CHAPTER 3.3
LOW PERMEABILITY CLAY LAYER

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CHAPTER 3.3 LOW PERMEABILITY CLAY LAYER

3.3-1. GENERAL. The purpose of the low permeability clay layer in a landfill cover or liner system is to inhibit the movement of water into or out of the waste. Soils used for the clay layer are selected to meet a specific hydraulic conductivity requirement (typically 1×10^{-7} cm/sec). If suitable clay materials are not found in the vicinity of the project, a common practice is to blend available soils with bentonite. The following steps are required to properly construct a low permeability clay layer:

- locate and test borrow sources to ensure appropriate clay material is available;

- preprocess soil liner material, if necessary, to adjust the water content, to remove oversized particles, to break down clods of soil, or to add amendments such as bentonite;

- prepare the subgrade to provide a firm foundation on which to place clay;

- place and compact the clay material at the appropriate moisture content and density. Clay barrier layers are normally a minimum of 600 mm (24 inches) in thickness. They are typically placed in several lifts with a compacted lift thickness of approximately 150 mm (6 inches). Heavy compactors with feet that penetrate the loose lifts of soil are ideal for compaction of clay layers. The Caterpillar 815B and 825C are examples of equipment that have been successfully used for compaction of clay layers;

- freeze-thaw cycles and desiccation cracks will increase the hydraulic conductivity of a clay layer. Therefore, it is critical to protect the clay layer until the layer is completed and covered.

a. Equipment.

(1) Compaction Equipment.

(a) Verify the compaction equipment proposed for use are footed rollers. The compactors should also meet the weight requirements described in the specifications.

(b) During compaction operations, the spaces between the tamping feet should be kept clear of materials.

(c) Do not allow compaction equipment to be operated at speeds exceeding specified limits (generally 2.2 meters per second (5.0 miles per hour)).

(2) Scarification Equipment. Verify scarification equipment is capable of scarifying to the depth specified (generally 25 to 50 mm (1 to 2 inches)).

(3) A smooth steel wheeled non-vibratory roller should be used to produce a smooth compacted surface on the final lift of the clay layer if a geomembrane will be placed on top of the clay layer.

(4) Ensure hand operated tampers consist of impact type

equipment. Vibratory type equipment should not be allowed.

b. Preconstruction Submittals. The contractor should provide preconstruction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Materials Handling Plan which describes the processing, placement, and protection of the clay layer.

(a) The contractor's plan for protecting the clay layer should address how the clay will be kept at the correct moisture content after placement (this includes evenings and weekends).

(b) Generally, construction of the cover or liner should progress in stages so the clay layer is periodically covered by other soil layers in order to provide protection from desiccation and freeze/thaw damage. Covering the clay layer with geosynthetics only may not provide adequate protection.

(2) Name and qualifications of the proposed commercial testing laboratory.

(3) Borrow Source Assessment Report. Borrow source assessment testing is sometimes done during the design phase. If this is the case, the amount of borrow source assessment testing done by the contractor will be greatly reduced.

(a) Borrow assessment tests should be performed on each type of soil proposed for use to develop compaction requirements for placement. At a minimum, one set of borrow assessment tests should be performed for each borrow source. A set of borrow source assessment tests generally consists of classification testing, moisture-density (compaction) testing, and hydraulic conductivity testing.

(b) An "Acceptable Zone" of moisture contents and densities which meet the hydraulic conductivity criteria should be developed and displayed on the compaction curve graphs.

(4) Samples of low permeability clay, if required.

c. Construction Submittals. The contractor should provide construction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Borrow classification test results.

(2) Subgrade test results.

(3) In-place moisture content and density test results.

(4) In-place hydraulic conductivity test results.

3.3-2. PRODUCTS

a. Low Permeability Clay.

(1) For composite geomembrane/clay covers and liners, the maximum particle size is typically 12.5 mm (0.5 inches) in the upper lift of clay to prevent puncturing of the geomembrane.

(2) The maximum allowable particle size will typically be 25-50 mm (1-2 inches) in the rest of the clay layer.

(3) Check the properties of the clay material being submitted against the requirements listed in the specifications.

(4) At sites where multiple borrow sources are used for clay, ensure the correct compaction curve is used for each type of soil being placed.

(5) Perform daily inspections of stockpiles or borrow sources to see if there are visible changes in the properties of the borrow. Additional borrow source assessment testing may be required if it appears the properties of the borrow source are changing.

b. Bentonite. If bentonite is used to improve the characteristics of the soil, the following paragraphs describe items which the QA Representative should monitor.

(1) Ensure that the bentonite has been pulverized to the extent required by the specifications. A fine powdered bentonite will behave differently than a coarse, granular bentonite. Check grain size distribution test results and also visually monitor the bentonite for changes in grain size distribution.

(2) Free swell (ASTM D 5890-95) , fluid loss (ASTM D 5891-95) and other tests are also commonly specified to ensure a high quality bentonite is being used. Verify these results meet the specified requirements.

(3) The bentonite and soil are commonly mixed together using a pug mill. An alternative mixing technique is to spread the soil in a loose lift, distribute bentonite on the surface, and mix the bentonite and soil using a rototiller or other mixing equipment. Visually inspect the mixing process to ensure that the bentonite is uniformly mixed throughout the entire lift of soil. The specifications may also require QC and QA testing be performed to verify the uniformity of mixing.

3.3-3. EXECUTION

a. Subgrade Preparation.

(1) Verify that the subgrade is composed of satisfactory materials as defined by the specifications.

(2) Check in-place density test results against specified requirements.

(3) Verify the lines and grades of the top surface of the subgrade are correct prior to clay placement.

(4) The subgrade surface should be scarified prior to placement of the first lift of clay to minimize preferential flow paths along the interface and to eliminate the development of a potential slip plane.

b. Installation.

(1) Clay Placement.

(a) Carefully inspect placement and compaction of clay placed above geosynthetic layers. Look for slippage of the compaction equipment on slopes which can cause tension in the geosynthetics. Also look for thin areas of clay which could allow the geosynthetics to be punctured or torn.

(b) Verify loose lifts are no greater than the specified maximum thickness (generally 205 to 230 mm (8 to 9 inches)). In areas where hand operated tampers must be used, the loose lift thickness should not exceed 102 mm (4 inches). The most common way to determine the loose lift thickness is to stand near the working face and observe the lift being placed.

(c) Periodically measure the loose lift thickness by digging a pit through the loose lift of soil and into the underlying layer. A cross-beam is then used to measure the depth from the surface of the loose lift to the top of the previously compacted lift. The zone of scarification should be counted in the loose lift thickness for the new lift of soil.

(d) Verify the clay contains no large clods or other material prohibited in the specifications. This can be done by positioning yourself near the working face as the soil is being placed and visually inspecting for stones, organic matter, debris and other material which is unacceptable.

(e) If highly plastic soils are being used, pay particular attention to preprocessing of clods, breaking up of clods during compaction, and protection from desiccation. No standard method is available to determine clod size. Inspectors should observe the soil liner material and periodically determine the dimensions of clods by direct measurement.

(f) Verify clay is being placed to the lines and grades shown on the drawings.

(g) Grade stakes should be numbered and they should be accounted for at the end of each shift.

(2) Moisture Control.

(a) Verify clay is placed and compacted within the approved moisture content range.

(b) Inspect the entire lift thickness to verify the moisture content is uniform throughout the lift.

(c) A spreader bar on the back of a water truck is the recommended device for moistening the clay. A disk or rototiller is then used to mix the water into the lift of clay.

(d) If water is being added to the clay layer, cure time is required to obtain uniform moisture. Require additional moisture content tests to be run if there is a question about the uniformity of the moisture content within a lift.

(3) Compaction.

(a) Refer to Section 3.9 Cover Soil, if the first lift of clay will be placed directly on top of geosynthetic layers.

(b) Verify the clay is compacted to the density requirements in the approved Borrow Source Assessment Report.

(c) Check to see if the specifications require a minimum number of passes by the compaction equipment. Spot check the contractor daily to ensure the correct number of passes are being used to compact the clay layer.

(d) Review the specifications to determine if there are any special requirements for compaction around pipes and other penetrations.

(e) Verify that soil placed around pipes and other penetrations does not contain voids and is adequately compacted.

(f) Inspect pipes which penetrate the clay layer for damage due to the compaction process.

(4) Scarification.

(a) Verify that all areas of the upper surface of each lift are scarified prior to placement of the next lift of clay.

(b) The final lift of clay should be rolled with a smooth steel wheeled roller if a geomembrane will be placed above the clay layer. Check the specifications to determine the minimum number of passes required.

c. Tests.

(1) Borrow Tests.

(a) Check borrow test results (moisture content, sieve analysis, Atterberg limits, and compaction tests) to verify that the borrow material being excavated is uniform. As an approximate guide, a relatively homogeneous borrow soil would be considered a soil in which optimum moisture varies by no more than +/- 3 percent and maximum density varies by no more than +/- 80 kg/cubic meter (5 lbs/cubic foot).

(b) Additional borrow assessment testing should be performed if the properties of the borrow source change. The contractor and QA personnel should agree on what constitutes a significant change in the borrow source prior to the start of construction.

(c) For highly variable borrow sources, it is recommended that an inspector observe all excavation of borrow soil in the borrow pit. This is the best way to monitor for changes in soil type. A useful guide in helping you to perform field identification of soils is ASTM D-2488, “Description and Identification of Soils (Visual-Manual Procedure).” A key factor to look for during excavation of the borrow pit are changes in plasticity of the clay.

(2) In-Place Moisture Content and Density Tests.

(a) Typically, moisture content and density tests are performed in an evenly spaced grid pattern. The grid pattern should be staggered for successive lifts so that sampling points are not at the same location in each lift.

(b) Verify that moisture content and density test results fall within the "Acceptable Zone" for the material type being tested.

(c) If test results are not within the "Acceptable Zone", additional tests should be taken in the area where the failed test was made. If all of the repeat tests pass, the failed test result may be ignored. If any of the additional tests fail, repairs should be performed.

(d) The contractor should submit documentation describing the corrective measures taken in response to failed test results.

(e) Verify moisture content and density tests are performed using specified test procedures.

(f) At the beginning of a project, at least 10 measurements of moisture content and density should be made on representative samples of site-specific soil using any rapid measurement methods proposed for use. These results should be compared against test results using standard test methods to verify there is good correlation.

(g) Verify nuclear gauges are standardized daily on a reference standard in accordance with ASTM D 2922 and ASTM D 3017.

(h) Make sure the contractor uses nuclear gages in the direct transmission mode to measure density. This means the probe is inserted into a hole in the soil layer. The probe rod is then pressed against the surface of the hole closest to the detector and the density measurement is taken.

(i) Nuclear gages are used in the back-scatter mode to measure moisture content. This means the probe is not inserted into the clay layer.

(j) The most serious potential source of error in using nuclear gages is improper use by the operator. One gross error that is sometimes made is to drive the source rod into the soil rather than inserting the source rod into a hole that has been made with a drive rod. Other sources of error include the following: improper separation of the source from the side and base of the hole, an inadequate period of counting, inadequate warm-up of the device, other sources of gamma radiation, and infrequent calibrations.

(k) Rapid moisture content tests taken using either the nuclear gage (ASTM D-3017) or microwave method (ASTM D-4643) should be checked periodically (one in every ten tests is typical) using the standard method for determining moisture content (ASTM D-2216). This is especially critical when the contractor is using a nuclear gauge because they are susceptible to interference which results in the gauge overestimating moisture content.

(l) Rapid nuclear density tests (ASTM D-2922) should be checked periodically (one in every twenty tests is typical) using a standard method such as the sand cone (ASTM D-1556) or rubber balloon (ASTM D-2167).

(m) When checking the accuracy of rapid moisture content and density tests, the standard moisture and density tests should be taken at the same location as the rapid tests so that results can be easily compared.

(n) When observing the contractor performing sand cone tests, check to make sure the hole dug in the soil layer does not contain rough edges or overhangs that can produce voids in the sand filled hole. Also inspect the sand to make sure it is not contaminated with soil particles. Vibrations from equipment working nearby can also affect sand cone test results by densifying the sand.

(o) When inspecting rubber balloon tests being performed, check the excavated hole for rough edges which leave small zones that cannot be filled with the pressurized balloon.

(p) A minimum of one moisture content and density test should be performed each day that clay is placed.

(3) In-Place Hydraulic Conductivity Tests.

(a) Verify undisturbed samples are taken for hydraulic conductivity testing at the specified frequency for each lift of clay placed.

(b) Verify the samples are collected and tested using the procedures described in the specifications. Thin-walled sampling tubes should be pushed (not pounded) into the clay perpendicular to the plane of compaction.

(c) Hydraulic conductivity testing is generally performed in accordance with ASTM D-5084. The specifications should indicate the confining pressure and head to be used for testing the samples. Contact the design district if this information is not provided. Typically, a confining pressure of 35 kPa (5 psi) is recommended for both liner and cover systems.

d. Protection.

(1) Clay placement and compaction should not take place if the temperature is below 0 degrees C (32 degrees F) or if it is raining.

(2) Excess Surface Water.

(a) Puddles and excess moisture should be removed by replacing the wet soil, discing, or allowing the soil to dry prior to placement of additional clay.

(b) Look for areas of erosion after each rainfall. Require the contractor to repair areas of erosion and reestablish grades.

(c) Reworked areas should be retested for moisture content and density as described in Paragraph e. Repairs.

(3) Desiccation and Freezing.

(a) Ensure the contractor keeps the clay surface moist at all times so that desiccation cracks are minimized. The allowable size of desiccation cracks is often not addressed in the specifications. If this is the case, discuss this issue with the contractor prior to construction so that criteria acceptable to both, is agreed upon. Typically, cracks which are no greater than 6 mm wide by 51 mm deep (.25 inches wide by 2 inches deep) are not considered a problem.

(b) The clay layer should be covered as quickly as possible with other soil layers. Geosynthetics alone may not provide adequate protection.

(c) Require additional moisture content tests be performed if there are indications the clay is drying out. A decrease in the moisture content of one to two percent is not considered serious and within the general accuracy of testing. However, larger reductions in moisture content provide clear evidence that desiccation has taken place.

(d) The clay layer may be tested at multiple depths to get a better feel for variations in moisture content.

(e) If the subgrade soils are dry they may also be pulling moisture out of the clay.

(f) Inspect for cracking or other damage if the clay layer is exposed to freezing temperatures. It is difficult to determine the depth to which freezing took place by examining the surface of the clay layer. Dig into the clay layer and look for hairline cracks. Also look for areas where the soil breaks apart into chunks along cracks caused by freezing.

(g) Freeze/thaw is often accompanied by desiccation. Require the contractor to measure moisture content of the clay within and beneath the zone of suspected frost damage. Density may also be measured. However, freeze/thaw often has little effect on density.

(h) If freeze/thaw damage is suspected, samples can also be hand trimmed from the clay layer for hydraulic conductivity testing. Sampling tubes should not be pushed into a clay layer suspected of having freeze/thaw damage because this procedure will probably close the cracks caused by the freeze/thaw.

e. Repairs. If the clay layer does not conform to the specifications, the first step is to define the extent of the area requiring repair.

(1) Require the contractor repair the lift of clay out to the limits defined by passing QC or QA tests.

(2) Do not allow the contractor to guess at the extent of the area that requires repair. To define and minimize the limits of the area to be repaired, additional tests are often performed.

(3) Once the area requiring repair has been defined, the area should be thoroughly disced, reworked, and recompacted. If the depth of soil requiring repair is greater than one lift, it may be necessary to strip away and replace the clay.

(4) After repairs have been made, the repaired areas should be tested at the same frequency as required for the rest of the project.

(5) Ensure that voids in the clay created for tests, samples, and grade stakes are repaired by placing and compacting clay backfill or bentonite in the voids. The backfill material should be placed in the hole in loose lifts (typically 50 mm (2 inches) thick) and tamped several times with a steel rod prior to placing the next lift.

(6) If sand cone density tests are performed, verify the sand is removed prior to repairing the void.