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Project Summary

Geotextiles for Drainage, Gas Venting, and Erosion Control at Hazardous Waste Sites

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Geotextiles (engineering fabrics) have proven to be effective materials for solving numerous drainage and stability problems in geotechnical engineering, and they can be used to solve similar problems in the containment and disposal of solid and hazardous waste. "Geotextile" is defined as any permeable synthetic textile product used in geotechnical engineering.

Important mechanical, hydraulic, and endurance properties of fabrics are discussed. Tensile strength and elongation as measured by the grab tensile test; tearing resistance as measured by the trapezoidal tear test; and puncture resistance as measured by the U.S. Army Corps of Engineers puncture test are emphasized as being the most important mechanical properties. Tests for other mechanical properties such as creep susceptibility, tear resistance, frictional and pull-out resistance with soil, and seam strength are also reviewed.

The important hydraulic properties of fabrics are their ability to allow free passage of fluids, to retain soil particles (piping resistance) and to resist clogging. The equivalent opening size (EOS) and gradient ratio tests used to evaluate these qualities are discussed, as well as possible causes of the long-term reduction of fabric hydraulic flow capacity.

Fabric resistance to ultraviolet light and chemicals and to biological degradation is considered .

Applications of geotextiles to (1) landfill cover drains, leachate collection systems, and ground-water control systems; (2) gas venting; and (3) protection of landfill covers and waste disposal sites from surface erosion are addressed in detail. In each of these applications, design considerations, fabric requirements, and construction techniques are discussed. Model specifications for fabrics in the various applications are given. For drainage systems and erosion control, criteria for selecting fabrics based on the fabric's piping and clogging resistance are presented. Strength requirements based on the severity of the construction environment and long-term chemical/biological degradation are addressed.

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

The use of geotextiles (engineering fabrics) has grown from 12.5 million m^2 (15 million yd^2) in 1977 to 115 million m^2 (138 million yd^2) in 1983 in the United States and Canada alone. In spite of this rapidly expanding use of geotextiles, their use and performance in applications related to waste containment and disposal has rarely been documented in the open literature. The information in this report draws on the experiences of the geotechnical field to provide guidance for the use of geotextiles in land waste disposal activities.

A geotextile is defined as any permeable synthetic textile product used in geotechnical engineering. Related products such as plastic grids (geogrids) or composite products such as drainage panels are also discussed because they are used in similar applications or include geotextiles as part of their structure.

Types of Geotextiles

Geotextiles are currently being made from polypropylene, polyester, polyethylene, nylon, polyvinylidene chloride, and fiber glass, with polypropylene being used far more than any of the other materials. The physical properties of all these materials can be enhanced by adding additives and by processing the polymer into fibers.

Geotextiles are usually grouped by method of construction, the major groups being woven, knitted, and non-woven. Construction type has an important bearing on both the mechanical and hydraulic properties of a geotextile and consequently its potential performance in a given application. Woven construction is expensive but tends to produce fabrics with high strengths and moduli and low elongations at rupture. Woven construction also produces fabric with a simple pore structure and narrow range of pore sizes or openings between fibers. This is beneficial in many filtration applications. Knitted construction is rarely used for geotextiles, although some filtration fabrics and some experimental reinforcement fabrics are made by this method. Non-woven fabrics are those which are neither woven nor knitted. In non-woven construction, the fibers are placed with a random orientation and the properties of the finished product can vary greatly depending on the fiber density and method of bonding the fibers together. The fibers may be either continuous or staple (short length) and are bonded by needle punching (needling), heat bonding, resin bonding, or a combination of those processes.

Functions

In geotechnical and waste management engineering, geotextiles perform one or more of the following functions: filtration, drainage, separation, reinforcement, and erosion control. As applied to geotechnical engineering, filtration is the process of retaining a soil or other particulate material in place while allowing liquid or gas to escape. Geotextiles are used in leachate collection systems where they act as a filter between the overlying waste and the drainage layer of gravel or synthetic drainage material.

A geotextile, when used as a drain, acts as a conduit for liquids or gases. Special grid products have successfully replaced sand and gravel as drainage layers in leachate collection and gas venting applications. Separation is the function of keeping two dissimilar materials from mixing, but differs from filtration in that there is no requirement for allowing liquids or gases to pass. Reinforcement is the process of increasing the mechanical strength of the geotechnical structure by including the geotextile in the system. Capping a waste lagoon with a geotextile overlain by soil illustrates both the separation and reinforcement functions. A geotextile performs in erosion control by preventing the tractive forces of wind or water from displacing soil or waste particles. Fabric placed in a drainage ditch and covered with gravel is an example of a fabric performing erosion control. In many applications, a geotextile performs more than one of the functions just described. Each function requires consideration of different fabric properties and different tests to evaluate the qualities of importance.

The material costs for geotextiles may vary greatly depending on the intended function and on installation practices. The cost of fabric for a specific project will also depend on current supply and demand and such factors as the prestige or significance of a particular project. It is often less costly to the project as a whole to select a fabric having a higher initial cost, if the fabric has properties which expedite construction, reduce labor costs, and reduce the chances of damage that must be repaired later.

Evaluation of Geotextile Properties

A geotextile may be evaluated on its general physical properties, mechanical properties, hydraulic properties, and environmental endurance properties. General physical properties include fiber composition, fabric construction, weight per unit area, thickness, and roll weight and dimensions. These properties are often cited in product literature and are useful for distinguishing between fabrics. They are also useful when considering ease of handling. However, properties that relate to the actual application must be known to properly design a system using fabric.

The mechanical properties of geotextiles include tensile strength, tensile stress-strain relationship (modulus), puncture and burst resistance, penetration resistance, creep resistance, abrasion resistance, tear resistance, flexibility, soil-fabric sliding resistance, and fatigue resistance. These qualities are most important to reinforcement applications of geotextiles and to the survivability of the fabric during installation. Ease of installation is also affected by such qualities a flexibility.

Puncture and burst failures of geote tiles are caused by localized stressing the fabric and failure depends largely o the omnidirectional strength and elonga tion characteristics of the geotextile.

Once a break has formed in a fabric, te resistance is a measure of the force r quired to propagate the break. The tea ing resistance of geotextiles can b evaluated by the trapezoidal tear test.

Soil-fabric friction is of vital importanc in reinforcement applications. For oth applications such as drainage and erosic control, soil-fabric friction is a factor in th ability of a fabric to remain in place on sloping surface as when used in conjun tion with rip-rap in an erosion contr application or on a landfill cover slope.

Fabric panels can be joined by overla ping, stapling, heat welding, or sewing. these methods, sewing is used where th two fabric panels must withstand tensi stresses or where the security of the sea is critical. Several types of sewn sean can be produced in the field and the selection will depend on the fabric bein sewn and the strength requirements f the seam.

Creep resistance can be a significa consideration for applications where a fa ric must withstand high loads for long pe ods. This is considered for reinforceme applications but not normally for draina or erosion control. Research has show that polyester fabrics are less susceptib to creep than polypropylene fabrics.

Abrasion resistance is the ability of fabric to resist wear by friction. It can b a consideration in slope protection applic tions where wave wash or water curren may cause repeated movements of sto or block protection elements against fabric.

The hydraulic properties of a geotexti are those properties which govern i ability to pass liquids (and gases) a retain solid particles. Hydraulic properti encompass piping resistance, permeabili and clogging resistance.

Piping resistance is the ability of a fab to retain solid particles and is related to t sizes and complexity of the pores or ope ings in the fabric.

When geotextiles are used in filtrati and drainage applications they must ha a flow capacity adequate enough to pr vent significant hydrostatic pressure bui up in the soil being drained and must b able to maintain that flow capacity for t range of flow conditions for that particul installation.

Clogging is the reduction in permeability of a geotextile because of fabric pores being blocked by soil particles or by bacterial or chemical encrustations. To some degree, clogging takes place with all fabrics in contact with soil and this is why permeabilities of fabrics measured in isolation are of only limited usefulness.

Whenever a soil is suspected of being internally unstable, the particular soil-fabric combination can be evaluated by a soil-fabric permeability apparatus and its clogging tendency quantified by the Gradient Ratio.

The ability of certain fabrics and certain special products such as grids, meshes, and panels to transmit significant quantities of fluids in the plane of their structure offers one of the greatest potential uses of these materials in the waste management area. The flow capacity of thin planar materials parallel to their plane can be expressed by Darcy's Law in the same way as flow perpendicular to the plane.

The environmental endurance properties of geotextiles are those properties which determine whether the fabric can continue to function for the life of the project.

All the polymers used in the manufacture of engineering fabrics are subject to degradation from exposure to the ultraviolet (UV) light portion of sunlight. The polymers vary in their resistance to UV radiation but all can be made much more resistant to UV attack by incorporating certain additives into the polymer formulation.

Geotextiles will come into contact with chemical leachate when used in leachate collection systems and in cover designs where, for example, they will be used as part of a gas venting system. Extensive tabulations are available showing the resistance of the common geotextile polymers to a wide range of chemicals. Unfortunately, this data can only be considered useful for screening purposes. Differences in plastic formulations and type and levels of additives can have a significant effect on a given plastic's reaction to a given chemical. It cannot be assumed that a plastic fiber or fabric will behave the same with similar chemicals.

Table 1, compiled from data available from manufacturers' literature and other sources, provides a summary of responses of geotextile plastics to a variety of chemicals. This type of information should only be used for preliminary screening purposes, and tests simulating conditions to be expected in the specific application are recommended where the geotextile is to be exposed to a known chemical environment for an extended period.

There are no known instances of geotextile failure due to attack by soil microorganisms, even though some geotextile installations are over 20 years old. Certain microorganisms are known to cause gelatinous iron precipitates to form in drainage systems including those using geotextiles.

The effects of temperature extremes, repeated freezing and thawing, and long-term water immersion on the performance of geotextiles have been investigated and no significant detrimental effects have been recorded for these conditions.

Design of Filters and Drainage Systems

Rules for designing filters and drainage systems using sand and gravel are well established and have been used successfully for many years. When substituted for granular filters in these applications, geotextiles must fulfill the same requirements imposed on granular filters: the fabric must prevent piping of the soil to be drained while remaining sufficiently permeable over the life of the project to prevent the buildup of hydrostatic pressures. There have been numerous approaches to developing filter criteria for geotextiles. At least in the United States, most hydraulic criteria for geotextiles are based in whole or in part on tests and criteria originally proposed by the U.S. Army Corps of Engineers.

Recommended geotextile selection criteria for filtration and drainage applications in hazardous waste landfills are given in the main report and include mechanical, hydraulic, and environmental requirements.

Gas Venting

Thick geotextiles with significant in-place permeability have been used as a venting layer beneath impermeable synthetic membrane liners at liquid impoundments for over a decade. In landfills, gases generated by decomposition of organic matter or volatilization of chemicals can lead to undesirable gas migration with consequent dangers of explosions and poisoning of people and vegetation. Geotextiles with sufficient gas transmissivity can relieve this problem.

Erosion Control

In landfill cover protection, erosion most commonly occurs in sheet form when vegetative cover is inadequate or in localized areas where rainwater runoff concentrates in surface depressions, swales, and ditches. Removal of cover soils leads to exposure of synthetic membrane covers with consequent deterioration of the cover from ultraviolet light or mechanical damage. Layers of stones or rip-rap (broken rock) can prevent surface erosion on cover slopes or areas of concentrated runoff but these stones must be supported and protected from sinking into the underlying soils. Traditionally, a bedding layer of sand or gravel has been used, but a properly selected geotextile can be substituted for

Table 1. *Effects of Various Chemicals on Geotextile Plastics*[a]

Chemical	*Concentration Percent*	*Effect of Chemicals on*		
		Polyester	*Polypropylene*	*Nylon*
Acetic Acid	*100 (glacial)*	*None*	*None*	*Substantial*
Sulphuric Acid	*10*[b] *(pH = 1)*	*None*	*None*	*Substantial*
Sodium Hydroxide	*10*[b] *(pH = 12.4)*	*Destroyed*	*None*	*None*
Aniline	*100*	*None*	*None*	—
Acetone	*100*	*None*	*None*	*None*
Ethylene Glycol	*100*	*None*	*None*	*None*
Isooctane	*100*	*None*	*Some*	—
Xylene	*100*	*Some*	*Some*	*None*
Chlorobenzene	*100*	*Some*	*Some*	*None*
Methylene chloride (dichloromethane)	*100*	*None*	*Substantial*	*None*
Ferrous sulphate	*Saturated*[b]	*None*	*None*	—

[a] *Consensus of data available to the author for room temperature exposure of at least one month.*
[b] *Aqueous solution.*

the sand and gravel bedding layer. Generally, fine sands, silty sands, and silts are most susceptible to erosion and are in most need of protection.

In drainage ditches and culvert outlets, fabric should be selected and placed as landfill covers. In cases where erosion potential is less severe, specialized mat-like geotextile related products may be installed as a supplemental root anchor to maintain vegetative cover. This should only be used where vegetative cover can be established to provide adequate permanent protection. Where stone is used in conjunction with geotextiles to line ditches and protect culvert outlets, proper preparation of the soil surface and proper alignment of fabric panels are essential.

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The complete report, entitled "Geotextiles for Drainage, Gas Venting, and Erosion Control at Hazardous Waste Sites," (Order No. PB 87-129 557/AS; Cost: $18.95, subject to change) will be available only from:
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