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Hazardous Waste Engineering Research Laboratory
Cincinnati OH 45268

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Project Summary

Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments

G. N. Richardson and R. M. Koerner

Geosynthetic compounds beneath and above hazardous waste materials in a landfill cell provide the primary separation between leachate generated within the cell and the surrounding environment. This report provides recommendations for the design of these geosynthetic components—the polymer flexible membrane liners, textiles, nets, grids, and composites used to limit the flow of leachate and used for the drainage and filtration components (the leak collection and removal system). Design guidance is also given for ancillary components including ramps, berms, and standpipes.

This Project Summary was developed by EPA's Hazardous Waste Engineering 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

Because the use of geosynthetics in hazardous waste disposal cells and surface impoundments is an emerging technology with only relatively recent expertise, a need exists to develop design guidance for the users and for the regulators who must review the design. The report emphasizes the analyses of field conditions and laboratory-measured properties of the components that are needed to properly design these components. Construction and long-term physical considerations are also reviewed, but chemical considerations are not.

Geosynthetics

The geosynthetics considered here are the flexible membrane liners, textiles, grids, nets, and composites that are used as structural components of hazardous waste or surface impoundment facilities.

- Geomembranes are sheets made of impermeable synthetic polymers with additives to improve the physical or long-term aging characteristics. The geomembranes are used to prevent water flow into and out of hazardous waste or impounded material (fluid).

- Geotextiles are woven, nonwoven, and knit synthetic fibers made of polypropylene, polyester, or polyethylene. Geotextiles have relatively high permeability allowing liquid to move through the fabric while preventing the passage of soil particles. They can also be used to provide tensile strength to soils and to bridge discontinuities in the subgrade.

- Geogrids are made of extruded polypropylene or polyethylene by punching a regular pattern of holes into sheeting and drawing the sheeting uniaxially or biaxially to increase its modulus and strength. They are used principally as reinforcement material and can provide limited planar flow capacity.

- Geonets are extruded nets formed by extruding and bonding up to three layers of polymer rods oriented at acute angles to each other. They have significant capacity of planar flow and are commonly used with geotextiles to form systems for leachate or surface water collection/removal.

- Geocomposites are high-drainage polymerics that are made of a built-up open drainage core covered with geotextile that acts as a filter. They are used to provide drainage with such applications as lateral drains in roadways.

Design Guidance

Currently, the design of hazardous waste cells and surface impoundments is based on a mix of regulator-based minimum requirements (which are briefly described), of performance-based engineered designs, and of empirical rules-of-thumb. In this report, the analyses needed to properly design a synthetic component—analyses based on calculated field conditions and laboratory-measured component properties—are given. By using performance-based design, the designer/regulator is allowed to properly evaluate the true degree of protection against failure provided by regulatory minimums or rules-of-thumb.

The use of geosynthetic components beneath, within, and above the cell, and the construction and fabrication of caps, drainage, and filtration and subgrade are each discussed.

Each *design consideration* is derived from specific equilibrium equations and then illustrated with typical applications (see Figure 1 for one example) for components used:

- beneath the cell, e.g., leachate collection/removal system transmissivity, flexible membrane liners, and filters
- within the cell, e.g., ramps, interior berms, standpipes, etc.
- above the cell, e.g., surface water collection/removal systems

A potential failure mode is established A (Figure 1), a design procedure is developed based on calculated service conditions under field conditions F, and then a calculated design ratio G with minimum values is recommended for each design procedure. Because specific geosynthetic material properties B are needed to determine the design ratio in each design procedure, a suggested range of values, based on available data, is given C. Test procedures D and

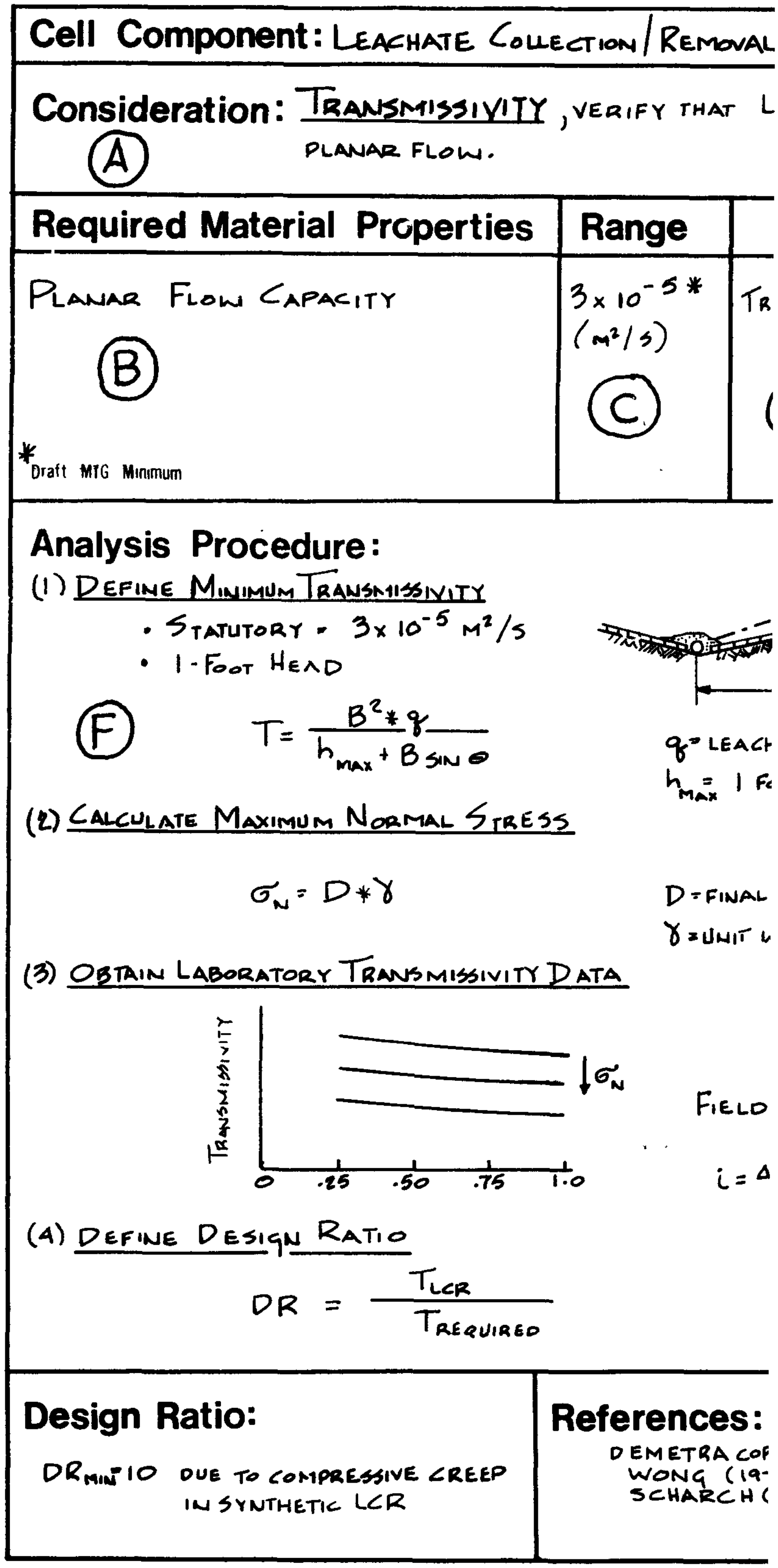

Figure 1. *Example design calculations for leachate collection and removal system.*

ADEQUATE

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STM D4617

(E)

FML

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4)

Example:

GIVEN:

- LANDFILL HT, D = 120'
- UNIT WT. WASTE, γ = 80 lb/FT³
- SLOPE ANGLE, $\theta = 4°$
- SLOPE LENGTH, B = 60'
- LEACHATE INFLOW RATE, q = 0.01 FT/DAY
- LABORATORY TRANSMISSIVITY DATA

(1) DEFINE MINIMUM TRANSMISSIVITY (FLOW CRITERIA)

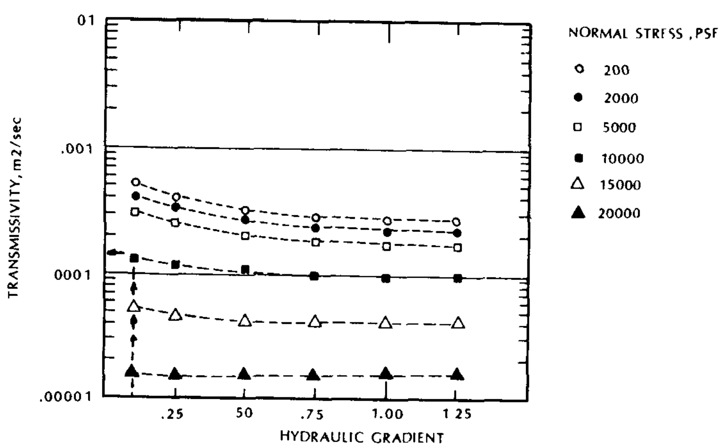
$$T = \frac{60^2 * 0.01}{1 + 60 \sin 4°} = 6.94 \text{ FT}^2/\text{DAY} = 7.46 \times 10^{-6} \text{ M}^2/\text{SEC}$$

$$\therefore T_{REQ} = 7.46 \times 10^{-6} \text{ M}^2/\text{s} \quad (> 3 \times 10^{-5} \text{ M}^2/\text{s})$$

(2) CALCULATE MAXIMUM NORMAL STRESS, σ_N

$$\sigma_N = 120 \times 80 = 9600 \text{ PSF}$$

(3) OBTAIN LCR TRANSMISSIVITY FROM LAB. DATA, T_{LCR}



$$\text{GRADIENT, } i = \frac{1 + 60 \sin 4°}{(60/\cos 4°)}$$

$$i = .086$$

$$T_{LCR} = .00014 \text{ M}^2/\text{s}$$

(4) CALAULATE DESIGN RATIOS

(G)

$$DR_{FLOW} = \frac{T_{LCR}}{T_{REQ}} = \frac{.00014}{7.46 \times 10^{-6}} = 18.8 \quad \underline{\text{OK}}$$

$$DR_{MTG} = \frac{T_{LCR}}{T_{MTG}} = \frac{.00014}{3 \times 10^{-6}} = 4.67 \quad \underline{\text{MARGINAL}}$$

Example No. 3.1

relevant standards E for each test are referenced when available.

The equations of equilibrium are based on "freebody" diagrams that express both the direction and magnitude of forces acting at a given point in the geosynthetic component and reflect the need for the sum of the forces to be equal to zero in a given plain for equilibrium conditions to exist. When a clear limit is known for the performance of the geosynthetic, a design ratio is calculated:

$$DR = \frac{\text{allowable material performance}}{\text{calculated actual material service conditions}}$$

Although a minimum value of 1.0 for the design ratio would be needed to prevent an undue amount of stress or strain or both, the performance limits of the components and the service conditions can not be accurately defined and a design ratio considerably larger than 1.0 is needed to ensure satisfactory performance.

Tests for the index properties for geomembranes and geotextiles and for the performance properties for geomembranes, geotextiles, and geonets/composites are summarized in the appendices. The index tests provide a means of quality control for the manufacturer and are usually independent of actual field conditions. Because the performance tests try to simulate true in-situ environments and are site-specific for the given field conditions, each test must be carefully reviewed to determine its applicability for each design situation.

Construction and Fabrication

The general requirements for successful installation of a flexible membrane liner and its drainage/filtration components are outlined: their delivery, storage, and quality control and quality assurance. Proper preparation of the subgrade is also touched upon.

The full report was submitted in fulfillment of CR No. 68-03-3338 by Soil & Material Engineers, Inc., under the sponsorship of the U.S. Environmental Protection Agency

*The EPA author, **Robert P. Hartley** (also the EPA Project Officer, see below), is with Hazardous Waste Engineering Research Laboratory, U S. Environmental Protection Agency, Cincinnati, OH 45268; G. N. Richardson is with Soil and Material Engineers, Inc., Cary, NC 27511; and R. M. Koerner is with Geosynthetic Research Institute, Drexel University, Philadelphia, PA 19014..*

The complete report, entitled "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments," (Order No. PB 88-131 263/AS; Cost: $25.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
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