Temperature Design Considerations in a Geogrid Landfill

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ABSTRACT: In 1990, the Town of Brookhaven, NY began investigating the possibility of constructing an expansion of one portion of their municipal solid waste landfill. The town's consulting engineers, Wehran EnviroTech of Middletown, NY proposed a unique horizontal expansion design which incorporated the use of a geogrid reinforced liner system which would be buried between the old and new waste. Because of its placement in the landfill cross-section it was anticipated that the geogrid reinforcement would be exposed to high temperatures caused by the anaerobic decomposition of the municipal solid waste. It was important, therefore, that a geogrid be chosen that would retain its high modulus at elevated temperatures over the life of the project.

This paper presents a case study on a design and post construction quality control methodology for incorporating geogrid reinforced liner systems in areas where high temperature considerations are a major factor.

1 INTRODUCTION

The scarcity of useable municipal landfill space has caused owners of landfill facilities to look for innovative engineering solutions to increase their solid waste airspace. The cost of designing, permitting and constructing new landfill facilities is far greater than the cost of building on an existing landfill facility. This cost differential has created a substantial interest in the expansion of existing facilities. One such technique for creating an engineered expansion is to build upon the existing landfill facility in either a horizontal or vertical arrangement, thereby eliminating or delaying the need for new permitted space.

2 BACKGROUND

In 1990 the Town of Brookhaven, NY was faced with a landfill capacity constraint at their municipal waste facility. The present landfill had been in operation since 1974 and was nearing capacity with the exception of one area on the north side of the facility. Rather than begin immediate permitting proceedings at another location it was the town's desire to continue filling at the present site until all useable space was exhausted. There was, however, one major concern immediately apparent to the design engineers was that related to the differential settlement of the underlying roadblock to this strategy. After the initial phase of landfill construction, the New York State regulations governing the construction of landfill facilities were changed to require that all landfills in the Long Island area of New York be built over double lined systems with leachate collection. Much of the area proposed for the new landfill expansion was only underlain with a single liner system. The New York State Department of Environmental Conservation (NYSDEC) agreed to allow the proposed expansion if a state-of-the-art double lined system could be built over the entire limits of the waste placement area. By necessity much of this double lined system would have to be placed on the slope of an in place solid waste cell, thus creating a horizontal expansion of the existing facility.

Although the challenge to develop an engineered solution to the city's waste area expansion was great, the rewards to the city would be significant. The use of the proposed site would add 2.1 million m^3 of airspace to the landfill, and provide the city with the necessary time required to go through the process of permitting a new waste disposal area.

3 DESIGN

In order to meet the state's design requirements the town contracted with Wehran EnviroTech of Middletown, NY to develop a design for a double lined system that could be placed over the existing solid waste. The major design waste as the landfill became loaded over time. Large differential settlement may result in the yielding of the geomembrane beyond the 12% maximum strain normally associated with HDPE membranes. In order to provide a safety factor against rupture a maximum system strain of 5% was therefore established.

The other design concern was the possibility of potential ponding on the side slopes due to settlement. This concern was alleviated by adopting a minimum base slope design of 20 and 25% over the older and newly placed refuse, respectively.

3.1 Settlement prediction modeling

Before a technique for preventing differential settlement could be developed, a method for predicting the response of the underlying waste to overburden placement needed to be established. For this particular project two methods, the Soil Arching-Tensioned Membrane (SATM) method and the finite element method (FEM) were performed. Details of these analyses have been described in previous papers. (Beech, et al 1988 and 1990) (Badie and Wang 1985). The SATM method assumes that a void of a given diameter or width with rigid side walls develops within the underlying waste after the waste overburden has been placed (Beech, et al 1988). The analysis then assumes that the vertical loads above the void are transferred to the rigid side walls through an arching mechanism. From this analysis a computation of the vertical stresses that must be carried by a reinforced overliner support system can be made assuming the soil and/or waste above the liner and void have reached a limit state.

The finite element method for designing overliner support systems requires that the actual properties of the waste mass be allowed to determine the response of the waste to the applied loadings. This is a very detailed approach that necessitates the need for in situ measurement of the waste properties and modeling of the waste mass.

The ultimate result of the FEM analysis is a close approximation of the predicted waste settlements and the subsequent overliner tensile strains.

3.2 Data collection and settlement analysis

The engineers chose the FEM as its primary analytic technique for determining the required loading in the overliner system. Waste properties were calculated by measuring the transmission velocities of shear and compression waves through seismic geophysical techniques (Carey, et al 1990). This data yielded calculations of Young's modulus, bulk modulus, shear modulus and Poisson's ratio for the waste at varying depths around the site. Using this data a FEM was performed for an overall cross-section which assumed no weak zones, and one which assumed weak zones placed across the cross-section at different elevations. This analysis showed that only those weak zones located within the upper 4.6 meters of the waste fill could create differential settlements large enough to create excess strain in an unreinforced liner system.

A simulation which assumed no reinforcement directly beneath the liner was first performed to determine the maximum differential settlement that could occur over soft zones in the existing waste. The model predicted a differential settlement of 0.94 meters using very low strength parameters. A second simulation was then performed by assuming the placement of a high strength geogrid below 0.6 m of cover soil. For analysis purposes the modulus of the geogrid layer was varied until the FEM predicted a tensile strain of 3 percent in the geogrid. Three percent strain was achieved when a long term modulus of 677 kN/m (490 kN/m in the warp and 187 kN/m in the fill) was selected. The FEM analysis showed that the introduction of the geogrid layer reduced the differential settlement to 0.73 m in any area where weak zones could occur.

A SATM analysis using an assumed 1.8 m diameter void was also performed to see how the results compared to the geogrid reinforced FEM. The soil arching theory analysis yielded a required long term 5% modulus of 380 kN/m. This modulus requirement was considerably lower than what the FEM predicted would be needed.

4 GEOGRID SELECTION

Once the design requirements had been identified by the FEM the proper selection of the geogrid to be used as the overliner support needed to be made. The FEM was used because of its more conservative strength prediction. Based on the results of the settlement modeling a geogrid performance specification was written which is shown in Table 1.

Table 1. Geogrid Specification

Property	Test Method	Value
Retained Modulus* (kN/m)	ASTM D-4595** ASTM D-5262	671

* 75 year design life and 5% limit strain

** 10 %/min. loading rate at 60°C temperature

"Retained modulus" refers to the ability of the geogrid to maintain a 5% limit strain design strength over the specified life of the project. For this project the specified design life was 75 years. Manufacturers were required to provide wide width testing performed at a temperature of 60°C in order to assure the engineer that the geogrid could maintain its strength when subjected to the elevated temperatures that are typically measured in solid waste landfills. The engineer identified 60°C as being representative of the temperature that could easily be experienced in the overliner zone in landfills of this type.

4.1 DETERMINATION OF TEMPERATURE REDUCED LONG TERM DESIGN STRENGTH

The determination of the geogrid's long term design strength requirement of 33.6 kN/m at 5% strain (671 kN/m x 0.05) was expressed in equation form in the following manner:

$$33.6\ \text{kN/m} = \frac{\text{Geogrid Ultimate Strength}}{(f_{CR})\,(f_{TEMP})\,(f_{D})\,(f_{ID})} \qquad (1)$$

where:

(f_{CR}) = Factor of safety for creep at a maximum 5% limit strain

(f_{TEMP}) = Factor of safety for temperature related strength loss at 60°C

(f_{D}) = Factor of safety for durability

(f_{ID}) = Factor of safety for installation damage

This equation is very similar to that used to design other types of geosynthetic reinforced structures with one major exception: a reduction factor for temperature related strength loss was added to account for the documented temperature related strength variability which takes place in some synthetic polymers. The engineers were very aware of research which has shown that polymers such as high density polyethylene can experience as much as a 70% reduction in strength when the temperature is increased from 21°C to 60°C (Van Zanten 1986). This was a very important design consideration that the engineers felt had to be included in the reinforcement equation in order to maintain the long term integrity of the geogrid system.

4.2 GEOGRID DESIGN CONFIGURATION

Because the required strength of 33.6 kN/m at 5% strain was needed in both directions a design utilizing two layers of geogrid was developed. The two geogrid layers were designed to be deployed at 90° angles to each other. This would allow biaxial geogrid with strengths in both directions (warp and fill) to combine their cross-directional strengths, or allow the use of two layers of very high strength uniaxial geogrids which develop full design strength in one direction. Based on its high resistance to strength loss at elevated temperatures and its biaxial configuration, it was assumed by the engineer that a high tenacity polyester geogrid would be the most cost effective product for the project.

5 QUALITY CONTROL AND INSTALLATION

The project construction contract was bid and awarded to DeBremont Enterprises of Massapequa, NY. The contractor submitted a high tenacity polyester geogrid, Fortrac 110/30-20 to the engineer for approval.

5.1 Independent QC testing

As specified in the contract documents independent testing was provided to substantiate the wide width strength of the product at 21°C and 60°C. Additional back-up data was also provided to establish the other factors of safety used in the design. Based on the project specific parameters provided by the engineer the following factors of safety were established for the geogrid used at the Brookhaven site.

$f_{CR\,@\,5\%} = 3.3$

$f_{TEMP} = 1.22$

$f_{D} = 1.02$

$f_{ID} = 1.02$

The f_{TEMP} was confirmed by independent testing which indicated a 18% loss in modulus due to exposure to a 60°C elevated temperature environment.

5.2 Installation

The geogrid reinforced overliner system was installed in November of 1990. Over 150,500 m^2 of geogrid were installed on a 4 on 1 slope over a 0.3 m intermediate soil cover and gas venting layer. 0.6 m of select soil, an 1.52 mm VLDPE membrane, a 2.03 mm HDPE membrane and 0.6 m of a primary granular drainage blanket were then placed over the reinforcement (see Figure 1).

5.3 Settlement and temperature monitoring

In order to monitor the relative movement of the overliner system a network of three horizontal inclinometers were installed during project construction (see Figure 1). A thermistor was also installed with the inclinometer sensor in order to provide continuous temperature measurements in the overliner zone.

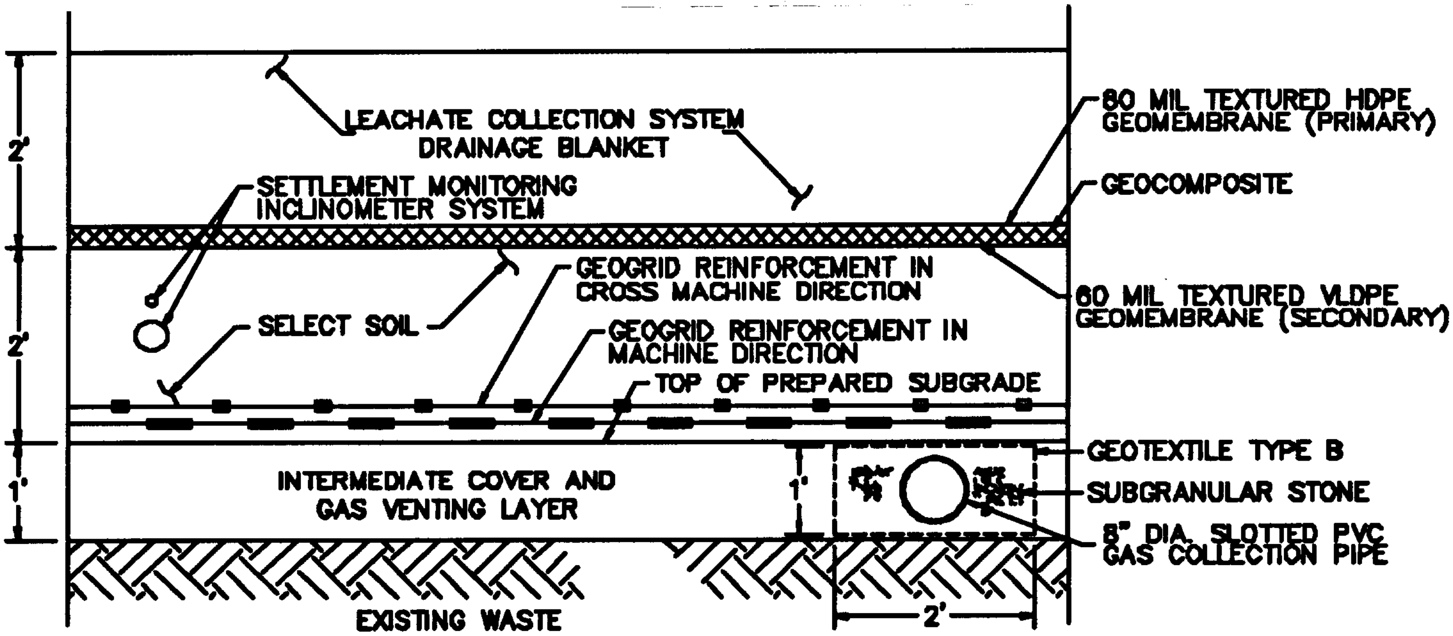

Figure 1: Overliner Detail

6 SYSTEM PERFORMANCE

Inclinometer and temperature readings have been taken quarterly ever since landfill filling began in July of 1991. To date the tensile strains in the overliner system caused by differential settlement have been 1%, much less than the 5% allowed in the project specification. With 3/4 of the landfill filled the temperature in the overliner zone has increased to 33°C, significantly higher than the ambient temperature level to which most geosynthetics are normally exposed.

7 CONCLUSIONS

The use of a geogrid reinforced overliner allowed the Town of Brookhaven to utilize 2.1 million m^3 of landfill airspace that would not have otherwise been available to them. The proper choice of a high temperature and high creep resistant geogrid also allowed the use of a cost effective reinforcement which saved the town thousands of dollars in material costs. This study specifically defines the key performance properties required in a geogrid reinforced overliner design of this type. It is hoped that the results of this study will assist other landfill designers considering similar cost effective options for designing vertical or horizontal expansions using reinforced overliner systems.

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