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.
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 a) 10,000-hour creep shear testing per Section 2.1 E and b) seam flow data at 13.7 kPa confining pressure per Section 2.1 F.
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 300,000m² in size.

C. Upon shipment, the Contractor shall furnish the GCL manufacturer’s Quality Assurance/Qualify 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. The GCL Installer must either have installed at least 100,000m² 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. 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 must be NAMAS (or equivalent) accredited.

B. 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 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.
C. Bentonite shall have a granular consistency (1 percent max. passing a 75 μm sieve), 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 products are Bentomat® ST, as manufactured by CETCO, Village Ler, Bhuj-kutch (Guj.), +91-02832 240301, or an engineer-approved equal.

B. The GCL shall have the properties shown in the Bentomat ST 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 6.5 N/cm. To maximize large-displacement shear strength, GCL reinforcement shall be achieved solely through needlepunching, without any supplemental heat treatment.

E. The GCL shall have 10,000-hour test data for large-scale constant-load (creep) shear testing under hydrated conditions. The displacement shall be 2.7 mm or less at a constant shear load of 12 kPa and a normal load of 24 kPa.

F. The GCL shall have seam test data from an independent laboratory showing that the seam flow with a grooved cut in the nonwoven geotextile is less than 1 x 10^-8 m³/m²/s at 13.8 kPa hydraulic pressure.

G. The minimum acceptable dimensions of full-size GCL panels shall be 45.7 m in length. Short rolls (those manufactured to a length greater than 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 3,500 square meters of GCL, whichever is less.

H. A 150 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 ST Certified Properties table.

B. Manufacturer’s test data for the finished GCL product demonstrating compliance with the values shown in the Bentomat ST Certified Properties table.

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

Manufacturer’s test data for finished GCL product(s), including GCL index flux, permeability and hydrated internal shear strength data, which demonstrate compliance with the performance parameters shown in the Bentomat ST Certified Properties table, are available upon request of the manufacturer.

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.
## BENTOMAT® ST CERTIFIED PROPERTIES

### GEOTEXTILE PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Frequency</th>
<th>Required Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woven geotextile mass per area</td>
<td>ASTM D 5261</td>
<td>20,000 m²</td>
<td>140 g/m² average</td>
</tr>
<tr>
<td>Non-woven geotextile mass per area</td>
<td>ASTM D 5261</td>
<td>10,000 m²</td>
<td>200 g/m² average</td>
</tr>
</tbody>
</table>

### BENTONITE PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Frequency</th>
<th>Required Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite Moisture</td>
<td>API 13 A</td>
<td>1 per 50 tonnes</td>
<td>14% max.</td>
</tr>
<tr>
<td>Bentonite Swell Index</td>
<td>ASTM D 5890</td>
<td>1 per 50 tonnes</td>
<td>24 ml/2g min.</td>
</tr>
<tr>
<td>Bentonite Fluid Loss</td>
<td>ASTM D 5891</td>
<td>1 per 50 tonnes</td>
<td>18 ml max.</td>
</tr>
</tbody>
</table>

### GCL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Frequency</th>
<th>Required Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite Mass/Area²</td>
<td>ASTM D 5993</td>
<td>6,000 m²</td>
<td>4.8 kg/m² min. @ 12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.29 kg/m² min. @ 0%</td>
</tr>
<tr>
<td>GCL Tensile Strength³</td>
<td>ASTM D 6768</td>
<td>6,000 m²</td>
<td>10 kN/m MARV</td>
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<tr>
<td>GCL Peel Strength³</td>
<td>ASTM D 6496</td>
<td>6,000 m²</td>
<td>6.5 N/cm min.</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>EN ISO 12236</td>
<td>25,000 m²</td>
<td>1.6 kN min.</td>
</tr>
<tr>
<td>GCL Index Flux⁴</td>
<td>ASTM D 5887</td>
<td>Weekly</td>
<td>1 x 10⁻⁸ m³/m²/sec max.</td>
</tr>
<tr>
<td>GCL Hydraulic Conductivity⁴</td>
<td>ASTM D 5887</td>
<td>Weekly</td>
<td>5 x 10⁻¹¹ m/sec max.</td>
</tr>
</tbody>
</table>

*Bentomat ST is a reinforced GCL consisting of a layer of granular sodium bentonite between woven and nonwoven geotextiles, which are needlepunched together.*

### Notes

1. Bentonite property tests performed at a bentonite processing facility before shipment to Ashapura Volclay’s GCL production facility.
2. Bentonite mass/area reported at 12 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.
4. ASTM D5887 Index flux and hydraulic conductivity testing with deaired distilled/deionized water at 551 kPa cell pressure, 531 kPa headwater pressure and 517 kPa tailwater pressure. This flux value is equivalent to a permeability of 5x10⁻¹¹ m/sec for typical GCL thickness. Actual flux values vary with field condition pressures.
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.

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 guidelines for each particular GCL.

3.0 EXECUTION

3.1 Shipping and Handling

A. The manufacturer assumes responsibility for initial loading of 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. In applications where the GCL is the only barrier, subgrade soils should have a particle-size distribution at least 80 percent finer than the 0.25 mm. In other applications, subgrade soils should range between fines and 25 mm. In high-head applications (greater than 30.48 cm), CETCO recommends a membrane-laminated GCL (Bentomat CL).

**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 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.

B. The minimum dimension of the longitudinal overlap should be 150 mm for Bentomat ST. If the GCL is manufactured with a grooved cut in the nonwoven geotextile that allows bentonite to freely extrude into the longitudinal overlap then no supplemental bentonite is required for this overlap. If the GCL does not have a grooved cut in the nonwoven
geotextile longitudinal overlap, then bentonite-enhanced seams are required as described below.

C. End-of-roll overlapped seams should be constructed with a minimum overlap of 600 mm for Bentomat ST. 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. End-of-roll overlapped seams require bentonite-enhanced seams as described below.

D. Bentonite-enhanced seams are constructed between the overlapping adjacent panels as follows. 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 150-mm line. The granular bentonite shall be applied at a minimum application rate of 0.4 kg per meter. A similar bead of granular sodium bentonite is applied at the end-of-roll overlap.

E. Cyclical wetting and drying of GCL covered only with geomembrane can cause overlap separation. Soil cover should be placed promptly whenever possible. Geomembranes should be covered with a white geotextile and/or operations layer without delay to minimize the intensity of wet-dry cycling. If there is the potential for unconfined cyclic wetting and drying over an extended period of time, the longitudinal seam overlaps should be increased based on the project engineer's recommendations.

F. To avoid seam separation, the GCL should not be put in excessive tension by the weight or expansion of textured geomembrane on steep slopes. The project Engineer should be consulted about the potential for GCL tension to develop.

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 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 by 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 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 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.

E. 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.