ALTERNATIVE LINING METHODS FOR TIROHIA LANDFILL

Miljenko Pavlinic, Waste Services Manager,
Eric Souchon, General Manager
HG Leach & Company Ltd.
Ph 07 8628727, Fax 07 8627940,
Email miljenko@hgleach.co.nz

1.0 Introduction

H G Leach & Company owns and operates the Tirohia Landfill and Quarry at Tirohia near Paeroa. The Tirohia Landfill is consented and opened for business in November 2001. Although the landfill liner system design was approved and successfully constructed, the Company has carried out an extensive investigation of alternative liners that are being used worldwide, in particular lining systems for steep sided quarry walls. Due to the scarcity of New Zealand expertise in vertical synthetic liner systems, the Company engaged an overseas consultancy service and undertook site several visits of similar "landfill in quarry" sites. This paper outlines the investigation that was carried out and proposes alternative liner designs for the next stages of the Tirohia Landfill.

2.0 Background

2.1 Consent Conditions

The Company applied for and was granted resource consents for the construction and operation of the Tirohia Landfill. The Resource Consent conditions specified that the landfill basal liner system is to comprise:

1. 600mm of clay compacted to achieve a permeability of not greater than 1 x 10^{-9} m/s.
2. A 1.5mm thick high-density polyethylene (HDPE) liner (FML), or an equivalent liner approved by the Waikato Regional Council.
3. 200mm of pit sand, or an equivalent approved by the Waikato Regional Council.

Resource Consent requirements for the side liner comprise:

1. 900mm of clay compacted to achieve a permeability of not greater than 1 x 10^{-9} m/s.
2. A 1.5mm thick high density polyethylene (HDPE) liner or equivalent liner approved by the Waikato Regional Council, for not less than the first 6m as measured vertically from the top of the basal liner.

The consent conditions also allow for alternative liner systems that have equivalent or better performance.

2.2 Construction Experience

Half of Stage 1 of the landfill was constructed during winter 2001. Difficulties in achieving the clay specification were anticipated in winter, so the Company opted to use a geo synthetic clay liner (GCL) placed on top of 300 mm of clay with permeability $K<1*10^{-7}$ m/s. However the first liner trials showed that the clay was too wet to meet shear strength design requirements that are important in relation to the overall stability of the landfill. In order to decrease the water content and to increase the shear strength the material was preconditioned with burnt lime. This method proved to be successful and permeability achieved was $<1 \times 10^{-9}$ m/s. However having placed only 300mm of clay on the floor GCL was installed to ensure compliance.

The major lesson learnt from lining stage 1 in accordance with the approved design, is that clay liner construction is the most challenging part of the liner system construction. Whilst during winter construction the clay was too wet and significant effort was required to precondition it to meet the specification, the converse problem arose during summer construction, namely the clay was too dry and had to be wetted.

In order to meet the requirements of the consent conditions, the side liner design results in the clay side liner being constructed 3 – 4 metres thick due to practical construction needs – i.e. minimum width for construction machinery access, which is significantly wider than the minimum 900 mm thickness specified. Therefore the volume of clay per square meter of vertical side-liner is face 3-4 m^3. As a result of the significant challenges involved with the placement of clay and exhaustive QA/QC testing regime, alternatives to clay lining were worth exploring to find more effective methods and materials, which will in turn minimise the demand for the naturally occurring clay found in pristine farmlands.

2.3 Overseas Experiences

Most of the modern landfill technology including that of lining was developed at large landfills in United States, where landfill cells do not have vertical walls. Hence there is unlimited technical knowledge and experience available on how to line landfill floors or slopes. Landfills in steep sided quarries are less common, so knowledge of vertical lining has not been developed to the extent of that of floor lining. Some experience is available in Hong Kong and United Kingdom. The landfill operators there had some earlier experience with vertical clay lining but the most are now using alternatives. The major technical issue is to ensure that the liner system remains impermeable without punctures or ruptures for the entire operating and post-closure life of the landfill. The liner system has to be laid on sharp rock on one side whilst being dragged down by significant refuse settlement forces on the other side, over a long term.

- **Hong Kong**

Shotcrete is widely used to smooth over the rock faces in the quarried landfills of Hong Kong (Cowland, 2002.), in order to prepare them to receive geosynthetic-lining materials. Shotcrete is a form of concrete that is easily applied by spraying, and it does not require formwork. A three-man team is usually adequate to operate the mixer, pump, hose and nozzle. The technique relies to an extent on the expertise of the nozzleman.

In Hong Kong landfills, it is standard practice to form the rock faces with benches at regular vertical intervals. Shotcrete is then applied to the surface of the rock face from one bench level to the next, and the liner is anchored along the benches.

- **United Kingdom**

Quarries are often used as landfill sites in United Kingdom resulting in a number of interesting alternative lining systems being developed. Accordingly (Gallagher 2000) three general types of non-mineral, patented, steep wall lining systems have been used at 11 UK landfills. These are:

  - **Vertical Barrier System**, which comprises of a triple row of HDPE tubes, the central row filled with bentonite slurry and outer rows filled with drainage metal, has been trailed as a prototype but has not progressed to a full-scale use.

  - **Reinforced Earth Wall with Polystyrene Former** has been used at several sites. The system creates smooth lines, which makes installation of the geo-membrane straightforward process. The reinforced earth technique requires the reinforcing grids to have an anchorage length into the fill, which would increase with the height of each lift, which would consumes significant landfilling void space.

  - **Steel frames** have been used to retain a gravel backfill at the High Moor Landfill located in a quarry, close to Oldham, England. Steel frames have been anchored with rock bolts of varying lengths to suit the shape of the rough rock face. The system has been developed over the past fifteen years, from double rows of gabions sandwiching a geo-membrane through to the above described framing, to the most recent development using galvanised steel plates mounted on the steel frames instead of the galvanised steel netting. The gravel infill is serving as a groundwater drainage layer, and the steel frames are being faced with steel sheets to form a smooth planar surface for the geo-synthetic lining materials. The refuse side is protected shredded refuse filled wool fadges and most recently bags filled with soil.

- **United States - Sprayed Elastomeric Liners**

The simplest solution of all to lining the sidewalls of the quarry would be the application of a sprayed coat directly onto the rock face. It has been suggested that a Polyurea Sprayed Elastomeric liner might be a suitable alternative. These materials are widely used to form waterproof layers in other industries, and Miller et al. (1994) have reported on a polyurea landfill liner trial, but as yet they have not been used to form a landfill liner.

The material can be applied in the field to form a continuous, seam-free liner. The polyurea spray elastomer consists of an isocyanate terminated prepolymer reacted with an amine terminated resin. The liquids are pumped by a two component dispensing unit at 13.8 MPa and 68^0C and sprayed through a mechanical purge gun in a fan-shaped pattern. They react almost immediately with a gel time of 3 seconds and tack free time of 6 seconds. The elastomer can be walked on in minutes. This is the major advantage, which makes polyurea insensitive to moisture and humidity in substrates and can be easily applied over cold and damp materials. The application can be by hand or with automated equipment utilizing a transversing spray gun. The immediate advantages of the spray elastomer for landfill applications include the development of a monolithic, seamless membrane, direct bonding of the material to soil and almost any underlying support material, high strength and elongation values to handle settling, the ability to apply the liner directly to surface obstructions such as vent pipes, the high interface friction angle, the composition which is 100% solids with no volatile organic compounds (VOCs), and the ease of repair to damaged areas.

A major disadvantage is that polyurea has never been used for a full-scale landfill liner system except for the above-mentioned trial. It is likely that QA/QC would have to be exhaustive and costly to prove that the applied liner is really impermeable. Polyurea is relatively expensive material at around NZ $ 70 per m^2. The price is too prohibitive for floor lining so it is unlikely that further trials will be carried out in near future. However for lining of the quarry sidewalls, the cost may be competitive and the material will be considered for future applications.

3.0 Proposed Alternative Lining Systems

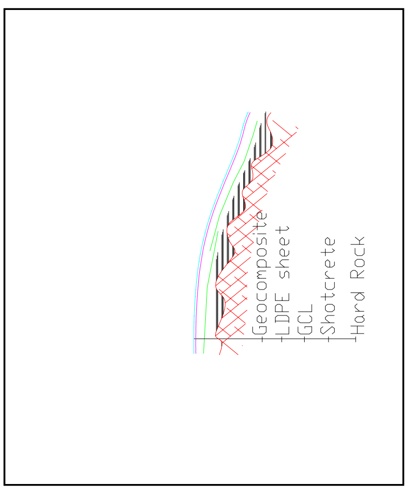
On the basis of the knowledge gained by site visits and acquiring overseas consultancy services the Company considered several different options for the sideliner, and one minor variation for the base liner. All of these options were being considered from an improved construction methodology point of view, without compromising the integrity and effectiveness of the landfill liner. The options include alternative materials with the same, low permeability characteristics as those materials already approved, and include methods of infilling irregularities on the rock face to present a smooth surface to be lined using synthetic liners.

Reinforced Earth Infill and Sandbag Infill and were considered but have been eliminated from the further consideration because the first does not offer volume gains and the second is labour intensive and probably would not create acceptable surface for GCL overlay.

- **Shotcrete Rock Face Infill**

Shotcrete is "mortar or concrete pneumatically projected at high velocity onto a surface". There are two different types of shotcrete: dry- mix and wet- mix. In the dry- mix procedure all ingredients except the water are mixed, and then the dry mixture is blown through the delivery hose in a stream of compressed air to the nozzle, where the water is added. In the wet- mix procedure, all ingredients including the water are combined in the mixer, and the resulting wet mixture is propelled to the nozzle where a blast of compressed air impels it on to the receiving surface. The materials used in shotcrete are essentially the same as those used in conventional cast-in-place concrete. There are, however, some differences in the proportioning of ingredients arising from the different application processes. While conventional concrete is poured into forms and then consolidated, shotcrete is consolidated by the impact process and then has to stay adhered to the substrate without sagging, sloughing, or falling out.

Trials of shotcrete mix designs have been carried out at Tirohia. The major factor that determines shotcrete financial viability is the thickness of the applied concrete. This will be directly proportional to the flatness of the existing rock wall surface.



The Company has tried several methods of pre split blasting and post trim blasting, as opposed to production blasting to get smoother quarry faces. These surfaces are currently being shotcreted. The trial shotcreting will be carried out in one lift of 8 m, which is 2 widths of the GCL rolls. The GCL rolls will be unrolled horizontally to minimise a number of vertical overlaps. The GCL will be anchored at the top using battens, Ramset into the quarry wall. The next GCL lift will overlap over the previous lift. It was decided to carry out the full-scale trial of this option fist and then depending on the result, proceed with further trials of the options discussed below or continue with shotcrete. The trial commenced 26 August 2002 so we shall be able to report the initial results at the WASTEMINZ conference.

If shotcrete option is not economical, further options will be trailed. These options are described below.

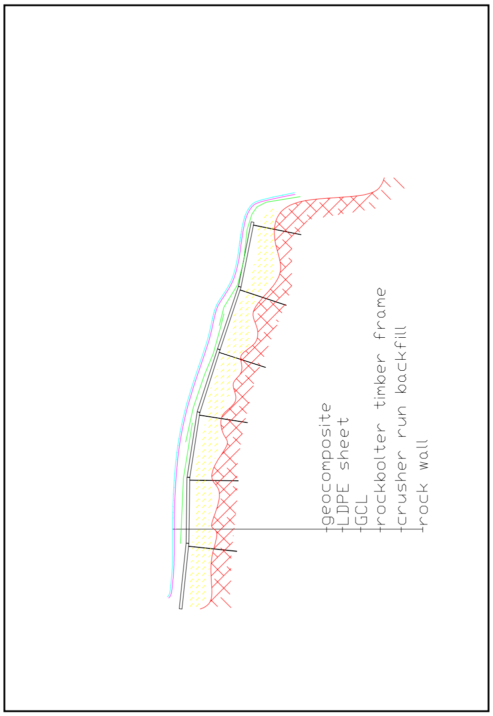
- **Steel Frames Rock bolted and Overlaid with GCL**

The proposed system comprises of steel frames 1500*1200mm overlaid with 3mm wire mesh. Each frame will be rock bolted at two points. The space behind the steel frames will be backfilled with lightly compacted crusher run. A heavy

Geotextile, 1200g/m³, will be placed against the mesh to protect the GCL against the crusher run. Based on UK costs this option is unlikely to be competitive with the current clay lining system.

- **Timber Frames Rock bolted and Overlaid with GCL**

The proposed system consists of a timber frame 2400mm *1200mm which is rock bolted and a 17mm plywood panel nailed to the frame. The frame is then backfilled with crusher run. Two important issues related to this system were considered in design. Firstly short term structural support for the backfill material until buttressed with refuse and secondly the required treatment to ensure long term structural integrity. The Company engaged Civil Engineering Tokoroa to assess a degree of treatment and check structural sizes and fixing details for a plywood based lining system. Although the designed system will ensure that the timber frames and plywood stay dry it is proposed that H4 timber protection is used.

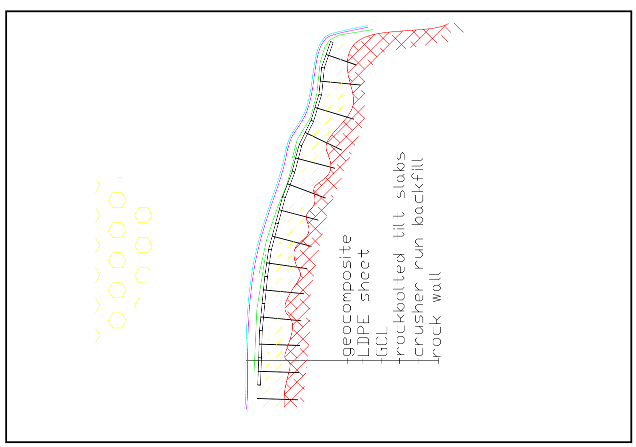


The timber frame will be backfilled with lightly compacted crusher run. The frame will be fixed on to a concrete footing. The rock bolts will be at 1200mm centres, 2m from the footing.

Plywood and timber frames will provide the simplest system to hang GCL over the plywood. The GCL will simply be nailed to the top frame.

- **Precast Concrete Tilt Slabs Rock bolted and Overlaid with GCL**

The principal of this system is the same as previous, except that instead of plywood on timber frames, a pre cast concrete panel is rock bolted to the quarry wall. Each panel would be 100mm thick made of 25MPa concrete with lifting eyes. It would be fixed to a patented Reidbar rock bolt with a Reidbar nut. The bottom panels will be fixed on to a concrete footing. The geometry allows for the liner to follow the uneven shape of the quarry wall. Reid Engineering Systems designed the system.



The row of tilt slabs will be backfilled with lightly compacted crusher run. The slabs will be overlaid with GCL.

The natural question arising from the above described systems is how long would steel or timber frames last until they corrode or decompose?

The purpose of the frames is to ensure that the liner is laid on a smooth surface. As soon as refuse is placed in front of the liner and the frames are backfilled behind there is no need for structural integrity of the frames in principle. However the gas and leachate generating capacity of the landfill diminishes after closure as natural decomposition occurs. If Tirohia Landfill was operational for 20 years then 50 years of structural integrity of the frames would be sufficient to guarantee that the geomembrane is intact until the leachate loading decreases to insignificant levels. Treated timber and galvanised steel can easily achieve 50 years target. To add to the argument, the head of leachate to the sideliner is not expected to be significant and finally there is the ability of a minimum of 60 metres of andesite rock or breccia to the groundwater table to contain or purify the lightly loaded leachate in the event of leakage.

- **Protection of the sidewall liner against puncture and drag down forces from refuse settlement**

By creating smooth sidewalls the GCL is protected from a puncture from the quarry wall side, but to ensure its integrity, protection is required on the refuse side. Three issues must be addressed:

- ❖ Protection against puncture by sharp object from within the compacted refuse
- ❖ Eliminate or reduce drag-down forces due to refuse settlement
- ❖ Prevent GCL getting wet until supported against lateral movement by compacted refuse.

The same issues were addressed in the original design where the clay liner had to be protected against down-drag and buttressed by the compacted refuse against lateral movement.

By placing two polyethylene slip-sheets over the GCL, they will create sufficient slip plane to eliminate this drag down effect. The originally designed clay sideliner used the same slip-sheets, which are easy to install. The slip sheets will protect the GCL from exposure to rain until covered with sand or an alternative protection layer and supported with selected refuse.

A geo composite consisting of the geo-textile and geo-net as a drainage layer, laid against the polyethylene slip-sheets is proposed as an alternative to the sand protection layer. Whilst the GCL has to be kept anchored until the next lift is placed, the slip-sheets and the geo-composite should be cut from the anchor and continue with the next lift. This will ensure that the protection drainage geo-composite layer is dragged down with refuse settlement while the GCL remains adhered to the surface of either the shotcrete, concrete panels or timber panels.

The decision on the preferred option will be made based on detailed consideration of the costs, constructability and service life of the system after several full-scale trials. A combination of these options may be applied depending on the quality of the quarry side- wall surface.

4.0 Conclusions

So far from the entire investigation and trials we have concluded:

- ❖ It is advantageous that Tirohia Landfill consent conditions relating to the liner made allowance for the use of an alternative, if it can be proven to Regional Council that the proposed alternative liner is equivalent or superior to that specified by the consent. This means that the Company is not required to undergo a lengthy consultation process if a consent condition variation is applied for. We strongly suggest to consent authorities and consultants to allow for the use of alternatives whenever possible, because it encourages continuous improvement and implementation of new and better practices when they become available.

- ❖ Unfortunately we found New Zealand expertise scarce in vertical synthetic liner systems, and the cost of overseas site visits and acquiring overseas consulting services are small compared to the savings that could be made by using world best practice instead of developing the system from scratch.

- ❖ Although it may initially seem that alternative materials are dearer than natural clay, the simplicity of application, reduced installation time and less weather dependency will shift the cost advantage to the use of alternative materials.

5.0 References

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