30 Year Exposed Geomembrane Landfill Cover: Performance, Material & Design Criteria

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ABSTRACT: The final closure of mixed waste, e.g. hazardous and low-level nuclear, landfills is not currently possible in the U.S.A. because performance standards have not been established by the United States Environmental Protection Agency. Interim geomembrane (GM) covers described in this paper were designed to allow performance confirmation and to resist exposure conditions during a minimum 30 year service life. Six common GMs are evaluated related to their ability to survive interim cover service and design criteria.

1 INTRODUCTION

An interim cover was required for a mixed waste landfill at the Oak Ridge National Laboratory in Tennessee, U.S.A. The area of the cover is approximately 10 ha. The interim cover was required to provide a minimum 30 year operational life and meet specific operational, performance, and design criteria.

1.1 Operational Criteria

During its 30 year life, the interim GM cover was required to be accessible for inspection and easily repaired, preferably by the laboratory maintenance staff. Additionally, the interim cover had to apply no significant increase in the weight supported by the waste mass. This latter requirement was to limit disruption of the waste and drove the need for the exposed GM interim closure concept. Facility maintenance also required that roadways be placed over the interim cover to allow vehicle access to existing gas and groundwater monitoring wells. These operational criteria generated specific design and performance data.

1.2 Performance Criteria

During its 30 year life, the interim cover would be required to resist damage resulting from subsidence of the waste, wind induced uplift pressures, weather exposure, and site surface water run-off impacts. The maximum subsidence feature was estimated to have a maximum 1 m settlement over a 4.5 m diameter of the cover. This corresponds to a maximum biaxial service strain in the GM of 22.2 percent. Regional weather conditions produce a minimum service temperature of -35°C, the maximum wind speed is 145 km/hr, and the 100 year rainstorm generates 15 cm of rain in 24 hours.

1.3 Design Criteria

The unique combination of operational and performance criteria resulted in specific design problems for the interim GM cover system.

High wind velocities in the region resulted in wind uplift pressures exceeding 0.84 kg/m^2 (Richardson and Koerner, 1988). The design had to provide sufficient anchorage of the GM to resist the uplift and potential excessive tensile stresses in the GM. An additional limitation was provided by the facilities desire not to do excavations within the existing cover, e.g. anchor trenches were not considered acceptable.

Placement of roadways over the interim GM cover presents stability, inspection of integrity, puncture, and controlled access problems to the design team. Vehicle were limited to small trucks with controlled access assured by the nature of the facility.

Design of control for water run-off resulting from the design storm must ensure that significant erosion does not occur at the perimeter of the interim cover where the water exits the cover system. This requires that the water be directed as it flows over the cover an integration of erosion control features at the perimeter.

2.0 GEOMEMBRANE EVALUATION CRITERIA

The required performance characteristics for the GM included UV resistance, seamability, seam durability, chemical resistance, puncture resistance, stress-strain characteristics, and interface friction. Each required performance characteristic was given a relative importance rating based on its importance to the performance of the interim cover and the difficulty of repairing the failure. The relative importance criteria for the interim covers is shown on Table 1. Criteria for covers is presented for comparison.

Using a low points scoring system (lower is better), a series of adjustment factors were developed to adjust the ordered ranking of the GM. Thus if a GM is ranked 2nd on a given performance characteristic, the adjustment factor for the criterion would be added to its ranking. The adjustment factors for relative importance ratings of 1,2,3,4 and 5 are -1.0, -0.5, 0.0, 0.5 and 1.0 respectively.

Table 1 Relative Importance of Evaluation Criteria

Criterion	Exposed Cap	Covered Cap	Liner
Seaming Reliability	3	2	1
Chemical Resistance	5	5	2
UV Resistance	2	2	5
Thermal Performance	2	4	4
Puncture Resistance	2	3	3
Stress-Strain Properties	1	2	2
Interface Friction	4	2	1
Long-term Monitoring	2	5	3
Maintenance	1	5	5

The following GM types were ranked for each of the criterion shown on Table 1: HDPE, VLDPE, PP, PVC, CSPE and PP/EPDM for exposed and covered cap GM application. For buried cap and liner applications, the top three GM alternatives are PP/EPDM, PP, and HDPE. For the exposed cap GM, the top three materials are PP/EPDM, PP, and HDPE. Actual ranking scores are not given since the process is somewhat subjective and application specific. This ranking process can be of general use to all designers however.

Based on this ranking program, the GM system used in the interim covers will be a polypropylene-based GM, be green in color, have an electrical-conducting bottom for periodic leak testing, will use double track fusion seams that allow for periodic seam integrity testing, and possibly reinforced on steep slopes.

3.0 COVER DESIGN CRITERIA

Key design objectives for the interim cover include wind uplift anchorage, roadway access, general puncture resistance and storm water control.

3.1 Wind Uplift

Short term wind uplift protection is commonly achieved using sandbags place on the GM. However, the larger design uplift pressure and long service life preclude the used of common sandbags on the interim cover. Three alternative systems were evaluated to restrain the GM against wind uplift: anchor trenches, screw augers, and strip weights. These are shown on Figure 1. The first two systems are intrusive and require penetrating the existing cover. The third system is nonintrusive and is simply a modification of the sandbag concept.

The anchor trench concept requires a network of parallel trenches placed across the cover. The spacing between the anchor trenches is controlled by the tensile strength of the GM and the pullout capacity of the anchor trench. The stress (F/L^2) in the GM is given by as follows:

$$F_{WIND} = [P^2L^2AE/2]^{1/3} \quad (1)$$

where P is the uplift pressure, L is the distance between anchor trenches, A is the GM thickness, and E is the elastic modulus of the GM. Using this formula with the allowable tensile stress of the GM allows calculation of the anchor trench spacing. In general, it was felt that anchor trench depths exceeding 0.3m would be sufficient to develop the allowable tensile capacity of common GM.

A review of commercial screw augers indicated that a penetration exceeding 3 feet into the existing cover would be required to obtain a reasonable auger spacing (>3m). It was felt that this would be to disruptive on the existing cover and was therefore eliminated from final consideration.

The strip anchors must be designer in a similar manner as the anchor trench system; the distance between the strips is a function of the tensile stresses generated in the GM. Equation 1 is used for evaluating the spacing of the weight strips.

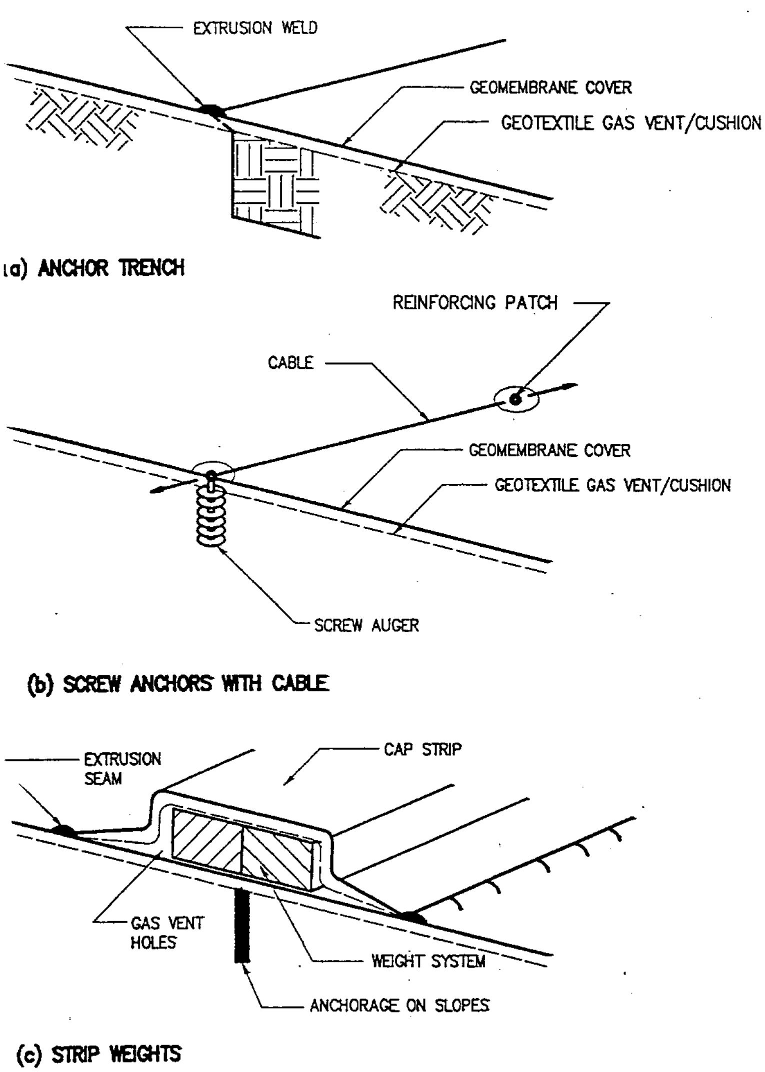

Figure 1 Wind Uplift Restraints

The actual "weight" used in the weight strips can be concrete filled pipe, geotextile (GT) wrapped gravel, etc. For this application, the weight will be provide by clean 2 cm gravel wrapped in a heavy non-woven GT. This allows the weight strips to be designed as part of a passive gas venting system. Holes are intentionally made in the GM below the gravel strips such that light gases rising from the landfill are collected in the strips and allowed to vent at the high points of the strips.

3.2 Roadways

Placing roadways over the GM is accomplished using the construction detail shown on Figure 2. The roadway is constructed of approximately 2 cm gravel placed within geocell forms to both increase the load carrying capacity of the road and to limit lateral spreading of the gravel. The gravel blanket in turns rests on a heavy weight nonwoven GT to protect the GM. The edges of the roadways are formed such that they prevent typical light trucks from leaving the roadway and driving directly upon the GM. Such roadways can be constructed only when the slope is less than 10 percent.

3.3 Slope Stability

On slopes less than 10 percent in grade, the strip weight system is stable. The stability quickly reduces as the slope increases. The "weight" must be stabilized against sliding on steeper slopes than 10 percent. This stabilization may require the use of anchorage stakes place through the "weight" or the use of a GM having an enhanced interface friction. The strip weight GM can be place on slopes exceeding horizontal:vertical in this manner.

An additional slope stability concern is generated by the roadway system placed over the GM. Such roadway systems cannot be staked to increase their stability without damaging the GM. Their use would therefore require either use of an interface friction enhanced GM or on slopes having grades less than 10 percent.

3.4 Storm Water Run-Off

The proposed interim cover makes use of the strip weights as a means of channeling the surface run-off. The channels formed by the strip weights must run down across topographic lines in such a fashion as to allow the surface water to drain uniformly to the perimeter of the cover. This prevents an excessive flow of surface run-off to a single point on the perimeter of the cover.

4.0 LONG TERM PERFORMANCE MONITORING

The continued performance of the interim cover during its 30 year design life must be easily verified. For those portions of the interim cover having exposed GM, the verification may prove to be little more than having to perform regular visual inspections. Two enhancements of the GM have been proposed to make this inspection easier: using a coextruded GM such that a color change

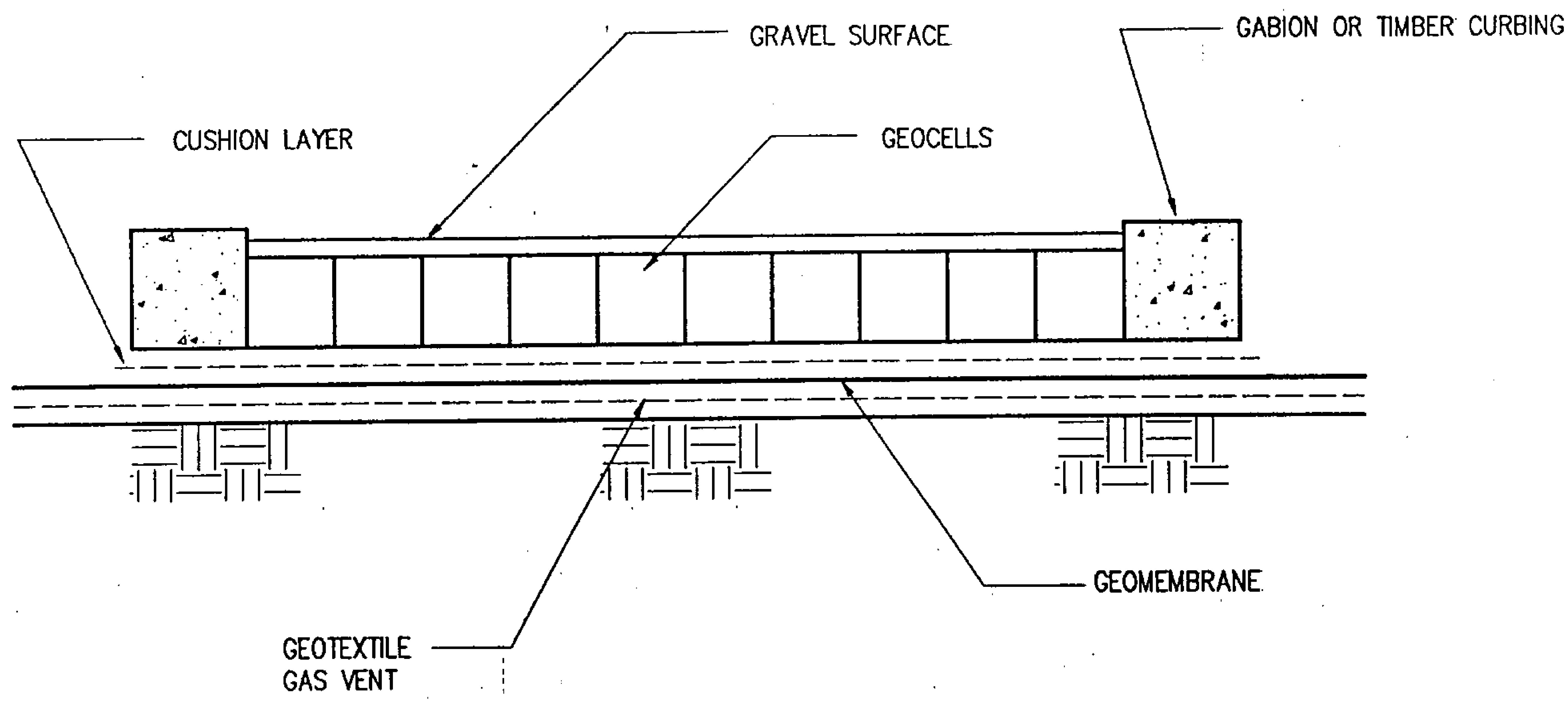

Figure 2 Roadways Over Interim Cover

can be seen at points of abrasion or puncture, and the use of a GM having a conductive layer coextruded on its bottom side so that punctures can be found using the spark test. Both enhancement make detection of puncture damage to the GM easier.

The proposed interim cover will also have reserve tabs of GM so that the deterioration with time of the physical properties of the GM can be evaluated. It is anticipated that such testing would be performed on an annual basis and at the same time that the cover is inspected for subsidence related damage.

Performance monitoring of the GM that lie beneath roadways on the cover offer a greater challenge to verify. While no system was developed that could provide complete verification of the GM integrity beneath the roadway, a compromise system was evaluated using continued testing of the double track fusion seams in that portion of the GM beneath the roadway. It is felt that significant damage of the GM cannot occur without damage to the seams.

5.0 SUMMARY

The interim cover concepts presented in this paper provides a means of limiting infiltration of surface waters into mixed waste landfills in an economical fashion. It is hoped that regulatory guidelines will be promulgated before the end of this decade and will shorten the need for and actual service life of this systems.

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6.0 REFERENCES

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