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Project Summary

Laboratory Studies of Soil Bedding Requirements for Flexible Membrane Liners

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A two-phase study was conducted to investigate the performance of membrane liners during construction of hazardous waste landfills and to develop a means for protecting the liners from damage. Phase I consisted of a series of full-scale field tests to determine a method of protecting flexible membranes from damage during the construction of landfills. Subgrade soils were selected to be representative of those typical of areas in which landfills are constructed. Four membranes were tested. Each was placed on top of a subgrade and covered with various thicknesses of a sand material. The test items were trafficked using three different vehicles representative of the loadings that might be applied during landfill construction. Performance of the membrane was judged by its resistance to puncture and wear. The lean clay bedding provided the best protection for the liner and was effective in preventing puncture by the subgrade.

Phase II developed three laboratory tests to simulate field loadings on flexible membrane liners during construction of hazardous waste landfills. One test method used a moving pneumatic-tire loading, another used a rotating gyratory load, and the third used a cyclic vertical plate load. Loading conditions and thickness of cover material over the membrane varied using Boussinesq equations to produce vertical stresses on the membrane similar to those encountered under field conditions.

Test results showed that the moving pneumatic-tire load test would be the most useful for determining cover and bedding criteria using available site soils and candidate membranes. Also, a layer of clay soil effectively prevented puncture of the membrane by the subgrade.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Many industrial wastes are highly toxic to the environment if their disposal is not properly controlled. A common disposal method is the use of landfills, but improperly designed landfills could result in contamination of ground and surface waters by toxic wastes. Contamination is the result of various physical, chemical, and biological processes that occur when water or fluids percolate through the wastes and produce a leachate that pollutes the soil and ground water. The placement of an impervious, flexible membrane over the subgrade in hazardous waste landfills could be one solution to controlling the leachate. But earthmoving equipment used during construction and underlying angular rock and soil particles present possible sources of puncture and other damage. To study the problem, the U.S. Environmental Protection Agency (EPA) requested the U.S. Army Engineer Waterways Experiment Station (WES) to investigate the requirements for protecting flexible membranes from damage.

The initial objective of this study was to investigate the performance of membrane liners during construction of hazardous waste landfills and to develop a means for protecting the liners from damage. This objective included the development of laboratory tests that could be used to determine bedding and cover requirements for protecting the membranes from puncture.

The study was conducted in two phases. In Phase I, the performance of flexible membranes was investigated through the construction and testing of full-scale test sections. A test section containing 12 test items was constructed and subjected to three types of vehicle traffic (tracked, pneumatic-tired, and cleated). During this phase of the study, four flexible membranes, six selected subgrades, three thicknesses of a protective sand layer, and two bedding materials were investigated.

In Phase II, three laboratory tests were developed to simulate field loading conditions on flexible liners during construction of hazardous waste landfills. The three tests included the use of a moving pneumatic-tire loading, a rotating gyratory load, and a cyclic vertical plate load. Tests were conducted using a gravelly sand or limestone subgrade under the membrane liner and a gravelly sand cover. In some tests, a lean clay or a fabric was placed between the liner and subgrade to protect the membrane liner. One type and thickness of cover and three membrane liners were used in the tests. Other special tests were conducted to develop a test that could possibly be used as a screening test for membrane liners.

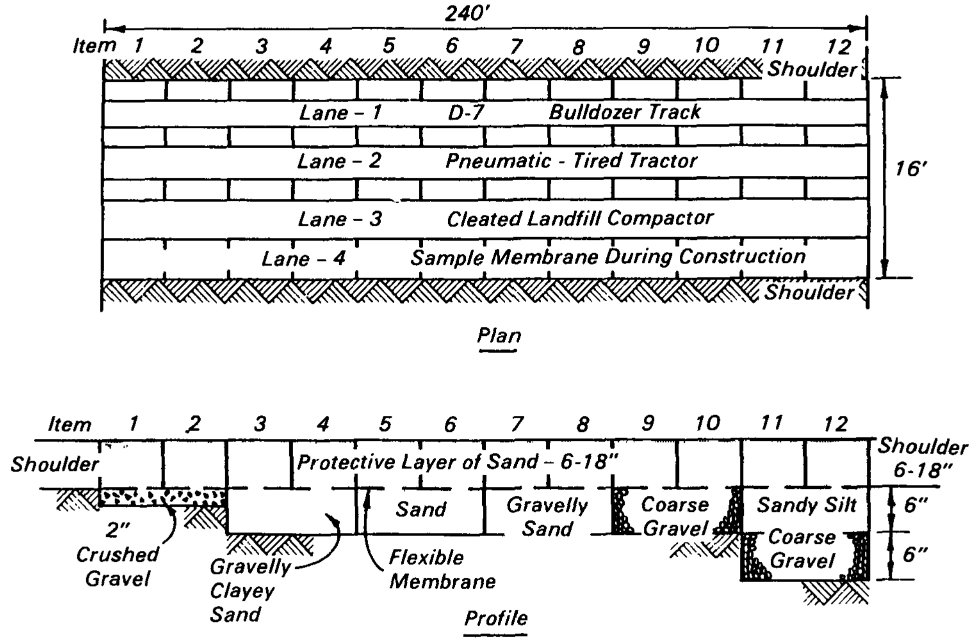

Figure 1. *Plan and profile of test section.*

Methods and Materials

Phase I: Full-Scale Test Section Studies

Construction of Test Sections

A 16- x 240-ft section was constructed under shelter at the WES. The test section consisted of 12 test items, each 20 ft long and 16 ft wide (Figure 1). Construction began with excavating an area of the subgrade floor of the shelter to a depth of 6 in. and a width of 16 ft. The last 40 ft at the north end of the test section was excavated to a depth of 12 in. to accommodate a 6-in. layer of coarse gravel that was overlaid with 6 in. of sandy silt. This fine-grained sandy silt was used as a bedding material to protect the flexible membranes from puncture during traffic tests. The remainder of the test section was backfilled with the selected subgrades, which were then compacted with pneumatic-tire and vibratory rollers. After the six subgrades were placed, each of the 12 test items in the test section was covered with flexible membranes. Shoulders were then constructed on both sides of the test sections using material that had been excavated previously from the floor of the shelter. Next, sand was dumped between the shoulders at each end of the test section. Then a bulldozer pushed the sand toward the center of the test section. At all times during the placement operations, care was taken to maintain at least 6 in. of sand between the bulldozer tracks and the flexible membranes.

Subgrade Soils

Six subgrade materials were selected and used for the 12 items of the test section. These materials were classified according to the Unified Soil Classification System (USCS) as follows:

Item No.	Classification
1-2	Crushed gravel(GP)
3-4	Gravelly clayey sand (SP-SC)
5-6	Sand (SP)
7-8	Gravelly sand (SP)
9-10	Coarse gravel (GP)
11-12	Sandy silt (ML)

Note that the sand in items 5 and 6 was the same type used for the protective cover layers. The sand was a local (Vicksburg, Mississippi) sand usually used as the fine aggregate in concrete.

Membranes

The four flexible membranes and one fabric used as a bedding material were as follows:

Designation	Thickness, mils	Type
M1	20	Elasticized polyolefin (3110)
M2	20	Polyvinyl chloride (PVC)
M3	30	Chlorinated polyethylene (CPE)
M4	36	Reinforced chlorosulfonated polyethylene (CSPE-R)
F1	30	Nonwoven polypropylene and nylon

Traffic Vehicles

The vehicles used to apply traffic to the various test programs were (1) a D-7 bulldozer equipped with 22-in. -wide tracks weighing approximately 44,000 lb and having a contact pressure of 9 psi; (2) a pneumatic-tired tractor weighing 37,190 lb and equipped with two 29.5 x 29, 22-ply tires (each tire had a contact area of 574 in.^{2}, which produced a contact pressure of 32 psi); and (3) a model 816 landfill compactor weighing 40,900 lb and equipped with four cleated steel wheels with a contact pressure of 18 psi.

Traffic Pattern

Traffic tests were conducted on each test item to simulate actual heavy equipment operations during the construction of landfills. Traffic was applied with both the tracked bulldozer and the cleated landfill compactor in the same manner.

Soil Data

Except for the crushed and coarse gravel material, laboratory compaction tests and unsoaked California bearing ratio's (CBR's) were performed on the selected subgrades. Field tests were also performed to determine moisture content, density, and CBR value on the in-place material of the test section.

Membrane Evaluation

Only the after-traffic condition of the flexible membranes was considered. After 10 passes of the traffic vehicles, a trench was excavated across each traffic lane in all 12 items. A sample of the membrane was removed from each traffic lane in each item, marked for identification, and inspected. After the membrane was patched and the protective layer of sand in the trenches was replaced, traffic was continued on the membrane that showed only a few or no punctures. After 30 passes, traffic was stopped and a final inspection was made.

Failure Criteria

Each sample of membrane was placed over a light table and inspected for punctures. A 5-ft area within the wheel path was marked on the membranes, and from this area the number of punctures noted was recorded. A membrane was considered to have failed if any punctures were noted.

Phase II: Laboratory Studies

After completion of the full-scale tests, laboratory tests were developed to determine bedding and cover requirements for protecting membrane liners from punctures. One criterion for equipment was that it be readily available to most commercial laboratories and that it be adaptable for testing membrane materials. The three types of test equipment selected were a gyratory compactor, a plate-loading machine, and a moving pneumatic-tired wheel. The initial tests were conducted using the plate-loading equipment since this method has been used to test fabrics used as reinforcement in pavements. The gyratory tests were conducted next since they required a small sample and were easy to conduct. The pneumatic-tire tests were conducted last and required the development of test equipment to simulate the effects of a moving tire load. In all laboratory tests, selected parameters were adjusted to approximate field conditions by modeling the stress on the membrane.

Results

Phase I: Full-Scale Test Section Studies

The four membranes investigated during this study received numerous punctures when subjected to the subgrades containing gravel-sized material. But a considerable decrease in the number of punctures was observed when the membranes were trafficked on the items containing the sand and sandy silt subgrades. After some traffic operations were completed on these test items, no punctures were detected in several of the membranes. When the fine-grained sandy silt soil was used as a bedding material and 6 in. were placed over the coarse gravel subgrade in items 11 and 12, fewer punctures resulted.

Another type of bedding material, a nonwoven polypropylene and nylon-type material, resulted in a small reduction in the number of punctures in the M2 membrane but not in the M1 membrane.

Inspection of the trafficked membrane also revealed that most of the punctures detected occurred from the bottom in an upward direction. Thus a bedding and/or cushioning material would be required to prevent punctures for subgrades containing angular gravel and coarse soil particles.

The three types of vehicle loadings (tracked, pneumatic-tired, and cleated) used to apply traffic to the membranes produced similar degrees of damage.

Phase II: Laboratory Studies

The pneumatic-tire tests conducted in the laboratory showed that separating the membrane from the granular material by a lean clay will prevent or reduce punctures in the membrane. In the laboratory tests, the fabric bedding material prevented or reduced the number of punctures in all tests. The field tests also indicated that the use of a geotextile under the liner might protect it from puncture, but not all field tests indicated this.

A limited number of field tests could be used for direct comparison with the laboratory tests since the latter were conducted to produce a stress on the membrane liners equal to the stress of the pneumatic tire on the field liners under 6 in. of cover. Since the laboratory pneumatic-tire load is the same type of load as applied by construction equipment in constructing landfills, it is considered to be the most applicable test for determining bedding and cover requirements for membranes used in landfills.

Conclusions

Based on the study results, the following conclusions are warranted:

1. The three traffic vehicles used in the full-scale tests produced similar amounts of damage to each membrane.
2. The 6 in. of bedding material placed in the full-scale test section reduced the number of punctures in the membranes.
3. The pneumatic-wheel load test is the most useful laboratory test for determining cover and bedding criteria using available site soils and candidate membranes.
4. Both the cover material placed above the liner and the bedding material should consist of a soil classified as a clay, silt, or sand with a gradation similar to the clay or concrete sand used in this study. Material should have no particles larger than 3/8 in.
5. The 1 in. of lean clay bedding material effectively prevented puncture of the liner material by the gravel subgrade during laboratory tests.
6. Use of the geotextile as a bedding material reduced the number of punctures, and the use of a thicker geotextile may prevent punctures from occurring.

Recommendations

The tests reported here show strong performance trends for liner materials placed in landfills and need to be continued to develop a complete range of design criteria. The following recommendations therefore apply:

1. Additional laboratory tests should be conducted using other subgrade materials and methods for protecting the liners.
2. Further analytical work should be accomplished on the field and laboratory data to extend criteria.
3. Criteria obtained from laboratory tests should be validated by conducting full-scale field tests.
4. Additional series of tests should be performed with the laboratory gyratory equipment and the artificial rocks (barbs) to develop a laboratory test method for screening membranes.
5. Compaction requirements should be established for bedding and cover materials.

The full report was submitted in fulfillment of Interagency Agreement No. EPA-86-R-X0937 by U.S. Army Engineer Waterways Experiment Station under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Laboratory Studies of Soil Bedding Requirements for Flexible Membrane Liners," (Order No. PB 84-141 498; Cost: $11.50, subject to change) will be available only from:
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