equipment.

Testing equipment shall be comprised of the following:

An air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa).

A air hose with fittings and connections.

A sharp hollow needle or other approved pressure feed device.

Procedure:

Seal both ends of the seam to be tested by tack welding and clamping with Vise Grips;

Insert needle into the air test channel created by the fusion weld.

Inflate the channel as applicable to pressure between 25 and 30 psi (160 and 200 kPa), close pressurized air source valve and monitor air pressure drop for five (5) minutes.

Remove needle or other approved pressure feed device and seal.

If pressure drop exceeds values tabulated herein or does not stabilize, locate faulty area and repair and re-test until defects are corrected and test values are passing.

Pressure tested seams are recorded on Daily Progress Reports.

TABLE 6.2
SEAM PRESSURE TEST ALLOWANCE

Material Thickness	Minimum psi Test Pressure	Maximum psi Test Pressure	Maximum psi Drop Allowed After 5 Minutes
30 mil	24	30	3 PSI
40 mil	24	30	3 PSI
60 mil	27	30	3 PSI
80 mil	27	30	3 PSI
100 mil & Thicker	30	32	3 PSI

6.2.1 Pressure Test Failure

Should excessive pressure drop occur, both ends of seam shall be checked to insure proper seal and be re-tested. Should failure reoccur, the top fusion seam shall be checked by applying a constant air pressure to the air channel and applying a soapy water solution over the weld length. Any failure or leak will be indicated by continuous bubbles appearing.

If no failure appears in the top fusion seam area the seam shall then be systematically isolated into in one hundred and fifty linear foot sections of seam which shall each be re-tested by pressure testing until the leak is located. Failed seam areas shall be repaired by extrusion welding the outside edge of the top fusion weld between areas of failure. The extruded edge shall be vacuum tested in accordance with this manual.

PART VII
Destructive Seam Testing

Destructive seam tests (if required by the project specification) shall be performed at random selected locations at a frequency of one sample per every 500 lineal feet of seam or as otherwise specified. Seam testing shall be conducted concurrent to the seaming work progress. The Owner's Representative if required, may select locations where seam samples are to be cut. If destructive seam tests are not required, representative seam samples may be substituted at a similar frequency using material samples of the actual material being installed so that no "damage" is done to the actual lining system requiring patching and testing, etc.

Procedure

Samples shall be cut by CLC as the seaming progresses. CLC shall:

Cut samples.

Assign a number to each sample, which is to be based upon seam and sample number and mark it accordingly.

Record sample location on daily report.

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 8.2.0.

7.1.0 Sample and Coupon Size and Extraction

Unless otherwise specified, the following sample preparation guidelines shall govern:

Trial, representative or destructive seam samples cut from the installed liner shall measure 12"/30cm in width x 3'/1m in length with the width of the seam centered in the long axis of the sample. Coupons shall measure 1"/25mm wide by 6"/150mm long with the seam centered perpendicular to the length.

Coupon extractions shall occur in three paired locations along the length of the seam sample:

2 coupons at the beginning, 2 coupons in the center and 2 coupons at the end of the sample for a total of six (6) extractions. Coupons may be extracted and evaluated incrementally.

Sample Distribution

Remnant 12"/30 cm square samples shall be cut into parts, labeled as specified and distributed as applicable:

One portion for independent geosynthetic laboratory testing if previously specified

and

One portion to the Owner for archive storage

7.2.0 Coupon Field Testing

Coupons shall be tested with a tensiometer and evaluated for bonded seam strength (shear) and peel using methods ASTM D4437. Tensiometer jaw separation rate for bonded seam strength/shear and peel test shall be 2"/minute (5cm/min.)

All shear strength samples shall yield Film Tearing Bond (FTB) as defined in NSF 54 Annex A,

If the initial sample coupon test passes shear analysis yielding a FTB, the sample qualifies for further testing to obtain quantitative results until three (3) each peel samples and three (3) each shear samples are evaluated from the beginning middle and end of each sample.

If more than one (1) of six coupons per sample fails, the seam should be repaired in accordance with Section 7.3.0.

TABLE 7.2
REQUIRED FUSION AND EXTRUSION SEAM TEST RESULTS
Per NSF 54 1993 Standards

	Minimum Values Required (In Units of Pounds per inch of Width)			
Material Thickness	**Peel Extrusion**	**Peel Fusion**	**Shear Extrusion**	**Shear Fusion**
30 mil HDPE	35	49	63	63
40 mil HDPE	48	86	86	86
60 mil HDPE	70	98	126	126
80 mil HDPE	92	115	166	166
100 mil HDPE	115	143	207	207
Textured 30 mil HDPE	31	44	56	56
Textured 40 mil HDPE	42	60	76	76
Textured 60 mil HDPE	63	88	113	113
Textured 80 mil HDPE	84	115	151	151
Textured 100 mil HDPE	105	143	189	189

Notes: Textured values are applicable to membranes textured on one side of the sheet only.
Only the inner weld track is peeled apart in this destructive test. The outer track (directly at sheet edge) is for the purpose of air pressure testing capabilities.

7.3.0 Procedures for Test Failure

Should a sample fail a destructive test, the defect may be remedied by:

Capping the respective seam in its entirety as described in this section,

or

If a defect is suspected to be local to a certain area it may be further investigated to isolate the defective are by:

Taking small coupon test samples located 10' on either side of the defective sample seam void area. If these additional samples pass tensiometer testing, then full samples are to be taken. If these samples pass the tests, then the seam is capped between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed. All acceptable seam areas must be bounded by two locations from which samples passing destructive tests have been taken.

Cap stripping of defective seams or isolated areas shall be performed using either wedge or extrusion welding techniques or combination thereof and re-testing the repaired area with applicable methods as described herein. Cap strips shall cover the defective seam by no less than 6"/15cm On either side of the original weld. Wider patches will be required to cover seam sample void areas.

CLC shall document all actions taken in conjunction with destructive test failures; e.g., capping of failed seam area.

PART VIII
Defects and Repairs

8.1.0 Identification

All seams and non-seam areas of the geomembrane shall be examined by CLC for identification of defects, holes, blisters, un-dispersed raw materials and any sign of contamination by foreign matter.

Defective/damaged materials shall be identified via a deficiency report, either separately or on the Daily Report. Actions taken to resolve or correct the problem will also be recorded on the similar form.

Defects, holes, blisters, un-dispersed raw materials, signs of contamination by foreign matter, unacceptable welds in geomembranes and other unsatisfactory conditions will be identified on the Daily Report form. The repair/corrective action to "fix" the problem will also be recorded on a similar form.

8.2.0 Repair Procedures

Available methods include:

Patching - used to repair large holes, tears, and contamination by foreign matter.

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

Spot welding or seaming - used to repair pinholes or other minor localized flaws;

Capping - used to repair large lengths of failed seams;

Methods for patching lining system defects shall consist of welding patches or caps over such areas using the same membrane lining material as used on the specific project. Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches.

Seaming, preparation and welding equipment deployment procedures previously addressed in this manual shall be adhered to during patching operations.

8.2.1 Verification of Repairs

Each repair shall be non-destructively tested using the methods described in Section 6 as appropriate. Repairs which pass the non-destructive test, shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and re-tested until a passing test result is obtained.

Part IX
Ancillary Items and Final Acceptance

9.1.0 Pipe Penetrations

Pipes penetrating through the lined area shall be sealed using pipe boot details that are welded to the lining system via extrusion weld method and sealed the pipe with double stainless steel banding clamps and butyl sealant tape. Pipe boots shall be fabricated from the membrane material being installed and shall fit snugly over the pipe and pipe to grade interface without undue slack or bridging. In instances where piping is

manufactured from HDPE, the pipe boot sleeve may be extrusion welded directly to the pipe foregoing the need for banding clamps.

9.2.0 Backfilling of Anchor Trenches

Anchor trenches, if any, shall be adequately drained by others to prevent ponding or otherwise softening the adjacent soils while the trench is open. The anchor trench shall be back-filled by others or as outlined in the specifications and bid documents.

Since back-filling the anchor trench can affect material bridging at toe of slope, consideration should be given to backfill the liner at its most contracted state; preferably during the cool of the morning or extended period of overcast skies. Care shall be taken when back-filling the trenches to prevent any damage to the lining system.

9.3.0 Lining System Acceptance

Once the lining system is installed and all quality assurance testing has been completed with satisfactory results, and the system is approved by Owner's Representative, the Representative shall sign an acceptance form provided by CLC prior to demobilization.

Promoting Industry Growth • Providing Better Quality Workmanship

Approved Installation Contractor

This Certificate Recognizes That

Colorado Lining International, Inc.

Has achieved Approved Installation Contractor status through
the International Association of Geosynthetic Installers.

Valid through July 8, 2010

Carl Apicella

Laurie Honnigford
Managing Director, IAGI

BENTOMAT® CL

GEOSYNTHETIC CLAY LINER SPECIFICATION GUIDELINES

This specification is intended for use as a GENERAL GUIDELINE for developing a specification for a specific project. It is NOT intended as a substitute for a detailed specification, which must be written to address site-specific conditions.

TR-400cl
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1.0 GENERAL

1.1 Scope

This specification covers the technical requirements for the furnishing and installation of the geosynthetic clay liner 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.

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.

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

Geotextile. Any permeable geosynthetic comprised solely of textiles.

Minimum Average Roll Value. For geosynthetics, the value calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

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 Unit Prices

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

1.4 Submittals

A. With the bid, the Contractor shall furnish the following information:

1. Conceptual description of the proposed plan for placement of the GCL panels over the area of installation.
2. GCL manufacturer's MQC Plan for documenting compliance to Sections 2.1 and 2.2 of these specifications.
3. GCL manufacturer's historical data for multi-axial tension testing of the laminated GCL per Section 2.1E.

4. A copy of GCL manufacturer's ISO quality Certificate of Registration.

B. At the Engineer's or Owner's request the Contractor shall furnish:

1. A representative sample of the GCLs.
2. 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.

C. 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.

D. As installation proceeds, the Contractor shall submit certificates of subgrade acceptance, signed by the Contractor and CQA Inspector (see Sections 1.6 and 3.3) for each area that is covered by the GCL.

1.5 Qualifications

A. GCL Manufacturer must have produced at least 300 million square feet (30 million square meters) of GCL within the past three years, including at least 30 million square feet (3 million square meters) with 3.5 lb/in (610 N/m) peel strength.

B. The GCL Installer must either have installed at least 1 million square feet (100,000 square meters) of GCL, **or** must provide to the Engineer satisfactory evidence, through similar experience in the installation of other types of geosynthetics, that the GCL will be installed in a competent, professional manner.

1.6 Construction Quality Assurance (CQA)

A. The Owner and Engineer shall provide a third-party inspector for CQA of the GCL installation. The inspector shall be an individual or company who is independent from the manufacturer and installer, who shall be responsible for monitoring and documenting activities related to the CQA of the GCL, throughout installation. The inspector shall have provided CQA services for the installation of the proposed or similar GCL for at least 5 completed projects totaling not less than 1 million square feet (100,000 square meters).

B. Testing of the GCL, as necessary to support the CQA effort, shall be performed by a third party laboratory retained by the Contractor and independent from the GCL manufacturer and installer. The laboratory shall have provided GCL CQA testing of the proposed or similar GCL for at least 5 completed projects totaling not less than 1 million square feet (100,000 square meters).

C. CQA shall be provided in accordance with the *GCL CQA Manual* provided by the engineer.

2.0 PRODUCTS

A. The GCL shall consist of a layer of granular sodium bentonite clay needlepunched between two geotextiles and laminated to a thin flexible membrane liner (Bentomat CL). The GCL shall comply with all of the criteria listed in this Section.

B. Bentonite shall be a high-swelling sodium bentonite, with a minimum swell index of 24 mL/2g and a maximum fluid loss of 18 mL. Bentonite shall be CG-50 granular bentonite, mined and processed by American Colloid Company.

C. Bentonite shall have a granular consistency (1 percent max. passing a No. 200 sieve [75 μm]), to ensure uniform distribution throughout the GCL and minimal edge loss during handling and installation.

D. 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. Contractor must also provide evidence of successful use of the proposed alternate material on past similar projects. This evidence can include past direct shear results against similar materials under similar site conditions, and/or past permeability/compatibility test results with a similar leachate or waste stream. The Contractor also must obtain prior approval of the alternative GCL by the Project Engineer.

2.1 Materials

A. Acceptable GCL product is Bentomat CL, as manufactured by CETCO, 2870 Forbs Avenue, Hoffman Estates, Illinois 60192 USA (800-527-9948), or an engineer-approved equal.

B. The GCL and its components shall have the properties shown in the Bentomat CL Certified Properties table.

C. The moisture content of the bentonite in the finished GCL shall be between 20 and 40 percent, to ensure uniform bentonite distribution, consistent needlepunch density, and adequate electrical conductivity to maximize leak location survey sensitivity.

D. GCL shall be needlepunch-reinforced, with a minimum peel strength of 3.5 lb/inch (610 N/m). To maximize large-displacement shear strength, GCL reinforcement shall be achieved solely through needlepunching, without any supplemental heat treatment.

E. The Bentomat CL GCL shall have multi-axial tension testing data per ASTM D5617. The GCL shall achieve a minimum multi-axial strain of 9.49%.

F. For projects in cold-weather climates, the GCL shall have passing test results for both Brittleness (ASTM D1790) and Low-temperature flexibility (ASTM D1970) tests, at temperatures as low as -40 degrees C.

G. The minimum acceptable dimensions of full-size GCL panels shall be 150 feet (45.7 m) in length. Short rolls [(those manufactured to a length greater than 70 feet (21 m) but less than a full-length roll)] may be supplied at a rate no greater than 3 per truckload or 3 rolls every 36,000 square feet (3,500 square meters) of GCL, whichever is less.

H. A 12-inch (300 mm) overlap guideline shall be imprinted on both edges of the upper geotextile component of the GCL as a means for providing quality assurance of the overlap dimension. Lines shall be printed in easily visible, non-toxic ink.

2.2 Product Quality Documentation

The GCL manufacturer shall provide the Contractor or other designated party with manufacturing QA/QC certifications for each shipment of GCL. The certifications shall be signed by a responsible party employed by the GCL manufacturer and shall include:

A. Certificates of analysis for the bentonite clay used in GCL production demonstrating compliance with the swell index and fluid loss values shown in the Bentomat CL Certified Properties table.

B. Manufacturer's test data for finished GCL product(s) demonstrating compliance with the values shown in the Bentomat CL Certified Properties table.

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

2.3 Product Labeling

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

1. Product identification information (Manufacturer's name and address, brand product code).

2. Lot number and roll number.

3. Roll length, width and weight.

2.4 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.

BENTOMAT® CL 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) min
GCL Tensile Strength[3]	ASTM D 6768	200,000 ft^2 (20,000 m^2)	45 lbs/in (78 N/cm) MARV
GCL Peel Strength[3]	ASTM D 6496	40,000 ft^2 (4,000 m^2)	3.5 lbs/in (4.4 N/cm) min
GCL Index Flux[4]	ASTM D 5887	Periodic	1 x 10^{-9} m^3/m^2/sec max
GCL Hydraulic Conductivity[4]	ASTM D 5887	Periodic	5 x 10^{-10} cm/sec max
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321 ASTM D 6243	Periodic	500 psf (24 kPa) typical

Bentomat CL is a reinforced GCL consisting of a layer of granular sodium bentonite between two geotextiles, which are needlepunched together and laminated to a thin flexible membrane liner.

Notes

[1] Bentonite property tests performed at a bentonite processing facility before shipment to CETCO's GCL production facilities.
[2] Bentonite mass/area reported at 0 percent moisture content.
[3] All tensile strength testing is performed in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request, tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.
[4] ASTM D5887 Index flux and hydraulic conductivity 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 92 gal/acre/day. This flux value is equivalent to a permeability of 5x10^{-10} cm/sec for typical GCL thickness. ASTM D 5887 testing is performed only on a periodic basis because the membrane is essentially impermeable.
[5] Peak value measured at 200 psf (10 kPa) normal stress for a specimen hydrated for 48 hours. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

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2.5 Accessory Bentonite

A. The granular bentonite sealing clay used for overlap 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. Seaming of GCLs shall be conducted in accordance with the manufacturer's specifications for each particular GCL. Please refer to the installation guidelines for Bentomat/Claymax GCLs.

3.0 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.

C. 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. 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).

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

A. Any earthen 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:

1. Vegetation.
2. Construction Debris.
3. Sticks.
4. Sharp rocks.
5. Void spaces.
6. Ice.
7. Abrupt elevation changes.
8. Standing water.
9. Cracks larger than one-quarter inch (6 mm) in width.
10. Any other foreign matter that could contact the GCL.

B. Subgrade surfaces consisting of granular soils or gravels may not be acceptable due to their large void fraction and puncture potential. Subgrade soils should range between fines and 1 inch (25 mm). In high-head applications (greater than 1 foot or 30.48 cm), CETCO recommends a membrane-laminated GCL.

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 (12 mm) from the surface shall either be removed, crushed or pushed into the surface with a smooth-drum compactor.

D. On a continuing basis, the project CQA inspector shall certify 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 or an equivalent runout shall be utilized in accordance with the project plans and specifications and as approved by the CQA Inspector. When utilizing an anchor trench design, the trench shall be excavated and approved 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 GCL Placement

A. The areas to be lined with GCL shall be agreed upon by the Installer and the Engineer prior to installation.

B. 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) should be in accordance with the Engineer's recommendations.

C. Equipment, which could damage the GCL, shall not be allowed to travel directly on it. If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

D. 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.

E. The GCL panels shall be placed parallel to the direction of the slope.

F. All GCL panels should lie flat on the underlying surface, with no wrinkles or fold, especially at the exposed edges of the panels.

G. Only as much GCL shall be deployed as can be covered at the end of the working day with soil, a geomembrane, or a temporary waterproof tarpaulin. The GCL shall not be left uncovered overnight. If the GCL is hydrated when no confining stress is present, it may 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.

3.5 Anchorage

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 or an equivalent runout design shall be utilized. When utilizing an anchor trench design, the front edge of the trench should be rounded so as to eliminate any sharp corners. Loose soil should be removed from the floor of the trench. The GCL should cover the entire trench floor but does not extend up the rear trench wall.

3.6 Seaming

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. Bentonite-enhanced seams are required for installation of membrane-laminated GCLs.

B. The minimum dimension of the longitudinal overlap for Bentomat CL should be 12 inches (300 mm). End-of-roll overlapped seams should be similarly constructed, but the minimum overlap should measure 24 inches (600 mm).

C. 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.

D. 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 within the zone defined by the edge of the underlying panel and the 12-inch (300 mm) line. A similar bead of granular

sodium bentonite is applied at the end-of-roll overlap. The granular bentonite shall be applied at a minimum application rate of one quarter pound per lineal foot (0.4 kg/m).

3.7 Detail Work

A. The GCL shall be sealed around penetrations and embedded structures embedded in accordance with the design drawings and the GCL Manufacturer.

B. Cutting the GCL should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the geotextile components of the GCL during the cutting process.

3.8 Damage Repair

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 a minimum overlap of 12 inches (300 mm) is achieved around all of the damaged area. Granular bentonite or bentonite mastic should be applied around the damaged area prior to placement of the patch. It may be desirable to use an adhesive to affix the patch in place so that it is not displaced during cover placement.

3.9 Cover Placement

A. Cover soils shall be free of angular stones or other foreign matter that could damage the GCL. Cover soils should be approved the project Engineer with respect to particle size, uniformity and chemical compatibility. Cover soils with high concentrations of calcium (e.g., limestone, dolomite) are not acceptable.

B. Soil cover shall be placed over the GCL using construction equipment that minimizes stresses on the GCL. A minimum thickness of 1 foot (300 mm) of cover should be maintained between the equipment tires/tracks and the GCL at all times during the covering process. This thickness recommendation does not apply to frequently trafficked areas or roadways, for which a minimum thickness of 2 feet (600 mm) is required.

C. Soil cover should be placed in a manner that prevents the soil from entering the GCL overlap zones. Cover soil shall be pushed up slopes, not down slopes, to minimize tensile forces on the GCL.

D. Although direct vehicular contact with the GCL is to be avoided, lightweight, low ground pressure vehicles (such as 4-wheel all-terrain vehicles) may be used to facilitate the installation of any geosynthetic material placed over the GCL. The GCL supplier or CQA engineer should be contacted with specific recommendations on the appropriate procedures in this situation.

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For the most up-to-date product information, please visit our website, www.cetco.com.

GSE®

GSE STANDARD PRODUCTS

Product Data Sheet

GSE HyperNet, HF, HS and UF Geonet

GSE HyperNet geonets are synthetic drainage materials manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. HDPE resins are inert to chemicals encountered in most of the civil and environmental applications where these materials are used. GSE geonets are formulated to be resistant to ultraviolet light for time periods necessary to complete installation. GSE HyperNet geonets are available in standard, HF, HS, and UF varieties.

The table below provides index physical, mechanical and hydraulic characteristics of GSE geonets. Contact GSE for information regarding performance of these products under site-specific load, gradient, and boundary conditions.

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE[b]			
			HyperNet	HyperNet HF	HyperNet HS	HyperNet UF
Product Code			XL4000N004	XL5000N004	XL7000N004	XL8000N004
Transmissivity[a], gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	9.66 (2 x 10^{-4})	14.49 (3 x 10^{-4})	28.98 (6 x 10^{-4})	38.64 (8 x 10^{-4})
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft^2	200 (5)	250 (6.3)	275 (7)	300 (7.6)
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft^2	45 (7.9)	55 (9.6)	65 (11.5)	75 (13.3)
Carbon Black Content, %	ASTM D 1603, modified	1/50,000 ft^2	2.0	2.0	2.0	2.0
Roll Width[c], ft (m)			15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)
Roll Length[c], ft (m)			300 (91)	250 (76)	220 (67)	200 (60)
Roll Area, ft^2 (m^2)			4,500 (418)	3,750 (348)	3,300 (305)	3,000 (278)

NOTES:

- [a] Gradient of 0.1, normal load of 10,000 psf, water at 70° F (20° C), between steel plates for 15 minutes.
- [b] These are MARV values that are based on the cumulative results of specimens tested by GSE.
- [c] Roll widths and lengths have a tolerance of ±1%.

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North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

www.gseworld.com

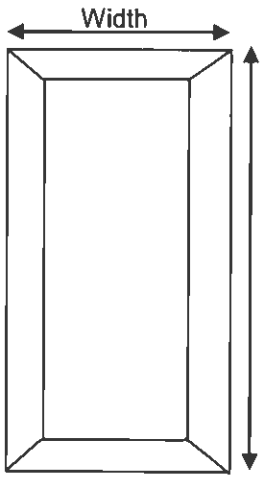
Design Calculations

Mautz Ranch Multi-Well Pit
Pit Volume Calculator*

Fox Engineering Solutions, LLC

Input | **Compute**

Length ft.	Width ft.	Total Depth ft.	Side Slopes Run ft.	Side Slopes Rise ft.	Total Pit Volume[1] yds.^{3}	Total Pit Volume[1] bbls	Free Board Required ft.	Free Board Volume yds.^{3}	Usable Volume yds.^{3}	Usable Volume bbls
350	150	15	1.5	1	23291.67	112000	2	3778.67	19513.00	93830



(1) Volume Formula=((((D14*C14)*(A14-2*(D14*C14))*C14)+((D14*C14)*(B14-2*(D14*C14))*C14)+((B14-2*(D14*C14))*(A14-2*(D14*C14)))*C14+1/3*(2*D14*C14)^2*C14))/27

* Not valid if the Width< 2(Depth x Run).

Fox Engineering Solutions
12/21/2010