LINERS FOR LAND DISPOSAL SITES

An Assessment

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A relatively recent development in sanitary landfill design technology is the use of barriers to inhibit the movement of leachate into water sources. Many materials have been proposed and used as barriers to line land disposal sites. This paper discusses the use of natural soils, asphalt treatments, polymeric membranes, and treated soils as liner materials. Material properties, construction methods, costs, future materials, and leak detection are discussed. For each liner material, a construction specification is included.

LINERS FOR LAND DISPOSAL SITES

An Assessment

Allen J. Geswein*

A sanitary landfill is a solid waste land disposal site located, designed, and operated to minimize environment impact. One potential environmental impact is contamination of ground and surface waters which can occur from improperly located, designed, or operated land disposal sites. The potential for contamination occurs because within a land disposal site various physical, chemical, and biological processes take place which produce compounds that can be dissolved or suspended in water percolating through the solid waste. Waters contaminated in this manner are called leachate.

The occurrence of leachate does not mean that ground and surface water will be polluted. Methods to control leachate are available. One of these methods is to collect the material and treat it to remove the harmful constituents. Collection of leachate requires that a barrier exists between the solid waste which produces leachate and the water that would become polluted. The barrier can be made from existing impervious soil or by importing other construction materials. The most common barrier is made by building the land disposal site so that a "bathtub" is formed. The sides and bottom of this type of site must be impermeable in order to contain the leachate. Also, provisions must be made so that the leachate collected can be removed

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for treatment. Sloping the bottom to a sump where a pump is installed is the most common way of providing for removal to a treatment facility.

The installation of impermeable liners in a solid waste land disposal site is a recent development, so very little is known about long term effects. The base of a landfill can be a hostile enviornment for these materials. Anaerobic, reducing conditions are encountered so the durability and integrity of the barrier can be questioned, particularly long term integrity. Even materials, such as layers of clay and polymeric membranes, which are usually considered inert may react with the leachate, resulting in liner failure.

The subject of this paper is the materials that have been proposed to line the sides and bottoms of land disposal sites to contain leachate. An impermeable liner can be made from many different types of materials including natural soil, treated soil, asphalt treatments, and polymeric membranes.

The construction of a large impermeable barrier can be a difficult task. The special techniques that are required for each different material type are presented later in this report.

Cost is a major consideration in any construction project. Because none of the proposed materials have been judged superior to another, cost will very likely be one of the considerations that can be examined closely during the design process. Cost estimates are presented later in this paper.

Research is underway to determine the long term capabilities of the various liner materials. In addition to research being conducted by the various manufacturers, the EPA is evaluating several materials. A summary of the liner related research activities being conducted by EPA is presented in Appendix A.

MATERIALS

The list of materials being used or proposed as land disposal site liners include conventional paving asphalts, hot sprayed asphalt, asphalt sealed fabric, polyethylene (PE), polyvinyl chloride (PVC), butyl rubber, Hypalon*, ethylene propylene diene monomer (EPDM), chlorinated polyethylene (CPE), compacted clay, and mixtures of the native soil with either montmorillonite or cement. These materials have been used successfully in other similar applications. Many industries and communities pond various fluids in man-made reservoirs. When the natural soil is porous, the reservoirs can be made by installing an impervious liner. In some cases, the liner material has been designed to contain a specific fluid.

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* Hypalon is a registered trademark of Dupont.

Because the liners have been used in other applications to form an impermeable structure, the landfill designers have assumed that the materials can be used to construct impermeable land disposal sites. Leaks may develop after the barrier is exposed to leachate because of the tendency of the leachate to react with the liner materials. However, there is no information available today on whether or not any of the liner materials will react with the leachate. The problems associated with the potential for a reaction between the leachate and the liner are compounded because the properties of leachate vary (Table 1).

Almost all of the above materials have been utilized at one or more land disposal sites. The following is a brief discussion of some of these sites. The discussion is presented using the following categories: asphalt, polymeric membranes, and treated soils.

Asphalt

Several types of asphalt liners have been used at various landfill sites. One of the first installations was constructed in 1971 at Montgomery County, Pennsylvania. The liner was a three inch thick tar cement pavement. The aggregate for this liner was the same as is commonly used for street paving except tar was used as the binder rather than asphalt. A one-eighth of an inch thick

Table 1

TYPICAL SANITARY LANDFILL LEACHATE COMPOSITION*

Analysis	Range of Values+ Low	High
pH	3.7	8.5
Hardness (carbonate)	35	8,120
Alkalinity (carbonate)	310	9,500
Calcium	240	2,570
Magnesium	64	410
Sodium	85	3,800
Potassium	28	1,860
Iron (total)	6	1,640
Chloride	96	2,350
Sulfate	40	1,220
Phosphate	1.5	130
Organic nitrogen	2.4	550
Ammonia nitrogen	0.2	845
Conductivity	100	1,200
BOD	7,050	32,400
COD	800	50,700
Suspended solids	13	26,500

* Source: Leonard S. Wegman Co., Inc. Typical specifications of an impermeable membrane. Lycoming County Board of Commissioners, Pennsylvania. Unpublished data, 1974.

\+ Values are given in milligrams per liter except pH (pH units) and conductivity (micromhos per centimeter).

coating of hot tar was then sprayed over the pavement as a sealer. The pavement was then protected by a two to three inch cover of crushed rock (maximum size three-eighths of an inch) and an additional 12 to 18 inches of incinerator residue was placed over the pavement. The base for the pavement consisted of four feet of broken stone, four feet of backfill, and a six inch layer of crushed stone (maximum size one inch). The base was built very thick because the site was an abandoned quarry and the contractor was building up to escape ground water. Tar was used as the binder in the bituminous paving because it, unlike asphalt, is heavier than water.[1]

The Rockford, Illinois landfill used two different asphalt systems at different locations in the same site. The first system was a two inch hot asphalt mix with a tar emulsion sealer. A later liner used was a two inch thick cold-mix asphalt pavement with three sealer coats. The first coat was an application of 0.25 gallon per square yard of emulsified asphalt. Two additional coats of 0.25 gallon per square yard of tar emulsion were added. Both liners were covered with six inches of sand prior to the placement of solid waste.[2]

A hot sprayed asphalt liner has been used at Bucks County, Pennsylvania. At this installation, a three-fourths of an inch thick layer of the specially formulated asphalt is built up in four or more passes by a truck equipped with a spray bar. The total application rate is about two gallons per square yard.[3]

There is a patented system using an asphalt emulsion sprayed on polypropylene fabric currently being evaluated as a sanitary landfill liner by both the manufacturer and the EPA. No full scale landfill applications of this material have yet been built, but the material has been found to be competitive for sewage lagoons and other applications.[4]

Polymeric Membranes

Six polymeric liner materials have been proposed as sanitary landfill liners. They are PE, PVC, butyl rubber, Hypalon, EPDM, and CPE. PVC is the most popular of these materials. It has been used at Romeo, Michigan, North Hemstead, and Brookhaven, New York, and has been selected for use in Lycoming County, Pennsylvania. (Further information on the Lycoming County project is given in Appendices B and C). Harrisburg, Pennsylvania, has installed a butyl rubber liner at a disposal site used for incinerator residue. The SHWRL has installed both Hypalon and CPE liners at the Boone County field site (Walton, Kentucky). There are no known full scale liner applications using either PE or EPDM.

Treated Soils

One commercial firm offers refined montmorillonite, a naturally occurring clay mineral, as an admixture to be used with native soils to provide a liner. The material is sold under the commercial names

Bentonite and Volclay. Crystal Lake, Illinois, has an operating site with this type of liner, and Toronto, Canada, is currently building one.[5]

Two types of Volclay are available. In addition to the pure montmorillonite, there is a bentonite with a polymer addition. The polymer addition is recommended when the fluid to be contained has a dissolved salt concentration exceeding 1,000 ppm. For most sanitary landfill applications, the polymer addition would be required.

Soil tests of the site are required to determine the application rate of the Volclay. A large site may require several different application rates at various points in the fill site.

Another system that has been proposed is the use of a soil-cement layer with a sealer coat of tar or asphalt. Sandy or silty soils will react with the cement more readily than will clays or soils with a high organic content and, therefore, require less cement to develop the desired properties. Soil tests are required to determine the amount and type of cement to be used at a specific site. There are no known instances where soil-cement has been used in a full-scale liner installation for a sanitary landfill.[6]

CONSTRUCTION METHODS

The construction of a sanitary landfill liner requires close attention by the field engineer. Three distinct phases of construction have been identified. These are: subgrade preparation, liner installation, and liner protection.

Subgrade Preparation

Any sanitary landfill liner must be built on a firm base in order to prevent significant differential settlement of the subgrade and subsequent loss of liner integrity. The specifications for the subgrade preparation should include the appropriate soil tests to insure that optimum compaction is achieved.

Wet and/or cold weather make the construction of the subgrade and the sanitary landfill liner more difficult and should be avoided when possible. When liners are built during adverse weather conditions, more efficient monitoring and control procedures should be used by the field engineer to insure the installation of a quality product.

Liner Installation

Most liner materials require an unique installation technique. The exception is the polymeric materials which use essentially the same installation procedures. The following is a brief discussion of how to install paving asphalt, hot sprayed asphalt, asphalt emulsion sprayed on polypropylene fabric, polymeric membranes, montmorillonite, and soil-cement liners. Standard specifications for the liner materials are included in the Appendices. These specifications give more detail on the proper installation procedures.

Paving asphalt is placed by a conventional paving machine. If a sealer coat is specified, it can be applied using a truck equipped with a spray bar or by using a hand held sprayer. Since the integrity of this type of liner can be damaged by weeds growing through it, the use of a soil sterilant on the subgrade to prevent plant growth may be required.[7] Specifications for this material prepared by The Asphalt Institute are given in Appendix D.

Hot sprayed asphalt membranes are constructed using a spray bar. The completed membrane will consist of one and a half to two gallons of sprayed asphalt per square yard and can range in thickness from one-fourth to three-fourths of an inch. Three or four passes of the spray bar are used to build up this membrane. If fewer passes are used (higher application rate per pass), there is a tendancy for bubbles to be formed. Leaks will develop when these bubbles rupture. Joints are formed by overlapping. The specified overlap varies from 1 to 12 inches.[3,8] Appendix D includes a typical specification for this material.

There is a three-stage construction process for the asphalt emulsion sprayed on polypropylene fabric. First the fabric is spread on the ground. The fabric is in sheets 15 feet by 300 feet which are sewed together. A mixture of water, a wetting agent, asbestos, and an asphalt emulsion is then sprayed in two coats. The first coat is applied at a rate of one gallon per square yard. When this coat dries, the evaporation of the water causes pin holes to develop in the membrane. A second coat of the mixture is then sprayed at a rate of 0.4 to 0.5 gallons per square yard. The final membrane is approximately 100 mils thick (one mil equals 0.001 inch).[9,10] The manufacturer does not recommend placing this membrane when the temperature is below 40°F.[4] Appendix E is the Soil Conservation Service Engineering Standard for this type of liner material.

Plastic and rubber membranes are delivered to the site in large sheets. These membranes range in thickness from 10 to over 60 mils. Typically, these sheets will have many factory splices in the material. In order to make the liner watertight, a number of field splices are required. The most difficult material to field splice is butyl rubber. Butyl requires a special two-part adhesive with a cap strip, and the operation must be performed under dry conditions. EPDM uses a much simpler single stage adhesive. Hypalon, PE, CPE, and PVC can be solvent sealed.[11]

Any of the polymeric materials can be fabricated with a reinforcing fabric (scrim) laminated between layers of the basic material. Nylon, dacron, polypropylene, and fiberglass are examples of commonly used scrim fabrics. Better dimensional stability, better puncture resistance, and greater hydrostatic load capacity are the advantages of the reinforced materials. The disadvantages are: less elongation prior to rupture, less conformity to ground irregularities, less flexibility, and greater cost.[12]

Polymeric liner materials are also classified as exposable and unexposable. Exposable materials are formulated to resist ozone and ultraviolet exposure longer than unexposable membranes. Butyl, EPDM, Hypalon, and CPE are exposable materials. PVC and PE are classified as unexposable.

While the general properties of all the basic polymeric materials can be stated (Appendix F), it should be recognized that the specific properties are determined by the manufacturer. Many different types of end products can be made by using various scrims, plasticizers, and resins. The manufacturer can provide a material tailored to a specific job.

Anchoring the edges of plastic and rubber membranes is accomplished by burying the edge in a shallow trench. Before the membrane is placed, the compacted subgrade should be smooth so that the material is not required to bridge over tire ruts and other surface imperfections.

Appendix C is the specification prepared for Lycoming County's proposed PVC liner. The Soil Conservation Service has engineering standards for several polymeric materials which can be used as pond liners. The standards are given in Appendix G.

The construction of a sanitary landfill liner using montmorillonite as an admixture to the native soil is accomplished using conventional farm and earth-moving equipment. Spreading the grayish-white granular material can be accomplished with a fertilizer, pesticide, or manure spreader. Typical application rates range from 10 to 20 pounds per square yard. Some experimentation may be required to determine the proper setting to use for a particular spreader. After the material is spread, three to four passes with a disk are required to mix the montmorillonite to the appropriate depth, usually six inches. Flat steel wheeled rollers or rubber tired rollers are recommended for compaction. The use of sheepsfoot rollers is not recommended by the manufacturers because these devices tend to force the montmorillonite deeper into the subgrade than six inches. The material is not an effective liner if it is placed deeper than the design depth.[5] An engineering standard of the Soil Conservation Service on the use of bentonite as a pond sealer is given in Appendix H.

Soil-cement is a mixture of pulverized soil and measured amounts of portland cement and water, compacted to high density. Since no full-size sanitary landfill liner has been built using this material, no special construction techniques have been developed. In general, soil-cement pavements are built using the following steps: (1) spread portland cement and mix, (2) apply water and mix, (3) compact the mixture, (4) perform final grading for drainage, and (5) cure the mixture. Depending on the soil type encountered, cement is added at a rate of 3 to 20 percent by weight to the soil. Spreading and mixing devices have been designed specifically for soil-cement pavement construction, but conventional earth-moving equipment can be used. To cure the soil-cement, a moisture-retaining cover is placed on the pavement to retain moisture and permit the cement to hydrate. Bituminous materials sprayed at rates varying from 0.15 to 0.30 gallons per square yard are the most common curing materials. Waterproof paper, plastic sheets, wet straw, sand, burlap and cotton mats have also been used. The soil-cement requires seven days to cure.[6] The Suggested Specifications for Soil-Cement Base Courses prepared by the Portland Cement Association are given in Appendix I.

Liner Protection

None of the proposed liner materials should be used as a pavement. While some of these materials can easily support rubber-tired construction equipment, no manufacturer recommends allowing collection vehicles to use the liner as a pavement because of the high wheel loadings. Equipment with crawler treads should not be allowed to operate directly on the liner. Manufacturers recommend protecting the liner with an earth cover one to two feet thick. This material should not contain jagged rocks or other sharp objects that could damage the liner. Similarly, the first lift of solid waste placed in the fill site should not contain items such as, bulky wastes, pipe or white goods that could puncture the liner during the filling operation. Such quality control is difficult to achieve, considering the heterogeneous nature of solid waste delivered in compactor trucks.

COSTS

The cost of liner materials is difficult to establish. Many of the proposed materials are petroleum products which are increasing in cost. The relative costs given in Tables 2 and 3 are as meaningful as the absolute values.

Table 2

COST FOR VARIOUS SANITARY

LANDFILL LINER MATERIALS*

Material	Installed cost+ ($/sq yd) (1973)	($/sq ft)
Polyethylene (10 - 20‡ mils§)	0.90 - 1.44	
Polyvinyl chloride (10 - 30‡ mils)	1.17 - 2.16	
Butyl rubber (31.3 - 62.5‡ mils)	3.25 - 4.00	
Hypalon (20 - 45‡ mils)	2.88 - 3.06	.32 - .34
Ethylene propylene diene monomer (31.3 - 62.5‡ mils)	2.43 - 3.42	
Chlorinated polyethylene (20 - 30‡ mils)	2.43 - 3.24	
Paving asphalt with sealer coat (2 inches)	1.20 - 1.70	
Paving asphalt with sealer coat (4 inches)	2.35 - 3.25	
Hot sprayed asphalt (1 gallon/yd^2)	1.50 - 2.00 (includes earth cover)	
Asphalt sprayed on polypropylene fabric (100 mils)	1.26 - 1.87	
Soil-bentonite (9.1 lbs/yd^2)	0.72	
Soil-bentonite (18.1 lbs/yd^2)	1.17	
Soil-cement with sealer coat (6 inches)	1.25	

* Source: Haxo, H. E. Jr. Evaluation of liner materials. U.S. EPA Research Contract 68-03-0230. October 1973.

\+ Cost does not include construction of subgrade nor the cost of earth cover. These can range from \$0.10 to \$0.50/yd^2/ft of depth.

‡ Material costs are the same for this range of thickness.

§ One mil = 0.001 inch.

Table 3

COST OF TAILINGS POND LINERS*

Liner material	Installed cost+ ($/sq yd)
Bentonite	
18 lb/sq yd	1.26
Asphalt	
Asphalt membrane	1.26
Asphalt concrete	1.80
Rubber	
Butyl	
1/16"	3.78
3/64"	3.24
1/32"	2.70
Ethylene propylene diene monomer	
1/16"	3.69
3/64"	3.15
1/32"	2.61
Synthetic membrane	
Polyvinyl chloride	
10 mils	1.17 (includes
20 mils	1.62 earth
30 mils	1.98 cover)
Chlorinated polyethylene	
20 mils	2.34
30 mils	3.06
Hypalon	
20 mils	2.34
30 mils	3.06

* Source: Clark, D. A., and J. E. Moyer. An evaluation of tailings ponds sealants. Environmental Protection Technology series EPA-660/2-74-065. Washington, U.S. Government Printing Office, June 1974. p. 22-23.

\+ Includes material and labor. Cost of subgrade preparation and, except where noted, earth cover is not included.

SPECIAL CONSTRUCTION METHODS

Two unusual leachate control methods have been identified. One method attempts to prevent leachate formation and the other attempts to control the horizontal movement.

For leachate prevention, the objective is to encase the solid waste in an impermeable material. Both the top and bottom of the filled area are covered. The assumptions for this type of construction are that the amount of leachate generated will be negligible and leachate will not flow from the site because the water from exterior sources, such as ground water, rainfall, and runoff will never be allowed into the fill. If more than one lift is required to complete a fill, there would be impermeable material placed over the top of each lift. The design may call for sealing the solid waste each year during the active life of the fill, so several liners may be required.[13] This method has reportedly been used at fill sites that accept primarily industrial or hazardous wastes. Bricktown, New Jersey, has proposed using this type of design for a sanitary landfill accepting primarily municipal solid waste.[14] Vents to allow gases of decomposition to escape from the fill are required for this type of construction.

A landfill at Croton Point, New York, as a result of a recently decided lawsuit, is also involved in leachate prevention.

On completed fill areas, the operating agency is required to cap to seal the site "in such a manner as substantially to eliminate infiltration of rainfall water or other source of recharge of the ground water."[15] The method must be approved by the State and EPA. No material selection has been made for this project.

Buffalo, New York, built an unusual leachate containment structure when their landfill was moved in 1973. At the new site, a clay layer was found at a depth of 25 to 30 feet. To take advantage of this impermeable layer, a three foot wide trench was dug with a backhoe until the clay layer was exposed. The trench was backfilled with a slurry of the natural soil and montmorillonite. The new site was completely encircled using this method of construction.[5] Theoretically, no horizontal or vertical movement of any leachate formed can occur.

The ten million dollar project required moving 1.8 million cubic yards of solid waste and also included the construction of a sump to collect any leachate formed within the site. No special precautions were taken to make the top of the new fill impermeable so leachate could be formed. The present plans are to pump this material to a sanitary sewer and treat the leachate at the municipal sewage treatment plant.

FUTURE MATERIALS

All of the discussion to this point has centered on materials that were designed as pond liners and/or paving. No material has yet been developed specifically to contain leachate. Since the properties of leachate can now be estimated (Table 1), the design of such a membrane is possible. One large firm (Goodyear) has begun the development of a polymeric material for this purpose.[16] No estimate can be made as to when this material will be commercially available.

Various soils can attenuate the minerals found in leachate. It may be possible to build a liner composed of several layers of different soils that will act as a treatment facility as the leachate percolates through the soil. Research is now underway that will provide the attenuation characteristics of some soils (Appendix A). At this time, the construction of such a liner is only a concept. Much additional work in this area will be needed before a full scale liner can be built.

LEAK DETECTION

Detecting leaks in a sanitary landfill liner is an important element in environmental protection. Unfortunately, very little effort has been directed toward developing leak detection systems for sanitary landfills. Systems are available for retention ponds which could be used for sanitary landfills.

While these systems can be used to determine whether or not the liner is leaking, the repair of the liner is a problem that has no simple solution. When a leak develops in a pond, repairing the liner is, comparatively, a simple operation. A pond can be drained to expose the liner for repairs. However, the same operation in a landfill would be a major excavation effort and the excavating equipment could cause even more damage to the liner.

Three methods can be used to detect leaks. They are ground water monitoring wells, piping systems below the liner, and electrical sensing systems.

Assuming that there is sufficient knowledge of ground water movement in the area of the fill, monitoring of the water quality could be used to detect leaks. However, if a leak was detected in this manner, there would be no way to determine its exact location.

Using a system of perforated pipe located below the liner to collect any material leaking from the site is another possible leak detection system.[12,p.40] Since some of the material is collected, it would be possible to provide treatment. The amount collected would depend on the permeability of the soil. Since a liner has been installed, the soil must be very porous and a considerable amount of leachate would not be collected by this system.

The electrical sensing system consists of a series of metal pins driven into the ground beneath the liner. The pins are connected by waterproof cable through a selector switch to a resistivity meter. The selector switch is used to take resistivity readings between any two pins. Leaks are detected as changes in resistivity. This system can be used to determine the exact location of a leak.[12, p.40]

CONCLUSIONS

All of the materials described in this paper, have been used successfully to contain fluids. It follows that a properly designed and constructed sanitary landfill liner of these materials could be used to collect leachate. The long term effect of leachate on any liner material has not yet been determined, but studies are now underway (Appendix A).

The use of any sanitary landfill liner requires the construction of a subgrade that will not settle and harm the liner.

All liners are susceptible to harm from construction and/or collection equipment and should be protected by applying an earth cover.

The successful installation of a liner requires a good specification and on-site control of the construction process, including placement of the first lift of waste.

While some systems exist to aid in leak detection, there is no system that has been specifically designed to detect leaks in a sanitary landfill liner.

This paper has discussed only materials that could be used to collect leachate. The leachate that is collected must be removed from the base of the sanitary landfill for treatment or recirculation.

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Appendix A

RESEARCH ACTIVITIES

The Solid and Hazardous Wastes Research Laboratory is evaluating both native soils and various membranes as sanitary landfill liners. Becuase the base of a sanitary landfill exhibits anaerobic, reducing conditions, the durability of any liner material is in question. Even clay could react with the leachate and cause structural changes in the clay lattice. These changes may cause liner failure by adversely affecting the hydraulic conductivity.

Test cell one at the Boone County field site was constructed by SHWRL using a double liner. The two liner materials are a natural silty clay and a 30 mil Hypalon sheet. The clay was backfilled over the Hypalon to a depth of 18 inches. Leachate is collected both above and below the clay liner. The preliminary results indicate that about six percent of the total leachate collected passed through the clay layer. There is no information available, as yet, on the attenuation characteristics of the clay liner. The clay liner used at the site has a hydraulic conductivity of 1.64×10^{-5} cm/sec, some clays have hydraulic conductivities as small as 10^{-8} cm/sec.

Test cell two has been constructed using a chlorinated polyethylene liner. No results are available from this site.

An extensive evaluation of liner materials is being conducted under U.S. EPA Research Contract 68-03-0230. Twenty-four lysimeters have been constructed with twelve different materials used as liner materials. Each material is being used in two lysimeters. The liners will be removed after one and two years of exposure to leachate to determine what changes have occurred in the physical properties of the liner materials. In addition to these 12 materials, there are 34 samples buried in the sand covers above the liners. These materials will also be examined and tested. All of the buried samples have splices, either factory or field, to be evaluated. The lysimeters have only recently been completed, so results from this study will not be available for some time.

A project entitled "Investigation of Leachate Pollutant Attenuation in Soils" being conducted under contract to the EPA by the University of Arizona and the Illinois State Geological Survey, is designed to provide the relative attentuation properties of different soils. Natural and synthetic landfill leachates are being applied under anaerobic conditions to well characterized samples from the major soil groups in the United States and to mixtures of the three important clay minerals. The data will provide information on attenuation of separate leachate constituents by clay minerals and whole soils and will be used to modify an existing computer simulation model so that it will be capable of predicting the rate and extent of attenuation in field soils. The limited amount of data that is presently available substantiates the importance of the clay minerals.

In addition to the active studies mentioned above, two additional efforts if the area of hazardous waste liners are being intitiated by SHWRL. The Industrial Waste Treatment Research Laboratory, Edison, New Jersey, will be supplying input for a grant which will develop a decision model for liner materials. This contract will primarily be a literature survey and will identify research needs.

The SHWRL is also funding a testing program to evaluate liners subject to leachate from hazardous wastes. Twelve liner materials will be evaluated, four synthetics, four admixtures, two clays, and the contractor can select two additional materials. One sludge will be strongly acid, one strongly basic, one pesticide, and three additional sludges to be chosen by the contractor. The change in physical properties of the liner materials will be determined after one and two years exposure. A total of 144 lysimeters will be built. Also,the contractor will investigate accelerated testing methods for the liner materials.

Appendix B

LYCOMING COUNTY

The OSWMP is monitoring the construction of a controlled sanitary landfill which is being built in Lycoming County, Pennsylvania. Funds for the project are being provided by the Appalachian Regional Commission and the Department of Health, Education, and Welfare.

The plans call for extensive subsurface drainage construction. Ground water will be collected in perforated pipe beneath the fill. This collection system allows the water to be removed from the site by gravity.

A polyvinyl chloride liner will be placed above the ground water collection system. This impermeable membrane will keep any leachate that is formed from polluting the ground water. The contractor has not yet been selected.

A leachate collection system will be installed above the liner. The leachate will be collected in perforated pipe and conveyed by gravity to a lagoon. Design calculations estimate that no significant amounts of leachate will be formed until approximately 20 years after the site has been initiated. When significant leachate quantities are produced, the appropriate treatment facilities will be designed and installed. Until that time, any leachate collected in the system will be sprayed onto the fill and recirculated.

Appendix C

TYPICAL SPECIFICATIONS OF

AN IMPERMEABLE MEMBRANE

LYCOMING COUNTY

BOARD OF COMMISSIONERS

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1. SCOPE

The work includes the supply, delivery, unloading and supervision of installation of an impermeable membrane for the collection of leachate produced by a sanitary landfill. The impervious lining shall be installed where indicated on the drawings or as directed by the Engineer. All work shall be done in strict accordance with the drawings and specifications subject to the terms and conditions of the contract. Basis of purchase is the square yard.

2. WORK BY OTHERS

Excavation, preparation of supporting surface and labor for installation.

3. APPLICABLE CODES AND SPECIFICATIONS

The work under these specifications shall comply with the latest editions and bulletins of all applicable local and state codes and specifications.

4. MATERIALS

The membrane supplied shall be sheeting made of polyvinyl chloride (PVC) no less than 20 mils thick and shall perform as specified in Section 6, "LEACHATE CONTAINMENT".

The supplier shall provide sufficient solvent, cement or adhesive to make fast and efficient field splices at temperatures ranging from 20°F to 90°F.

The supplier shall submit with the bid the values and test methods for:

Thickness
Specific Gravity
Tensile Strength
Modulus -- 100%
Elongation
Weight per sq. yd.
Shore "A" Hardness
Graves Tear Resistance
Color

5. PHYSICAL REQUIREMENTS

The polyvinyl chloride membrane film shall meet the physical requirements of Table 1.

PVC materials shall be manufactured from domestic virgin polyvinyl chloride resin and specifically compounded for use in hydraulic facilities in a standard minimum width of at least 54 inches. Reprocessed material shall not be used. The color shall be neutral

TABLE 1

PHYSICAL REQUIREMENTS

TEST	MINIMUM TEST VALUES	TEST METHOD
Specific Gravity	1.24-1.30	ASTM D-1505
Tensile Strength, psi, min.	2200	ASTM D882-B
Elongation, % min.	300%	ASTM D882-B
100% Modulus, psi	1000-1600	ASTM D882-B
Elmendorfer Tear, gms/mil,min.	160	ASTM D-1922
Graves Tear, lbs/in. min.	270	ASTM D1004
Water Extraction, % max.	0.35	ASTM D1239
Volatility, % max.	0.7	ASTM D1203
Impact Cold Crack, ^{o}F.	-20	ASTM 1790
Dimensional Stability, max.% (100^{o}C-15 minutes)	5	
Shore Durameter, "A"	65-75	ASTM D676
Outdoor Exposure To Sun, hrs.	1500	
Bonded Seam Strength, % of Tensile, min.	80%	
Pinholes/10 sq. yds. max.	None	
Resistance to Burial		(Meets USBR Test specifically formulated for resistance to micro-biological attack)
Alkali Resistance		Passes Corps of Eng. CRD-572-61
Color	Black or Grey	

gray to black. Thickness shall be as shown on the project drawings. Certification test results showing that the sheeting meets the specifications shall be supplied on request.

The membrane shall be shop fabricated into standard size large sections and into odd-sized pieces as required to suit the facility to minimize the number of field splices. After fabrication, the membrane shall be packed for easy and minimum handling in the field. Shipping containers capable of preventing damage to the contents during shipment and field handling shall be provided by the supplier.

The supplier shall submit with the bid complete drawings and/or sketches and literature indicating the dimensions of each standard-size section of membrane; type, size and weight of shipping container; procedure for splicing, connecting and anchoring membrane to soil, concrete and other appurtenances; and recommended methods of handling membrane by field personnel during membrane installation.

6. <u>LEACHATE CONTAINMENT</u>

The impermeable membrane shall be capable of preventing the leachate produced by the refuse from reaching the soil under the membrane.

The lining shall be capable of resisting the deleterious effect of constant exposure to the acids, gases, oils, changes in chemical and biological composition, changes in temperature and all other harmful conditions encountered in municipal sanitary landfills without loss of its impermeable quality.

Table 2 shows some chemical and biological characteristics of the leachate from a typical sanitary landfill that the lining shall be capable of resisting.

The membrane supplier shall carefully examine the listed sanitary landfill leachate components and their concentrations, and shall submit with the bid a signed statement attesting to the suitability of the membrane for the intended purpose.

7. <u>INSTALLATIONS</u>

Within 15 days of notice to proceed, the supplier shall submit for the approval of the Engineer (4) copies of a "Manual of Membrane Installation Practice".

The PVC lining shall be placed over the prepared surfaces to be lined in such a manner as to assure minimum handling. It shall be sealed to all concrete structures and other openings through the lining in accordance with the details shown on drawings submitted by the contractor and approved by the Engineer. The lining shall be closely fitted and sealed around inlets, outlets, and other project-

TABLE 2

TYPICAL SANTIARY LANDFILL LEACHATE COMPOSITION

Component	Range of Values[a]	
pH	3.7	8.5
Hardness (Carbonate)	35	8,120
Alkalinity (Carbonate)	310	9,500
Calcium	240	2,570
Magnesium	64	410
Sodium	85	3,800
Potassium	28	1,860
Iron (Total)	6	1,640
Chloride	96	2,350
Sulfate	40	1,220
Phosphate	1.5	130
Organic Nitrogen	2.4	550
Ammonia Nitrogen	0.2	845
Conductivity	100	1,200
BOD	7,050	32,400
COD	800	50,700
Suspended Solids	13	26,500

[a] Values in milligrams per liter except pH (pH Units) and Conductivity (Micromhos per centimeter)

ions through the lining. Any portion of lining damaged during installation by any cause shall be removed or repaired by using an additional piece of lining as specified.

Lap joints shall be used to seal adjacent lengths of factory fabricated pieces of PVC together in the field. The contact surfaces of the pieces shall be wiped clean to remove all dirt, dust, moisture, or other foreigh materials. Sufficient cold-applied vinyl-to-vinyl bonding solvent shall be applied to both contact surfaces in the joint area and the two surfaces pressed together immediately. Any wrinkles shall be smoothed out.

Any necessary repairs to the PVC shall be patched with the lining material itself and cold-applied vinyl-to vinyl bonding solvent. The bonding solvent shall be applied to the contact surfaces of both the patch and lining to be repaired and the two surfaces pressed together immediately. Any wrinkles shall be smoothed out.

All joints, on completion of the work, shall be tightly bonded. Any lining surface showing injury due to scuffing, penetration by foreign objects, or distress from rough subgrade shall, as directed by the Engineer, be replaced or covered and sealed with an additional layer of PVC of the proper size.

The supplier shall assign a representative to inspect the supporting surface prior to installation of the membrane. The representative shall remain at the site to supervise the membrane installation for as long as required and shall be responsible for all membrane installation operation.

8. GUARANTEE

The manufacturer shall warrant its plasticized PVC Sheeting to be free of defects at the time of sale and to deliver an expected minimum service life of 20 years from date of acceptance.

The supplier is notified that the in-place membrane shall be surrounded by a number of permanent observation wells and that periodic ground water quality tests shall be made of the ground water under and surrounding the membrane.

The warranty shall be based on installation of the liner on compacted sand free of sharp protrusions, continuous protection of the liner from atmospheric exposure and mechanical damage by a covering of soil and containment of fluid as characterized by the specification. Gross deviations from these conditions voids the warranty.

Any claim for alleged breach of warranty will be made promptly so that the manufacturer's representative may inspect the condition.

ASPHALT FOR WASTE WATER RETENTION IN FINE-SAND AREAS

(INCLUDES MODEL SPECIFICATIONS)

PART I: GUIDE FOR EMULSIFIED ASPHALT STABILIZATION OF SANDS FOR LAGOONS AND RETENTION BASINS

PART II: GUIDE FOR ASPHALT LININGS FOR LAGOONS AND RETENTION BASINS

THE ASPHALT INSTITUTE
Asphalt Institute Building
College Park, Maryland 20740

MISC-74-3
MAY 1974

PART I:

GUIDE FOR EMULSIFIED ASPHALT STABILIZATION OF SANDS FOR LAGOONS AND RETENTION BASINS

Waste water lagoons must be designed and built to prevent contamination of the subsoil by percolation. In addition, cohesionless sands, such as dune sands, that lack stability when dry, require stabilizing before asphalt membranes or hydraulic asphalt concrete linings are placed.

Therefore, specifications for construction of waste water treatment lagoons in cohesionless sands should include the following:

1. Site preparation, excavation, and embankment of the lagoon to the size and shape required with slopes no steeper than three-horizontal to one-vertical (essential for mixed-in-place stabilization).

2. Stabilization of the upper 4 to 6 in. (10 to 15 cm) of sands forming the lagoon bottom and embankment slopes to provide support for construction equipment necessary for placing an asphalt membrane seal or hydraulic asphalt concrete lining.

3. The required type of membrane seal or lining that the engineer feels essential for the required service life of the facility.

Model Specifications for Asphalt Stabilized Sand for Waste Water Lagoons and Retention Basins

1. Scope: Construct an asphalt stabilized sand working table as specified.

A. General Requirements

2. Site Preparation: All debris, vegetation, or other organic materials shall be removed from the job site. The site to be paved shall be graded to the required section and all excess material removed from the location of the work. Material in weak areas shall be removed to the depth required to provide a firm foundation and shall be replaced with suitable material.

Preceding embankment stabilization, all sewers, drains, control valves, and the like, shall be installed through the embankment areas to within the lagoon proper with adequately compacted backfill.

The sand shall be dampened if necessary to support stabilizing equipment.

If directed by the owner or his engineer prior to stabilizing the sand, designated areas shall be treated with a sterilant to prevent plant growth.

3. Thickness of Asphalt Stabilization: The sand shall be asphalt stabilized to a compacted depth of 4 or 6 in. (10 or 15 cm). (Note: Delete the depth not to be used.)

4. Equipment: The contractor shall provide the equipment necessary to complete the job acceptable to the engineer. Variations in the size and amount of equipment will depend on the size of the area being stabilized. (Note: More positive mixing is secured by single-pass type mixers.)

5. Sampling and Testing: If requested by the engineer the contractor shall furnish for test and analysis representative samples of the materials to be used in the work. Sampling and testing shall be in accordance with the latest revisions of the American Association of State Highway and Transportation Officials (AASHTO) or the American Society for Testing and Materials (ASTM) standard procedures for sampling and testing the materials being used in the project.

6. Smoothness: The surface of the completed work, when tested with a 10 ft (3 m) straightedge, shall not contain irregularities in excess of ½ in. (13 mm).

B. Materials

7. Asphalt: The asphalt used for stabilization shall be CMS-2h or CSS-1h emulsified asphalt as specified by the engineer prior to the letting of the contract. The asphalt material selected shall meet the requirements of ASTM Designation D 2397 (AASHTO Designation M 208).

8. Sand: The sand, for the depth of the stabilization, shall be free from vegetable matter, lumps or balls of clay, or other matter that will prevent coating with the asphalt materials.

9. Composition of Mixture: The application of emulsion into the sand shall be at the rate of 0.5 to 0.7 gal/yd 2 in. (0.9 to 1.3dm^3/m^{2}cm). [Based on a loose weight of 100 lb/ft^3 (1600 kg/m^3).] (Note: Designate the rate of application and delete the range shown.)

C. Construction

10. Restrictions: At the time the sand is to be stabilized the moisture content should be such that it will ensure the sand particles being coated with the asphalt emulsion. If necessary, water shall be added to the sand prior to mixing with asphalt. If CSS-1h emulsified asphalt is used, it may be diluted with water prior to application in lieu of adding water to the sand. Mixing, spreading, and compacting shall be performed when the air temperature is at least 50°F (10°C).

11. Application of Asphalt: The temperature of the asphalt emulsion at the time it is applied to the sand shall be within the following limits:

CMS-2h or CSS-1h 70° - 160°F (21° - 71°C)

12. Mixing Operations: The materials may be mixed by travel plant, rotary or mechanical mixing, or by motor graders.

13. Aeration: Before spreading and compacting commence, the moisture content shall be reduced enough by aeration to allow satisfactory compaction.

14. Spreading and Compaction: After the mixture has been aerated sufficiently to be compacted it shall be spread to uniform grade and cross-section and compacted with a pneumatic-tired roller or other suitable compaction equipment. Any irregularities in the surface shall be corrected by blading, shaping, and compacting until the surface is true to grade, slope, or cross-section. Special care shall be given to making all joints tight and of density equal to the adjacent material. (Note: A flush coat of 1 to 1 dilution of emulsion and water applied to the joint will improve tightness.)

15. Method of Measurement: The quantities to be paid for will be as follows:

(a) Excavation or Embankment per cu yd (m^3).
(b) Subgrade Preparation per sq yd (m^2).
(c) Mixing, Shaping, and Compacting per sq yd (m^2).
(d) Asphalt Materials - total number of gal (dm^3) measured at 60°F (15.5°C).

16. Basis of Payment: The quantities enumerated in Section 15 will be paid for at the contract unit price bid for each item or at a lump sum price bid for the job. Payment will be in full compensation for furnishing, hauling and placing materials, for rolling, and for all labor and use of equipment, tools, and incidentals necessary to complete the work in accordance with these specifications.

PART II:

GUIDE FOR ASPHALT LININGS FOR LAGOONS AND RETENTION BASINS

Lagoons and retention basins need to be sealed by placing membranes or impermeable mats of hydraulic asphalt concrete. For seals to be applied properly a firm working table is necessary. The Guide for Asphalt Stabilization of Sands, Part I of this publication, describes the preparation of a working table for placing seals. The firm working table allows application of hot asphalt or emulsified asphalt with conventional highway construction equipment to form a membrane seal. Such a membrane needs to be designed along with a protective cover, to retain the hydraulic head for the specific project. A membrane-type seal should not be employed to prevent loss by percolation where the maximum hydraulic head is expected to exceed 8 ft (2.4m).

Impermeable hydraulic asphalt concrete may be used in lieu of asphalt membrane as a seal. This will also provide a sturdy base on which to operate mechanical equipment for removal of deposits or sediment. For linings holding heads up to 7 ft (2 m), a single lift of hydraulic asphalt concrete having a minimum compacted thickness of 2 in. (5 cm) may be specified, provided all pavement joints lacking density are required to be heated and further compacted to provide density equal to or greater than that of the adjoining mat. For linings to hold heads of water 7 to 12 ft (2 to 3.6 m) two separate lifts of 1½-in. (4 cm) compacted thickness should be required, staggering joints at least 1 ft (0.3 m) to provide a positive seal. All joints need to be heated and recompacted where density is deficient or questionable.

All lagoons, lakes, or retention basins having horizontal dimensions greater than 200 ft (60 m) need to be designed to provide protection from wave action for a span of 3 ft (0.9 m) below and above the operating water level.

All membrane seals or asphalt concrete linings need to be designed to extend beyond the crest of slopes so as to be anchored in the embankment roadway or embankment top to effectively preclude erosion damage.

Model Specifications for Asphalt Linings for Lagoons, Lakes, or Retention Basins.

1. Scope: Furnish and construct an asphalt membrane or hydraulic asphalt concrete lining.

A. General Requirements

2. Surface Preparation: All leaves, debris, sands, loose and untreated, shall be collected and removed from the area to be treated. Any cracked or permeable areas shall be treated to provide a firm surface.

3. Tack Coat: A tack coat composed of CSS-1 or CSS-1h emulsified asphalt, mixed with equal parts water shall be applied to the stabilized base at a rate of approximately 0.10-gal/yd^2 (0.45 dm^3/m^2).

4. Thickness of Structure:

(a) Up to an 8-ft (2.4 m) depth

(1) Hot-sprayed asphalt membrane seal shall be placed at the rate of at least 1½ gal/yd^2 (6.8 dm^3/m^2) in at least 3 applications; or

(2) Emulsified asphalt membrane seal shall be formed by a double application of emulsified asphalt and aggregate. Application shall be as follows:

	CRS-2	3/8 in.(9.5 mm) Aggregate
1st Application, per sq yd	0.2 - 0.3 gal	12 - 18 lb (5-8 kg)
per m^2	0.9 - 1.4 dm^3	
2nd Application, per sq yd	0.3 - 0.4 gal	12 - 18 lb (5-8 kg)
per m^2	1.4 - 1.8 dm^3	

or,

(3) Hydraulic asphalt concrete laid in one course to a compacted thickness of 2 in. (5 cm).

(b) For 8 to 12 ft (2.4 to 3.6 m) depth.

Hydraulic asphalt concrete laid in two courses to a total compacted thickness of 3 in. (7.5 cm).

5. Equipment: The contractor shall provide the necessary equipment to complete the job acceptable to the owner. Variations in the size and amount of equipment will depend on the size of the area being paved.

6. Sampling and Testing: If requested by the engineer, the contractor shall furnish for test and analysis representative samples of the materials to be used in the work. Sampling and testing shall be in accordance with the latest revisions of the American Association of State Highway and Transportation Officials (AASHTO) or the American Society for Testing and Materials (ASTM) standard procedures for sampling and testing the materials being used in the project.

B. Materials

7. Asphalt:

(a) Hot-sprayed asphalt membrane seal. The asphalt shall conform to ASTM D 2521, "Asphalt for Use in Waterproof Membrane Construction for Canal, Ditch or Pond Lining."

(b) Emulsified asphalt membrane seal. The CRS-2 cationic emulsified asphalt shall conform to ASTM D 2397, "Cationic Emulsified Asphalt."

(c) Hydraulic asphalt concrete. The asphalt cement shall be 60-70 penetration grade or, AC-20 viscosity grade. The 60-70 penetration grade asphalt cement shall conform to ASTM D 946, "Asphalt Cement for Use in Pavement Construction" (AASHTO M 20, "Penetration Graded Asphalt Cement"). The AC-20 grade shall conform to AASHTO M 226, "Viscosity Graded Asphalt Cement."

8. Mineral Aggregate: Emulsified asphalt membrane seal. The 3/8 in. (9.5 mm) maximum size aggregate shall conform to the following grading*:

Sieve Size	Percent Passing, by Weight
1/2 in. (12.7 mm)	100
3/8 in. (9.5 mm)	85-100
No. 4	10-30
No. 8	0-10
No. 16	0-5

*ASTM D 693 (AASHTO M 43), Size No. 8

9. Hydraulic Asphalt Concrete: The mineral aggregate and asphalt (and if needed, mineral filler) shall be combined to meet the following gradations:

Sieve Size	Percent Passing, by Weight
1/2 in. (12.7 mm)	100
3/8 in. (9.5 mm)	95-100
No. 4	70-84
No. 8	52-69
No. 16	38-56
No. 30	27-44
No. 50	19-33
No. 100	13-24
No. 200	8-15
Asphalt (Percent by weight of total mix)	6.5-9.5

C. Construction

10. Spreading of Lining Materials:

(a) Hot-sprayed asphalt membrane seal. The membrane shall be placed by conventional asphalt distributor, usually with the spray bar offset to one side. The heated asphalt [minimum 400°F (204°C)] is sprayed on the stabilized base at the rate of at least 1½ gal/yd^2 (6.8 dm^3/m^2). The application shall be in at least three passes. All joints formed between passes of the asphalt distributor shall overlap 1 to 4 in. (2.5 to 10 cm) with no voided areas. Joints of subsequent applications shall be staggered from the joints of each preceding application by 2 ft (0.6 m) or more.

The membrane shall be covered with at least 1 ft (0.3 m) of acceptable cover material.

(b) Emulsified asphalt seal. Application of enulsified asphalt shall be by means of approved asphalt distributor. All joints formed between passes of the asphalt distributor shall overlap 1 to 4 in. (2.5 to 10 cm) with no voided areas. Joints of the second application shall be staggered from the joints of the first application by 2 ft (0.6 m) or more.

Immediately following application of the emulsified asphalt, cover aggregate shall be distributed uniformly over each emulsified asphalt application in such a manner as to provide uniform coverage as prescribed without spillage or excess. Care shall be taken to remove excess aggregate in event of spillage.

The cover aggregate shall be seated into the emulsified asphalt by rolling with a 3- to 5-ton (2.7 to 4.5 ton metric) pneumatic-tired roller immediately after aggregate placement.

Around all controls, inlets, or outlets extending through the floor or slopes of the basin, the emulsified asphalt shall be applied by hand-pressure distributor hose in a manner similar to that prescribed [illegible] shall be imbedded by acceptable hand methods so as to provide an effective seal comparable to the mechanical methods required.

(c) Hydraulic asphalt concrete. Rolling shall start as soon as the hot-mix material can be compacted without displacement. Rolling shall continue until thoroughly compacted and all roller marks have disappeared.

In areas too small for the roller, a vibrating plate compactor or hand tamper shall be used to achieve thorough compaction.

The void content of the compacted asphalt lining shall not exceed 4 percent. The void content shall be determined by the procedure detailed in ASTM D 3203, "Test for Percent Voids in a Compacted Bituminous Paving Mixture".

Paving around all valves, inlets or outlets in the floor or slopes of the basin shall be placed and compacted while the mix is hot. Areas to be paved shall receive a tack coat prior to paving.

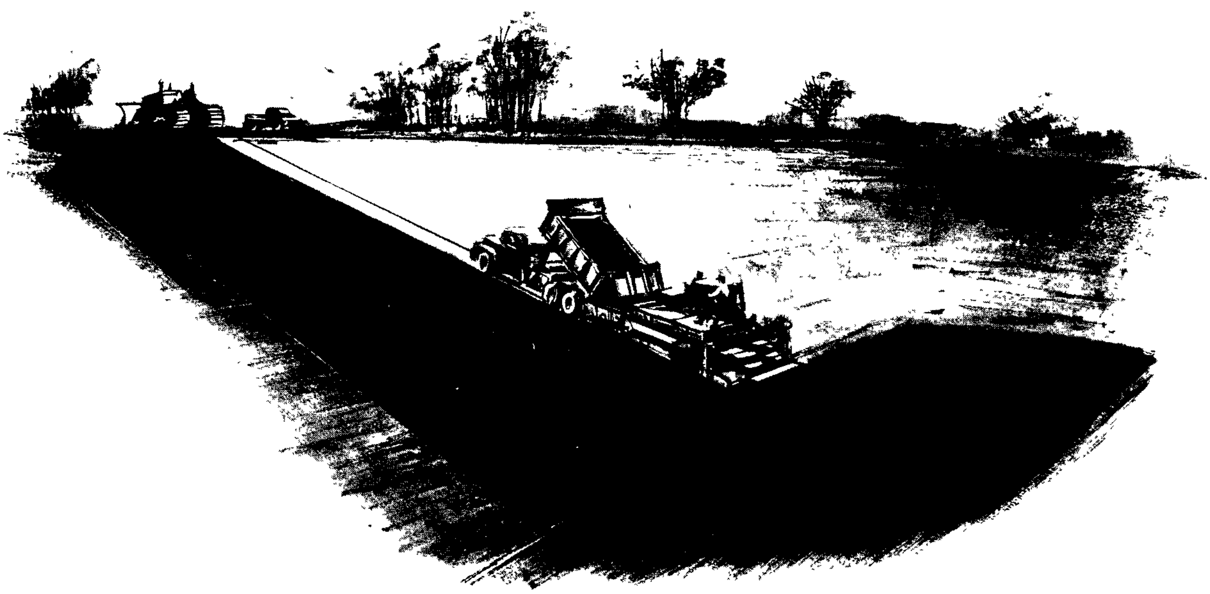
11. Method of Measurement: The quantities to be paid for will be as follows:

(a) Asphalt for membrane seal - total number of gallons (dm^3) (tons) measured at 60°F (15.5°C).

(b) Aggregate for emulsified asphalt seal - total number of tons [cubic yards] (m^3)

(c) Hydraulic asphalt concrete - total number of tons of asphalt mixture actually incorporated into the work.

12. Basis of Payment: The quantities enumerated in Section 10 will be paid for at the contract unit price bid for each item or at a lump sum price bid for the job. Payment will be in full compensation for furnishing, hauling and placing materials, for rolling, and for all labor and use of equipment, tools, and incidentals necessary to complete the work in accordance with these specifications.



Asphalt Concrete May Be Applied By Conventional Paving Machine If Slopes Are Not Too Steep

Appendix E

SOIL CONSERVATION SERVICE

ENGINEERING STANDARD

POND SEALING OR LINING

Asphalt Sealed Fabric Liner

Definition

Installing fixed lining of impervious material or treating the soil in a pond mechanically or chemically to impede or prevent excessive water loss.

Scope

This standard applies to the use of flexible membrane linings made of asphalt sealed fabric.

Conditions Where Practice Applies

This practice applies where water loss from a pond through leakage is or will be of such proportion as to prevent the pond from fulfilling its planned purposes, or where leakage will damage land, crops, cause loss of unacceptable amounts of water, or ground-water pollution.

Design Criteria

Ponds to be lined shall be constructed to meet the Soil Conservation Service Engineering Standard and Specifications for Pond, Irrigation Pit or Regulating Reservoir, Irrigation Storage Reservoir, Wildlife Watering Facility, Disposal Lagoons, or Holding Ponds as appropriate.

The flexible membranes to be used as linings shall be constructed of high quality ingredients and shall be certified by the manufacturer to be suitable for this use. Base material used for asphalt sealed liners shall be highly resistant to bacteriological deterioration. Asphalt used shall be Anionic Asphalt Emulsion SS-1h.

All membranes shall be of a quality that meets or exceeds the attached materials specifications for Asphalt Sealed Fabric Liner. Minimum nominal thickness shall be 100 mils.

Livestock shall be excluded from the site to prevent damage to the lining.

Plans and specifications for installation of Pond Sealing or Lining, Asphalt Sealed Fabric shall be in keeping with this standard and shall describe the requirements for application for the practice to achieve its intended purpose. See S-521-E for items to be considered in development of specifications.

ASPHALT SEALED FABRIC LINER

TEST DESCRIPTION	REQUIREMENT	TEST METHOD
Fabric Material	95 Percent Polypropylene Staple	-
Fabric Structure	Non Woven and Fused One Side	-
Fabric Weight	5.0 Ounces Per Square Yard	-
Fabric Maximum Pore Diameter	500 Microns	ASTM E 128
Asphalt Sealant-R&B Softening Point	200 Degrees-F	ASTM D 36-(Solvent Extraction)
Weight of 7M-02 Asbestos Fibers in Cured Sealant	10 Percent by Weight	
Ductility of Cured Sealant	5 Centimeters	ASTM D 113
Minimum Weight Asbestos Asphalt Residual	3.5 Pounds Per Square Yard	-
Minimum Membrane Thickness	100 Mils	ASTM D 113
Minimum Membrane Specific Gravity	1.0 (Air Evacuated from Fabric)	-
Breaking Strength-Either Direction	50 Pounds	ASTM D1682
Elongation-Either Direction	80 Percent	ASTM D1682
Joint Strength-Percent of Tensile	100 Percent	ASTM D1682
Tear Resistance (Notched Sample In Tension)	20 Pounds	ASTM D1004 - Die C
Elmendorf Tear Resistance	3200 Grams	ASTM D1922
Puncture Resistance	65 Pounds	USDA-ARS (1)
Hydrostatic Burst-Mullen	200 Pounds Per Square Inch	ASTM D751
Hydraulic Testing-35 Feet Head	No Water Loss	Pressure Cell (2)

(1) 3/8" sphere forced into membrane at 10" per minute. Pounds force at rupture is recorded..

(2) 6" diameter placed in pressure cell. One side of the sample, reinforced by 1/4" mesh screen, is open to air. Water under pressure equivalent to 35 feet water depth (15 PSI) at 100 degrees F is applied to the other side for 7 days. Observe for water loss through the membrane.

SOIL CONSERVATION SERVICE

ENGINEERING SPECIFICATIONS GUIDE

POND SEALING OR LINING

Asphalt Sealed Fabric Liner

Subgrade Preparation

The area to be lined shall be drained and allowed to dry until the surface is firm and will support the men and equipment that must travel over it during installation of the lining.

All banks and fills within the area to be lined must be sloped not steeper than 1 to 1 for exposed lining and 2 1/2 horizontal to 1 vertical for buried linings.

The foundation area shall be smooth and free of projections that might damage the lining. Stumps and roots shall be removed. Rocks, hard clods, and other such material shall be removed or shall be rolled so as to provide a smooth surface or shall be covered with a cushion of fine soil material.

Where needed an effective sterilant shall be applied to the subgrade at the rate recommended by the manufacturer.

An anchor trench shall be excavated completely around the area to be lined at the planned elevation of the top of the lining. The trench shall be 8 to 10 inches deep and about 12 inches wide.

All lining material shall be free of damage or defect. Each package delivered to the job site shall be marked with the name of the material, the manufacturer's name or symbol, the quantity therein, and the thickness or weight of the material.

Placing the Lining

The liner will be fabricated on site to the shape of the basin in accordance with the manufacturer's instructions. Joints shall be machine sewn with heavy duty inert synthetic fiber thread.

The fabric shall be unrolled so that the unfused side will be up after installation. Joints shall be made by placing two widths of the fabric together, one directly on top of the other, aligning the edges and seaming at least one inch back from the fabric edge. The top layer of fabric shall then be unfolded so that the seam edge lies beneath the liner. The jointing operation shall be continued until the entire liner is completed.

Attachment to any pipe projecting through the lining shall consist of boots fabricated of the lining material, slipped over the projecting pipe, bonded to the pipe with mastic, and hand or machine sewn to the liner. Attachments to concrete, and similar structures shall be sealed with mastic and fastened with a batten strip.

Liner edges shall be trimmed and a minimum of 12" of fabric placed in the perimeter anchor trench. Trenches shall be backfilled only enough to secure the edges.

When the polypropylene fabric is in place it shall be sealed by spraying with the following proportioned mixture of sealant.

Anionic Asphalt Emulsion SS-1h	100 gal.
Asbestos Fiber 7M-02	60 lbs.
Water	44 gal.
Wetting Agent (Phillips or equivalent)	2 lbs.

The water and wetting agent shall be mixed in a tank or suitable container. The asbestos shall be added and mixed. The asphalt emulsion shall then be added and thoroughly mixed.

Sealant temperature shall not exceed 200 degrees F when applied. Ambient air temperature shall be 45 degrees F or higher to insure sealant cure. Two coats of sealant mix shall be applied to the liner at a rate of 0.7 gallons per square yard, per coats. Each coat shall be allowed to cure sufficiently so that it is not tacky before applying the next coat or placing the liner in service. Trenched edges shall be sprayed a minimum of 6" below grade.

Following curing the anchor trenches shall be backfilled and compacted.

Safety

Workers exposed to asbestos material shall comply with the Occupational Safety and Health Act and Environmental Protection Agency Regulations concerning handling and use of asbestos material.

Appendix F

POLYMERIC MATERIALS

Six polymeric materials have been previously discussed as sanitary landfill liner materials. The construction of a sanitary landfill liner is much the same for all the materials. However, the properties of the basic materials are quite different. This section will address the mechanical and chemical properties of polyethylene (PE), polyvinyl chloride (PVC), butyl rubber, Hypalon, ethylene propylene diene mononer (EPDM), and chlorinated polyethyene (CPE).

Polyethylene

Polyethylene is the least expensive of the membrane materials being considered. It has few restrictions on chemical exposure. PE is a flexible material with good tensile strength and low temperature characteristics. The poor weatherability and puncture resistance of the material can be offset by the use of a soil cover during installation.

Polyvinyl Chloride

Polyvinyl chloride is the most popular polymeric landfill liner material and also has been used frequently in the oil field and other industries. Many different plasticizers are used with the basic material to provide specific properties. Some of these plasticizers can be degraded by micro-organisms but this condition can be remedied by using a microbiocide in the material. In general, PVC is tolerant to a wide range of chemicals and petroleum products. PVC will become stiff at low temperatures thus making cold-weather installation a problem.

Butyl Rubber

Butyl rubber has excellent resistance to permeation of water. The material is resistant to water based inorganic salts, sewage, oxidizing chemicals, animal and vegetable oils and fats. Butyl rubber is not recommended for the retention of hydrocarbons and solvents. This is a very difficult material to splice in the field.

Hypalon

Hypalon is a synthetic rubber with good puncture and temperature characteristics. It is resistant to corrosive fluids, acids, and alkalis. The major disadvantages are high cost and low tensile strength.

Ethylene Propylene Diene Monomer

Ethylene propylene diene monomer is a synthetic rubber designed for contact with potable water. It is resistant to mild concentrations of acids, caustics, and other chemicals. EPDM is not recommended for solvents or hydrocarbons. The material has good weathering characteristics, low temperature flexibility, and heat resistance.

Chlorinated Polyethylene

Chlorinated polyethylene is a relatively recently developed polymer produced from a chemical reaction between polyethylene and chlorine. The material is frequently used in conjunction with other plastics and rubbers as a base to improve crack resistance. Good tensile and elongation strength are other favorable properties. The basic material has little resistance to chemicals, acids, and caustics.

SOIL CONSERVATION SERVICE

ENGINEERING STANDARD

POND SEALING OR LINING
Flexible Membrane

Definition

Installing fixed lining of impervious material or treating the soil in a pond mechanically or chemically to impede or prevent excessive water loss.

Scope

This standard applies to the use of flexible membrane linings made of plastic, rubber, and similar material.

Conditions Where Practice Applies

This practice applies where water loss from a pond through leakage is or will be of such proportion as to prevent the pond from fulfilling its planned purposes, or where leakage will damage land, crops, or cause waste of water, and environmental problems.

Design Criteria

Ponds to be lined shall be constructed to meet the Soil Conservation Service Engineering Standard and Specifications for Pond, Irrigation Pit or Regulating Reservoir, Irrigation Storage Reservoir, Wildlife Watering Facility, Disposal Lagoons, or Holding Ponds and Tanks as appropriate.

The flexible membranes to be used as linings shall be suitably constructed of high quality ingredients and shall be certified by the manufacturer to be suitable for this use. Pigmented polyvinyl or polyethylene plastics, rubber, and similar materials that are highly resistant to bacteriological deterioration will be acceptable base materials.

If the membranes are reinforced, an inorganic reinforcing material must be used.

All plastic membranes should have a cover of earth or earth and gravel not less than 6 inches thick. Rubber membranes need not be covered except in areas subject to travel by livestock. In these areas, a minimum cover of 9 inches shall be used on all types of flexible membranes. The bottom 3 inches of cover should not be coarser than silty sand.

All membranes shall be of a quality that meets or exceeds the attached materials specifications for Polyvinyl Chloride, Polyethylene and Rubber--Tables I, II, III, and IV. Minimum nominal thickness shall be:

Soil Material Not Coarser than:	Plastic Sheeting	Rubber Sheeting	
		Nylon Reinforced	Unreinforced
Sands; SM, SP, SW	8 mil.	20 mil.	30 mil.
Gravels; GC, GM, GP, GW	12 mil.	30 mil.	30 mil.

Plans and Specifications

Plans and specifications for installation of Pond Sealing or Lining, Flexible Membrane shall be in keeping with this standard and shall describe the requirements for application for the practice to achieve its intended purpose. See page S-521-A-1 for items to be considered in development of specifications.

TABLE I

POLYVINYL CHLORIDE PLASTIC SHEETING

TEST DESCRIPTION	REQUIREMENTS	TEST METHOD
Tensile Strength, Each Direction Minimum psi	2000	ASTM-D-882
Elongation, Each Direction, Minimum %	250	ASTM-D-882 (Method A)
Volatility, % Maximum Loss	0.7	ASTM-D-1203
Water Extraction, Maximum % Weight Loss	0.5	ASTM-D-1239
Tear Resistance (Elmendorf) Each Direction - Minimum Grams/Mil	160	ASTM-D-1922
Compost Resistance		Page S-521-A-2
Tensile Retained, Each Direction Minimum %	95	
Elongation retained, Each Direction Minimum %	80	
Commercial Field Splice Strength Shear Force, % of Minimum Tensile	80	Commercial field splice, one inch wide strip, pulled in shear at 10"/ minute, after 7 days cure at room temperature

TABLE II

UNREINFORCED RUBBER SHEETING

TEST DESCRIPTION	REQUIREMENTS TYPE "A"	REQUIREMENTS TYPE "B"	TEST METHOD
Tensile Strength, Minimum psi=	1200	1200	ASTM-D-412
Modulus at 300% Elongation, Minimum psi	600	600	ASTM-D-412
Ultimate Elongation, Percent Minimum	300	300	ASTM-D-412
Shore "A" Hardness	60±10	60±10	ASTM-D-2240
Ozone Resistance - Procedure "A"			ASTM-D-1149
No cracks - 50 pphm - 100°F - 20% Elongation	7 days		ASTM-D-518
No cracks - 50 pphm - 100°F 100% Elongation		14 days	
Heat Aging - 7 days at 212°F			ASTM-D-573
Tensile strength retained, % of original	75	75	
Elongation retained, % of original	75	75	
Water Vapor Permeability - at 80°F Perm-mils, maximum	.002	.05	ASTM-E-96 (Procedure BW)
Tear Resistance, lbs. per inch., minimum	150	150	ASTM-D-624 Die "B"
Dimensional Stability, 7 days at 212°F, % of change in length or width	±0.5	±0.5	
Commercial Field Splice Strength Shear force, % of minimum tensile	60	60	Commercial Field Splice, one inch wide strip pulled in shear at 10" per minute, after 7 days cure at room temp.

NOTE: Type "A" sheeting is recommended for general purpose outdoor usage.

Type "B" material is suggested where an extreme outdoor environment requires a highly weatherable lining.

TABLE III

NYLON REINFORCED RUBBER SHEETING

For Canal Lining

TEST DESCRIPTION	REQUIREMENTS UP TO 20 MILS THICKNESS	 20 MILS THICK & GREATER	TEST METHOD
Breaking Strength, Minimum lbs./inch			ASTM-D-751
Warp Direction	75	100	
Fill Direction	75	100	
Ultimate Elongation, % Maximum			ASTM-D-751
Warp Direction	30	30	
Fill Direction	30	30	
Ozone Resistance - Procedure "B"			ASTM-D-1149
50 pphm - 100°F	7 days	7 days	ASTM-D-518
Hydrostatic Strength After Ozone Exposure (7 days) (Mullen) % Retained	100	100	Fed. Spec. CCC-T-191b, Method 5512, ASTM-D-518
Heat Aging - 7 days at 212°F			ASTM-D-573
Tensile strength retained, % of original	90	90	
Elongation retained, % of orig.	90	90	
Tear Resistance - Minimum Warp or Fill Direction, Lbs.	8	8	ASTM-D-751 (Tongue)
Hydrostatic Burst (Mullen), psi Minimum	100	175	ASTM-D-751
Dimensional Stability, 7 days at 212°F % change in length or width	±1.0	±1.0	-*-

*One foot square sample, 10" bench marks in warp and fill direction, placed on Aluminum or Stainless plate in changing air over.

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TABLE III (CONTINUED)

NYLON REINFORCED RUBBER SHEETING

For Canal Lining

TEST DESCRIPTION	REQUIREMENTS UP TO 20 MILS THICKNESS	REQUIREMENTS 20 MILS THICK & GREATER	TEST METHOD
Low Temperature Flexibility (Optional) No cracking or flaking	$-40^{o}F$	$-40^{o}F$	Fed. Spec. CCC-T-191b Method 5874
Commercial Field Splice Strength Shear Force, % of Minimum Tensile	75	75	Commercial field splice one inch wide strip, pulled in shear at 10"/minute, after 7 days cure at room temperature

TABLE IV

POLYETHYLENE AND ETHYLENE CO-POLYMER PLASTIC FILM

For Canal Lining

TEST DESCRIPTION	REQUIREMENTS TYPE I POLYETHYLENE	TYPE II CO-POLYMER	TEST METHOD
Tensile Strength Each Direction, Minimum Avg. psi	1800	2000	ASTM-D-882 Method "A"
Ultimate Elongation Each Direction, Minimum Avg. %	500	500	ASTM-D-882 Method "A"
Impact Resistance Minimum Average, Grams/Mil	45	65	ASTM-D-1709 Method "B"
Water Vapor Permeability - Perm-Mils	0.7	1.5	ASTM-E-96
Tear Resistance (Elmendorf) Each Direction, Minimum Grams/Mil	80	80	ASTM-D-1922
Compost Resistance			
Tensile retained, Each Direction, Minimum %	95	95	Page S-521-A-2
Elongation retained, Each Direction, Minimum %	80	80	
Luminus Transmittance % Maximum	1.0	1.0	CS-238, paragraph 6.8

( ) = recommendations, ASAE, December 1969 draft of Stds.

SOIL CONSERVATION SERVICE

ENGINEERING SPECIFICATIONS GUIDE

POND SEALING OR LINING
Flexible Membrane

Subgrade Preparation

The area to be lined shall be drained and allowed to dry until the surface is firm and will support the men and equipment that must travel over it during installation of the lining.

All banks and fills within the area to be lined must be sloped not steeper than 1 to 1 for exposed lining and 2 1/2 horizontal to 1 vertical for buried linings.

The foundation area for flexible membrane linings shall be smooth and free of projections that might damage the lining. Stumps and roots shall be removed. Rocks, hard clods, and other such material shall be removed or shall be rolled so as to provide a smooth surface or shall be covered with a cushion of fine soil material.

Where needed an effective sterilant shall be applied to the subgrade at the rate recommended by the manufacturer.

An anchor trench shall be excavated completely around the area to be lined at the planned elevation of the top of the lining. The trench shall be 8 to 10 inches deep and about 12 inches wide.

All lining material shall be free of damage or defect. Each package delivered to the job site shall be marked with the name of the material, the manufacturer's name or symbol, the quantity therein, and the thickness or weight of the material.

Placing the Lining

Membranes shall be carefully spread over the subgrade so they lie in a relaxed state. Polyethylene film requires about 5 percent slack for satisfactory results.

All field splices shall be made in accordance with the manufacturer's recommended technique, using materials furnished for the purpose. The joints shall be watertight and maintain its integrity through the expected life of the lining.

Approximately 8 inches of the top of the lining shall be placed in the anchor trench and anchored with compacted backfill.

For covered membranes the material to be used for protective cover shall be free of large clods, sharp rocks, sticks and other objects that would puncture the lining. The cover shall be placed to the specified depth without damage to the membrane.

The test for soil burial will be as follows:

The soil burial test shall be performed by preparing six 6-inch long by 1-inch wide test specimens, 3 in machine direction and 3 in traverse direction, as done for tensile strength testing ASTM D 882B, and bury them vertically to a depth of about 5 inches in soil rich in cellulose destroying micro-organisms. At the end of 30 days, the tensile strength and ultimate elongation shall be determined. The soil used for specimen burial shall be composted soil prepared according to usual greenhouse practice and should have a pH of 6.5 to 7.5. The moisture content of the soil shall be maintained between 25 to 30 percent on an oven-dry basis. The test shall be performed with the soil containers stored in a room maintained between 90 to 100^{o}F. The microbiological activity shall be frequently checked by burying untreated 10-ounce cotton duck for one- and two-week periods. Satisfactory activity is indicated by tensile strength losses above 70 percent of strength in one week and above 90 percent in two weeks.

SOIL CONSERVATION SERVICE

ENGINEERING STANDARD

POND SEALING OR LINING
Bentonite

Definition

Installing fixed lining of impervious material or treating the soil in a pond mechanically or chemically to impede or prevent excessive water loss.

Scope

This standard covers the sealing of ponds with bentonite or similar high swell clay materials.

Conditions Where Practice Applies

Where water loss from a pond through leakage is or will be of such proportion as to prevent the pond from fulfilling its planned purpose, or where leakage will damage land or crops.

Design Criteria

Ponds to be sealed shall be constructed to meet Soil Conservation Service Engineering Standards and Specifications for Pond, Irrigation Pit or Regulating Reservoir, Irrigation Storage Reservoir, Wildlife Watering Facility, Disposal Lagoons, or Holding Ponds and Tanks as appropriate.

Soil Properties

Sealing with bentonite or similar materials is more applicable on coarse-grained soils where more than half of the material is larger than the No. 200 sieve size.

Rate of Application

The rate of application shall be based on laboratory tests unless sufficient data are available on the field performance of previously tested soils with a similarity, texturally and chemically, to the soils to be sealed.

In the absence of laboratory tests or field performance data on the soils to be sealed, the minimum application shall be:

Pervious Soil	Application Method	Application Rate
clay	pure membrane or mixed layer	1.0 - 1.5 lb./sq. ft.
sandy silt	mixed layer	1.0 - 1.5 lb./sq. ft.
silty sand	mixed layer	1.5 - 2.0 lb./sq. ft.
clean sand	mixed layer	2.0 - 2.5 lb./sq. ft.
open rock or gravel	clay or sand mixed layer	2.5 - 3.0 lb./sq. ft.

Thickness of Treated Blanket
The minimum thickness of the finished treated blanket shall be 4 inches for water depths up to eight feet. Additional thickness shall be provided for greater water depths, for pond areas exposed to drying, and for areas subject to wave action.

Plans and Specifications

Plans and specifications for installation of Pond Sealing or Lining - Bentonite shall be in keeping with this standard and shall describe the requirements for application for the practice to achieve its intended purpose. See page S-521-C-1 for items to be considered in development of specifications.

SOIL CONSERVATION SERVICE

ENGINEERING SPECIFICATIONS GUIDE

POND SEALING OR LINING
Bentonite

The following items should be considered:

1. The area to be treated shall be drained and dried.

2. All vegetation, trash, stones, and other objects of a size to interfere seriously with the operation shall be removed.

3. Holes shall be filled.

4. Sealing material shall be distributed evenly over the surface.

5. For mixed layers, the material shall be thoroughly mixed to the specified depth with disk, rototiller, or similar equipment.

6. Each treated layer shall be compacted to a dry density of 90 percent or more of maximum standard Proctor with soil at optimum moisture content.

7. Treated areas shall be protected from puncture by livestock trampling. Areas near the water line and at points of concentrated surface flow into the pond should be protected against erosion.

Construction will be carried out in such a manner that erosion and air and water pollution will be minimized. The completed job shall present a workmanlike finish.

Suggested Specifications for Soil-Cement Base Course

1. General

1.1—**Description**: Soil-cement base course shall consist of soil, portland cement, and water uniformly mixed, compacted, finished, and cured in accordance with these specifications. It shall conform to the lines, grades, thicknesses, and typical cross-section shown on the plans.

2. Materials

2.1—**Portland Cement**: Portland cement shall comply with the latest specifications for portland cement—AASHO M85, M134, M151; ASTM C150, C175, C595 (Types IS and ISA); Federal SS-C-192, SS-C-197; or CSA A5—for the type specified. In the United States, 1 bag of portland cement shall be considered to weigh 94 lb. and 1 bbl. to weigh 376 lb. In Canada, 1 bag shall be considered to weigh 80 lb.

2.2—**Water**: Water shall be free from substances deleterious to the hardening of the soil-cement.

2.3—**Soil**: Soil shall consist of the material existing in the area to be paved, of approved borrow material, or of a combination of these materials proportioned as directed. The soil shall not contain gravel or stone retained on a 2-in. sieve or more than 45 percent retained on a No. 4 sieve.

3. Equipment

3.1—**Description**: Soil-cement may be constructed with any combination of machines or equipment that will produce the results meeting these specifications, 4.2 to 4.9 inclusive.

4. Construction Methods

4.1—**Preparation**: Before other construction operations are begun, the area to be paved shall be graded and shaped as required to construct the soil-cement in conformance with the grades, lines, thicknesses, and typical cross-section shown on the plans. Unsuitable soil or material shall be removed and replaced with acceptable soil.

The subgrade shall be firm and able to support without displacement the construction equipment and the compaction hereinafter specified. Soft or yielding subgrade shall be corrected and made stable before construction proceeds.

4.2—**Pulverization**: The soil shall be so pulverized that, at the completion of moist-mixing, 100 percent by dry weight passes a 1-in. sieve, and a minimum of 80 percent passes a No. 4 sieve, exclusive of gravel or stone retained on these sieves.

4.3—**Cement Application, Mixing and Spreading**: Mixing of the soil, cement, and water shall be accomplished either by the mixed-in-place or the central-plant-mixed method.

No cement or soil-cement mixture shall be spread when the soil or subgrade is frozen or when the air temperature is less than 40 deg. F. in the shade.

The percentage of moisture in the soil, at the time of cement application, shall be the amount that assures a uniform and intimate mixture of soil and cement during mixing operations. It shall not exceed the specified optimum moisture content for the soil-cement mixture.

The operations specified in 4.3 to 4.5, inclusive, shall be continuous and completed in daylight within 6 hours.

Any soil-and-cement mixture that has not been compacted and finished shall not remain undisturbed for more than 30 minutes.

Method A. Mixed-in-Place: The specified quantity of cement shall be spread uniformly on the soil. Spread cement that has been displaced shall be replaced before mixing is started.

The cement shall be mixed with the soil until they are sufficiently blended to prevent the formation of cement balls when water is applied. Water shall then be incorporated into the mixture.

Excessive concentrations of water on or near the surface shall be avoided. A water supply and pressure distributing equipment shall be provided that will assure a maximum of 3 hours for the application of all mixing water required on the section being processed.

After all mixing water has been applied, mixing shall continue until a uniform and intimate mixture of soil, cement, and water has been obtained.

Method B. Central-Plant-Mixed: The soil, cement, and water shall be mixed in a pugmill of either the batch or continuous-flow type. The plant shall be equipped with feeding and metering devices that will add the soil, cement, and water into the mixer in the specified quantities. Soil and cement shall be mixed sufficiently to prevent cement balls from forming when water is added. Mixing shall continue until a uniform and intimate mixture of soil, cement, and water is obtained.

The mixture shall be hauled to the roadway in trucks equipped with protective covers. The mixture shall be placed on the moistened subgrade in a uniform layer by an approved spreader or spreaders. Not more than 30 minutes shall elapse between the placement of soil-cement in adjacent lanes at any location except at transverse and longitudinal construction joints. The layer of soil-cement shall be uniform in thickness and surface contour, and shall contain sufficient material for the completed base to conform to the required grade and cross-section. Dumping of the mixture in piles or windrows upon the subgrade shall not be permitted.

Not more than 60 minutes shall elapse between the start of moist-mixing and the start of compaction of soil-cement.

4.4–**Compaction**: At the start of compaction, the percentage of moisture in the mixture and in unpulverized soil lumps shall not be below or more than two percentage points above the specified optimum moisture content, and shall be less than that quantity which will cause the soil-cement mixture to become unstable during compaction and finishing. The specified optimum moisture content and density shall be determined in the field by a moisture-density test, AASHO T134 or ASTM D558, on representative samples of soil-cement mixture obtained from the area being processed at the time compaction begins.

Prior to compaction, the mixture shall be in a loose condition for its full depth. The loose mixture shall then be compacted uniformly to the specified density. During compaction operations, initial shaping may be required to obtain uniform compaction and required grade and cross-section.

4.5–**Finishing**: During finishing operations, the surface of the soil-cement shall be shaped to the required lines, grades, and cross-section. The moisture content of the surface material shall be maintained at not less than its specified optimum moisture content during finishing operations.

If necessary, the surface of the base shall be lightly scarified to remove any tire imprints or smooth surfaces left by equipment. The resulting surface shall then be compacted to the specified density. Any portion of the soil-cement that has a density of 5 lb. or more below that specified shall be corrected or replaced to meet the specifications. Rolling shall be supplemented by broom-dragging if required.

Compaction and finishing shall be done in such a manner as to produce, in not longer than 2 hours, a smooth, dense surface free of compaction planes, cracks, ridges, or loose material.

4.6–**Curing**: After the soil-cement has been finished as specified herein, it shall be protected against drying for 7 days by the application of bituminous materials. The finished soil-cement shall be kept continuously moist until the bituminous curing material is placed. The curing material shall be applied as soon as possible, not later than 24 hours after the completion of finishing operations.

At the time the bituminous material is applied, the soil-cement surface shall be dense, shall be free of all loose and extraneous material, and shall contain sufficient moisture to prevent excessive penetration of the bituminous material.

The bituminous material specified shall be uniformly applied to the surface of the completed soil-cement at the rate of approximately 0.2 gal. per square yard with approved heating and distributing equipment. The exact rate and temperature of application for complete coverage without excessive runoff will be specified by the engineer.

Should it be necessary for construction equipment or other traffic to use the bituminous-covered surface before the bituminous material has dried sufficiently to prevent pickup, sufficient granular cover shall be applied before such use.

The curing material shall be maintained by the contractor during the 7-day protection period so that all of the soil-cement will be covered effectively during this period.

Finished portions of soil-cement that are traveled on by equipment used in constructing an adjoining section shall be protected in such a manner as to prevent equipment from marring or damaging completed work.

Sufficient protection from freezing shall be given the soil-cement for 7 days after its construction and until it has hardened.

4.7–**Construction Joints**: At the end of each day's construction a straight transverse construction joint shall be formed by cutting back into the completed work to form a true vertical face.

Soil-cement for large, wide areas shall be built in a series of parallel lanes of convenient length and width meeting the approval of the engineer. Straight longitudinal joints shall be formed at the edge of each day's construction by cutting back into the completed work to form a true vertical face free of loose or shattered material.

4.8–**Traffic**: Completed portions of soil-cement may be opened immediately to local traffic and to construction equipment provided the curing material is not impaired as specified in 4.6. The section may be opened to all traffic after the 7-day curing period, provided the soil-cement has hardened sufficiently to prevent marring or distorting of the surface by equipment or traffic.

4.9–**Maintenance**: The contractor shall be required, within the limits of his contract, to maintain the soil-cement in good condition until all work has been completed and accepted. Maintenance shall include immediate repairs of any defects that may occur. This work shall be done by the contractor at his own expense and repeated as often as may be necessary to keep the area continuously intact.

Faulty work shall be replaced for the full depth of treatment. Any low areas shall be remedied by replacing the material for the full depth of treatment rather than by adding a thin layer of soil-cement to the completed work.

5. Measurements and Basis of Payment

5.1–**Measurements**: This work will be measured in square yards of completed and accepted soil-cement base course and in barrels of cement.

Unsuitable soil or material removed and the replacement material in accordance with 4.1 will be measured in cubic yards in its original position by the method of average end areas.

5.2–**Basis of Payment**: This work will be paid for at the contract unit price per square yard of completed and accepted soil-cement base course and at the contract unit price per barrel of total quantity of cement used as authorized for incorporation into the work.

Soil moved in accordance with 4.1 will be paid for at the contract unit price per cubic yard for common excavation.

Contract unit prices will be full payment for furnishing all materials, equipment, tools, labor, and incidentals necessary to complete the work and to carry out the maintenance provisions in these specifications.

No allowance will be made for any materials used or work done outside the lines established by the engineer.

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KEY WORDS: compacting, curing, density, finishes, inspection, joints, maintenance, measurement, soils, soil cement, specifications, subgrades.

ABSTRACT: Specifies materials to use and construction methods needed to produce soil-cement base courses. A resume of preparation; pulverization; cement application, mixing and spreading (mixed-in-place and central-plant-mixed methods); compaction; finishing; curing; jointing; maintenance; measurements; and basis of payment for a soil-cement base course.

REFERENCE: *Suggested Specifications for Soil-Cement Base Course* (IS008.09S), Portland Cement Association, 1969.