CASE HISTORY OF EXPOSED GEOMEMBRANE COVER FOR BIOREACTOR LANDFILL

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SUMMARY: Design challenges for installing an exposed geomembrane cover for a landfill included (a) providing adequate anchorage of the geomembrane to resist the typically strong wind forces, (b) making sure all important geomembrane welds were constructed so that they would only be stressed in a shear mode and not in peel, (c) managing intense stormwater runoff from the exposed geomembrane area, (d) ballast for low-wind conditions, and (e) managing the large number of penetrations through the cover geomembrane that would cause localized stresses during wind storms. Design and operational lessons learned are presented in the paper.

1. INTRODUCTION

The Yolo County Central landfill near Davis, California, USA chose to use an exposed geomembrane cover as part of a long-term experimental bioreactor cell. The bioreactor cell is 1.3 ha in area and contains approximately 60,000 tonnes of compacted solid waste. The maximum slope height is 16 m, with an inclination of 1V:2H The purpose of the cover system was to provide complete encapsulation of the waste so that the gas extraction could be closely controlled. The waste was contained on the bottom with a composite (geomembrane and clay) liner system. Numerous penetrations were installed through the cover system to allow for leachate injection, gas extraction, and instrumentation. Since the bioreactor cell may eventually be either incorporated in the larger landfill complex, or reclaimed by screening the composted waste, the Owner chose to use an exposed geomembrane cover instead of a more complete final cover system that would incorporate soil.

2. GENERAL DESIGN APPROACH

The design approach used followed the method described by Giroud et al. (1995) to evaluate the forces acting on the geomembrane and the anchor trench due to wind uplift, which is the largest design consideration for this application. Several other design references are available in the literature describing the approach (Gleason et al., 1998, Gleason et al., 1999, Germain et al., 2001). Using this design method, the only viable hold-down mechanism to keep the cover from being blown away due to a significant wind velocity is to use fully backfilled anchor trenches or soil berms on benches. The primary author believes this is conservative as evidenced by successful designs that have not used such extensive ballasting. Nonetheless, to reduce the probability of failure, the more conservative design approach was used for a maximum assumed wind velocity of 40 m/s. A general picture of the completed cover system is shown in Figure 1.

Figure 1. Completed Exposed Geomembrane Cover System from Top Crest of Slope.

3. GEOMEMBRANE MATERIAL SELECTION

Based on the authors' experience and a literature search, it appears that two primary materials have successfully been used for exposed geomembrane covers: reinforced polypropylene and high density polyethylene. Table 1 presents a list of criteria that would be used to evaluate a potential exposed geomembrane cover material.

For durability, functionality, and reparability, the authors recommended that Yolo County select reinforced polypropylene with a minimum thickness of 0.75 mm. The selection of this material was based on the criteria listed in Table 1, and the specific minimum thickness of 0.75 mm was based on very positive experience with this material at another project that had very demanding durability requirements (Thiel, 2001).

4. CONSTRUCTION DETAILS

The primary construction details of interest were the anchor trenches, temporary ballast system, pipe penetration boots, and storm water runoff control. Since storm water control is very specific to a given site, no further discussion is provided in this paper other than to say that it was collected in lined ditches at the toe of the fill, which were designed to accommodate the flow to the site drainage ways.

Table 1 - Geomembrane Selection Evaluation Criteria.

CRITERIA	TEXTURED HDPE	REINFORCED POLYPROPYLENE
Exposure to UV and temperature extremes	Excellent (backed by warranty)	Excellent (backed by warranty)
Exposure to physical impact	Reasonably good	Excellent because of dense reinforcement
Resistance to down-slope creep	Poor. High expansion and contraction will result in progressive wrinkles occurring at toe.	Good. Low expansion and contraction coeff.
Resistance to wind-related uplift damage and tear resistance	Moderately good	Excellent because of high strength in both tension and tear modes
Repairability	Good, but need specialized welding equipment, extrusion rod, and trained welder	Very good, can do with minimal training with a hot-air gun, not requiring extrudate
Demonstrated performance	Several projects	At least one large project, plus Thiel inflated cover experience
Surface texture	Available with textured surface to allow easier slope access by foot	Surface not available textured
Availability and cost	The most available of all products and probably the lowest cost	Good availability but requires potentially more lead time than HDPE; material costs more than HDPE

4.1 Anchor Trench Construction

The primary design goals of the anchor trench were (a) to provide adequate ballast to resist wind uplift, and (b) avoid putting any geomembrane seams in peel because the peel strength of most geomembrane seams, and especially for polypropylene, can be quite low compared to their shear strength. These goals were accomplished by (a) digging rectangular-shaped anchor trenches into the waste or subgrade of adequate size to so that when backfilled with soil they would provide the required dead weight, and (b) requiring that the geomembrane welds were on the bottom of the anchor trench. Condition (b) could have been satisfied in other manners, as well, but this specification avoided any confusion. In addition, the anchor trenches were capped with an additional piece of geomembrane simply to avoid water from ponding inside the soil-filled trench. A detail of a typical anchor trench is shown in Figure 2.

4.2 Temporary Ballast Construction

A temporary ballast system was installed that consisted of 20 kg sand bags on a 2.4 m × 2.4 m grid. This ballast system would counteract the uplift forces the vast majority of the time, and potentially may even be adequate all by itself. The primary author has found this level of ballast adequate for large installations (> 10 ha) of temporary plastic tarps on landfills, and Gleason et al. (2001) describe one successful exposed geomembrane cover that used a similar ballast system. Because of the large number of penetrations at the Yolo County installation, it was deemed prudent to have both the temporary ballast in addition to the more substantial anchor trenches.

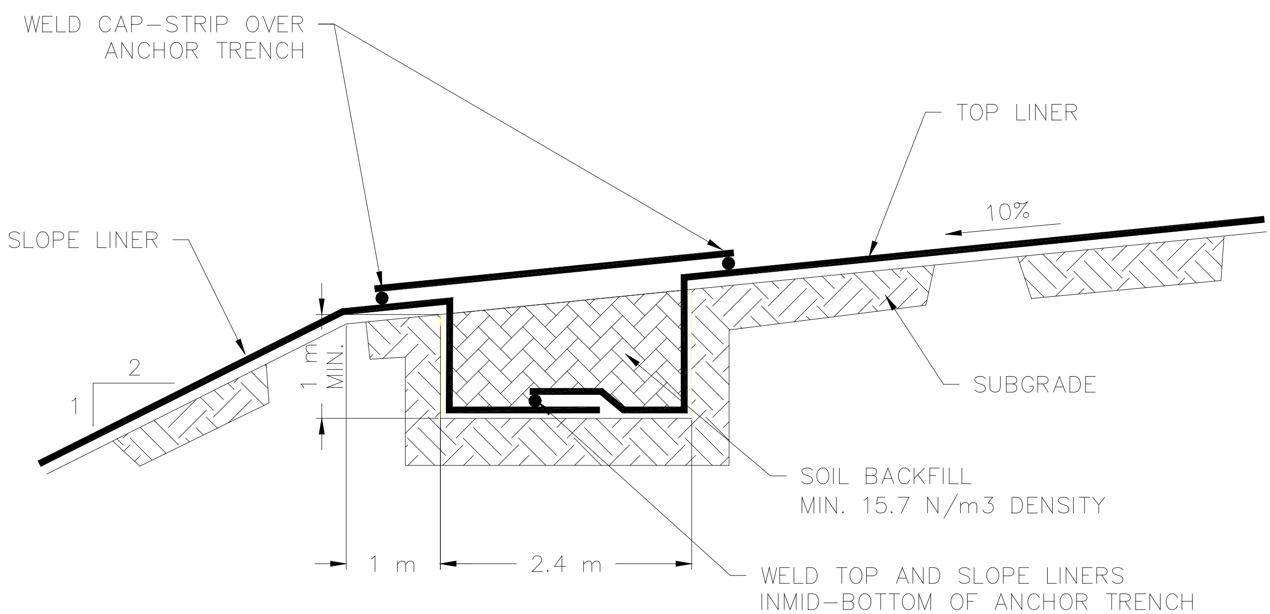

Figure 2. Typical Anchor Construction Detail.

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The interesting aspect of the ballast installation lies in the exact details of how it is installed and maintained in place. If sand bags were simply to be placed on the liner with no other restraint, the first real wind would cause the sandbags to be tossed around and end up at the toe of the slope. To keep the bags in place, the bags are tethered together with a rope grid made from 3-strand twisted polypropylene rope. The horizontal ropes were specified as 10 mm rope, and the vertical ropes were specified as 20 mm rope because of the greater load they might carry. At each node where the ropes crossed, a sand bag was tied. The type of attachment affects the long-term durability. Plastic electrical ties eventually break due to exposure and stress. Crimped wire hog rings are the most long lasting. Experience has shown that if installers of this ballast system attempt to be frugal or save time by leaving out ropes, or not adequately fastening the bags and fixing the nodes tightly, they will end up redoing the work.

It is also important to use sandbags that are durable and have good UV resistance. The material-only cost for a new (unfilled) sandbag at the Yolo County project was approximately $1 USD. This bag was manufactured from two plys of 0.08 mm polyethylene laminated together having nylon reinforcing threads at a 12 mm spacing

each way. Experience has shown this material lasts approximately 5 years in an exposed environment. A typical sandbag attachment at a rope intersection is shown in Figure 3.

Figure 3. Photo of Sandbag Attached to Rope Node (note bird pecking holes).

4.3 Pipe Penetrations

To the extent possible it is desirable that pipe penetrations be reduced or eliminated because experience has shown that these locations will provide the most operational problems over time with exposed geomembrane covers. The nature of the Yolo County test cells, however, is such that numerous penetrations are required for purposes of instrumentation and operation of the test cells. The design noted that problems and repairs at the penetration points would be expected over time due to wind uplift. The nature of the problems might include ripped cover material, ripped boots, and broken pipes. As problem areas become identified and repaired, it is possible that additional cover ballast could be added at those locations to reduce the chances of repeat failures at the same locations. Over the 1.3 ha site, a total of 107 pipe penetrations were installed!

The type of boot specified for the penetration was a pre-manufactured boot and skirt that could be welded to the geomembrane cover, and clamped to the pipe. In the two years that the exposed cover system has been operational, only one tear occurred. A photograph of some typical pipe boots is presented in Figure 4.

5. OPERATIONAL ISSUES

The single largest operational issue has been bird (seagulls in particular) pecking at the liner and sandbags. Other operational issues have been sandbags detaching from the rope nodes, and pipe penetrations creating stress on the pipe boots.

The issue of the birds was foreseen, but not to the degree it was actually experienced. The two main areas that the birds peck at are the flaps on geomembrane seams, and the sand bags. If the flap left over from welding the geomembrane was left in place, the birds felt an irresistible need to peck inside the flap, thereby endangering the geomembrane. This was solved by cutting away the flap, and the birds stopped pecking on the seams. Solving the issue for the sandbags has been more problematic. The problem became so severe, that tires with covers were placed over the sandbags to protect them. The bottom side of the tires had to be cut out to fit over the sandbags, and a stiff piece of polyethylene geomembrane inserted over the top of the tire to keep the birds out. A photo of the tire protection installation is shown in Figure 5.

Figure 4. Photo of Pipe Penetration Group.

Figure 5. Photo of Tire Protection Over Sandbag.

6. SUMMARY AND CONCLUSIONS

Design of exposed geomembrane covers appears to be a viable technology for various circumstances. In the case of Yolo County, it provided the necessary means for a controlled experiment to occur for the purpose of evaluating a full scale landfill bioreactor. A combination of substantial anchor trenches plus a tethered-sandbag ballast system has been successful in preventing significant damage that might have otherwise been caused by severe winds, especially considering the large number of pipe penetrations through the cover system. Other potential users of exposed geomembrane covers may benefit from these experiences, and should be especially cognizant of the tendency for birds to pick at the liner system.

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