Geocomposite Systems Designed and Engineered to Specific Site Requirements

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ABSTRACT: Many geosynthetic materials are marketed today as commodity products. The physical, mechanical, and hydraulic properties are set by the producers to accommodate production and marketing requirements as well as engineering functional requirements. There are cases where specialty products must be engineered to meet a particular set of functional qualifications. This paper describes a restoration project that had definite, restrictive criteria for a geosynthetic product. A geocomposite lining system was designed to meet the project criteria and was successfully installed to complete a regionally important irrigation and hydroelectric canal structure. The geocomposite is a reinforced polypropylene geomembrane with specially selected geotextiles bonded to each side in panels custom sized to fit the canal. As designed, the geocomposite provided the required soil interface friction for side slope stability and superior tear and puncture resistance to handle installation stresses and environmental conditions.

1 INTRODUCTION

Many of today's marketable geosynthetic products, including geotextiles, geomembranes, geonets, and geocomposites are manufactured as commodity products that vary in mass, thickness, and physical and mechanical properties. The properties, and thus the type or stock number of the geosynthetic selected, are specified based on functional design criteria such as tensile strength, apparent opening size, transmissivity, impermeability, or chemical resistance. Designs are often governed by properties of the materials that are available to meet the primary function of the geosynthetic.

Geocomposites, a relatively new form of geosynthetics, combine two or more types of products, such as a geotextile and a geomembrane, into a single system with multiple functions. The geocomposite can be designed for special applications by selecting specific geosynthetic components, interlayer bonding methodology, and installation requirements.

This paper presents the technical requirements that were designed into a geocomposite system. Functional requirements such as site installation stress, direct shear interface friction, tensile strength, puncture and tear resistance, and environmental and chemical compatibility are explored as design parameters for a geocomposite system used as the lining system for a large hydroelectric feeder canal.

2 GEOCOMPOSITES

The term geocomposites is applied to products that are manufactured from two or more geosynthetic materials that, in combination, perform specific functions more effectively than when used separately. A commonly used geocomposite is polyethylene drainage net with geotextile bonded to one or both surfaces. Wick drains, which have a polymeric core wrapped with geotextile, are another specific type of geocomposite.

Geotextiles are commonly used in conjunction with geomembranes for puncture protection, drainage, and improved tensile properties. Bonding a geotextile to a geomembrane to form a geocomposite is a relatively new approach. It was first successfully marketed as a light geotextile bonded to a PVC-P (polyvinyl chloride-plasticized) geomembrane. There are now a variety of composite geomembrane systems.

3 TECHNICAL REQUIREMENTS FOR GEOCOMPOSITES

3.1 Physical Properties

The physical properties important in a geocomposite are panel size, flexibility, and unit weight, which allow handling and deployment at the required location. Size and weight limitations are governed by transportation and handling systems. The flexibility determines whether the material can be folded or rolled for transportation and how well it conforms to site conditions.

3.2 Mechanical/Hydraulic Properties

The mechanical properties are related to the required function the geocomposite is to perform. Tensile strength and tear and puncture resistance are important for manufacturing, handling, and deployment. Depending on the function, other properties such as permeability, impermeability, interlayer bonding, transmissivity, surface friction, seaming, and flexibility are designed into the geocomposite to form a functional system.

4 CASE HISTORY–HYDROELECTRIC FEEDER CANAL

A geocomposite lining system was designed and manufactured for installation on an 8-km (5-mile)-long feeder canal used for irrigation and hydroelectric power supply along a hillside in eastern Idaho in the western United States. The original project failed during construction due to inadequate design and construction practices by the engineer/contractor. Heavy rains caused the washout of overflow structure piping because of inadequate soil compaction around the pipe. Steep slopes on the outside of the canal were constructed with safety factors near 1.0 that jeopardized the integrity of the canal embankment. The original geomembrane lining was not anchored on the slope, and fine-grained cover soil placement caused the lining to slide off the slope. The redesign was conducted by another engineering firm and the original contractor was retained by the owner, for contractual reasons, to finish the project.

4.1 Project Background, Criteria, and Scheduling

The project was unique because the supply of irrigation water had to be maintained during construction, the designed hydraulic capacity had to be maintained to support power generation, and the project had to be redesigned and constructed in less than 8 months to meet the summer irrigation schedule.

The schedule was driven by the need to provide irrigation water by the month of June and to begin power generation shortly thereafter. The owners were compelled by financing agreement to begin the economic payback for the design and construction investment.

The hydraulic characteristics of the canal could not be changed by the redesign. The slopes of 2.5 horizontal to 1 vertical could not be modified. The alignment was changed slightly for slope stability reasons and this was done without compromising the gradient or capacity. Fig. 1 illustrates a representative cross-section of the canal.

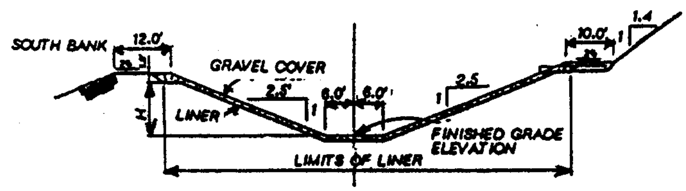

Figure 1 Canal Cross-Section

The soils underlying most of the canal are wind blown loess, a fine silty material that can collapse on wetting. Some exterior slopes were too steep for long-term stability and required some realignment. This made leakage from the canal a critical control function. Access to the canal was also limited to one roadway on the left bank.

5 GEOCOMPOSITE SYSTEM DESIGN PARAMETERS

For this particular case history, the following functional requirements and design parameters were used to design a site-specific geocomposite.

Canal Geometry:

- 2.5 horizontal to 1 vertical slopes
- Slope length up to 9.8 m (32 ft)
- Radius of curvature at bends in canal
- Profile must be maintained for original hydraulic conditions and flow of 0.07 m^3/sec (2.5 cfs)

Underlying Soil Type:

Windblown loess (silt)

Overlying Granular Protection Layer:

450 mm (18 in.) thickness of crushed (angular) well-graded gravel 40 to 150 mm (1.5 - 6 in.) size.

Watertight Lining System:

Because water loss due to seepage could jeopardize slope stability, the geomembrane materials and seams were carefully researched.

High Puncture and Tear Resistance:

A tough, puncture-resistant composite lining system was needed to resist shipping, handling, and installation stress as well as damage from the placement of angular cover gravel.

Tensile Strength:

A material with a relatively high tensile modulus and low susceptibility to creep was required due to handling and placement on slopes. In addition, a material was designed that would give some factor of safety for long-term durability of the system on a steep inclined surface.

Direct Shear Interface Friction:

The underlying silt interface with a typical geomembrane exhibits a much lower friction angle than the overlying granular material. To reduce shear stress development in the geomembrane system, a series of large-scale direct shear tests were performed on a variety of composite materials following ASTM D 5321 methods. Shear box sizes used were 30.5 x 30.5 mm (12 x 12 in.) for silt and 45.7 x 45.7 mm (18 x 18 in.) for the angular gravel. Table 1 illustrates the final shear test parameters used.

Table 1 Direct Shear Test Parameters

	Test Conditions				
Shear Box Size	γ_{di} (pcf)	ω_{di} (%)	Soaking Stress (psi)	ω_{df} (%)	Normal Stress (psf)
12"x12"	98.3	21.4	50	28.2	50
	98.4	21.4	100	26.8	100
	98.2	21.4	200	25.0	200
	98.3	21.4	400	25.4	400
12"x12"	97.3	22.2	50	24.2	50
	97.5	22.2	100	22.0	100
	97.3	22.2	200	26.5	200
	97.6	22.2	400	24.7	400
18"x17.5"	126.0	0.1	N/A	4.1	100
	125.3	0.2		3.8	200
	125.8	0.1		4.5	400
18"x17.5"	126.1	0.3	N/A	3.8	100
	126.5	0.1		4.2	200
	125.8	0.2		3.5	400
12"x12"	125.5	0.2	N/A	3.1	100
	126.1	0.1		3.5	200
	125.7	0.1		3.4	400

Environmental Considerations:

Due to the canal location, the lining system was subject to extremely low temperatures, ice accumulation during winter months, and freeze/thaw of the subgrade above the water level.

Regulatory Requirements:

Because the canal was linked to a hydroelectric scheme, the final design had to be submitted to state and federal regulatory agencies for approval.

Taking into consideration all of the functional requirements, design engineers developed a set of minimum physical/mechanical properties for the geocomposite system and internal geomembrane. Tables 2 and 3 illustrate the minimum specification requirements for the composite system and the geomembrane.

Table 2 Composite System Properties

Property	Required Values	Test Method
Thickness, mils	150	ASTM D5199
Grab Tensile Strength, lbs	350/4" width	ASTM D751 Mod.
Tear Resistance, lbs	170	ASTM D4533
Puncture Resistance, lbs	180	ASTM D4833
Diaphragm Burst, psi	510	ASTM D3786
Bonded seam peel strength, lbs/in.	FTB and 25	ASTM D4437
Residual Friction Angles Cover Gravel Native Soil	 32 degrees 32 degrees	ASTM D5321
Peel Strength of Geotextile from Polypropylene (min)	8 lbs per inch width	ASTM D413

Table 3 Geomembrane Properties

Property	Required Values	Test Method
Thickness	45 mils nominal	ASTM D1777
Breaking Strength	250 lb, min.	ASTM D751, Method A
Tear Strength	55 lb, min.	ASTM D751, Modified, Tongue Tear
Puncture Resistance	100 lb, min.	ASTM D4833

6 COMPONENTS OF THE GEOCOMPOSITE SYSTEM

6.1 Geomembrane

An internally scrim reinforced membrane was selected to provide a high degree of tensile strength, puncture and tear resistance, as well as dimensional stability and flexibility. The polymer chosen was polypropylene, a polyolefin that exhibits outstanding thermal field seaming capabilities, low water absorption, high dimensional stability, low temperature flexibility, and long-term durability. The internal reinforcing scrim are 10 x 10 x 1000 denier (1 denier = 1 gm/9000 m) high-tenacity polyester fibers that provide the requisite high tensile, tear, and creep resistance as well as increased dimensional stability.

6.2 Geotextile

The requirements for the geotextile bonded to both sides of the geomembrane precipitated from preliminary direct shear testing and bonding requirements. The geotextile polymer could be either polyester or polypropylene; however, due to the fusion methods during lamination and availability of coarse fiber, a polyester geotextile was chosen. The general requirements for the geotextile was for a coarse staple fiber with a fiber denier range of 15 - 16 denier per fiber, minimum breaking tenacity of 3.3 gm per denier and minimum fiber length of 100 mm (4 in.). A coarse staple fiber was chosen to maintain coarse surface texture and loft for optimum soil/geotextile interface characteristics.

6.3 Bonding System

A proprietary thermally reactive polymeric bonding system was used to bond the polypropylene geomembrane and the polyester geotextile at specific heat, pressure, and dwell time to produce a minimum bond strength of 143 gm/mm (8 lb/in.) in peel adhesion.

6.4 Production Geocomposite

The final product was a 4-mm (160-mil)-thick geocomposite panel 6.1 m (20 ft) in width and up to 25 m (82 ft) in length. Each panel was designed with a 150-mm (6-in.)-wide selvage edge of unbonded geotextile for field overlap and thermal seaming.

7 INSTALLATION

The geocomposite panels were delivered to the site in rolls and installed in a shingle fashion with the upstream panel overlying the downstream panel. A self-propelled hot air fusion welder was used to thermally weld all panel seams. Figs 2 and 3 illustrate panel seaming and placement. After placement, welding, and field quality control testing, the coarse gravel cover material was placed as shown in Fig. 4.

8 SUMMARY

The critical canal lining project required a special geocomposite system to satisfy demanding design and site requirements. After much investigation, product review, and laboratory testing, a geocomposite system was designed to meet specific project criteria and was successfully installed within critical time constraints. As designed, the geocomposite provides the required mechanical strength to resist installation stress and soil/gravel interface friction for side slope stability. In addition, the geocomposite materials will provide the necessary durability for the design life of the project.

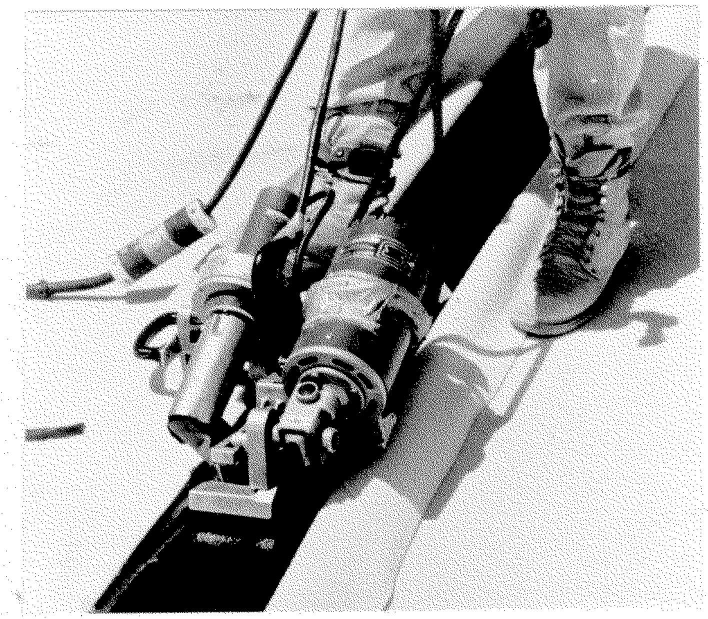

Figure 2 Field Seam Welding

Figure 3 Geocomposite Panel Layout

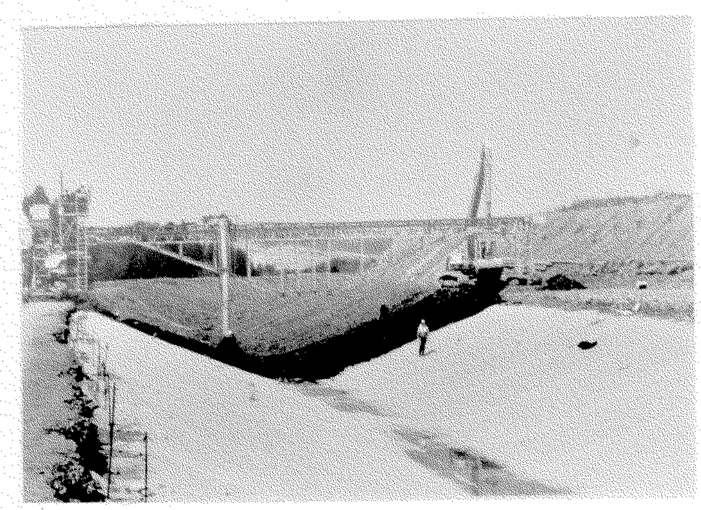

Figure 4 Gravel Cover Material Placement