CASE HISTORY: KWAI CHUNG PARK VIADUCT AT GIN DRINKER’S BAY LANDFILL, HONG KONG

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ABSTRACT: One section, about 250 m of the Airport Railway Express linking the Chek Lap Kok International Airport and the city center runs through the Gin Drinker’s Bay Landfill, which ceased operation in 1979. The site had no landfill lining system and existing subsoil drains were largely ineffective in intercepting migrating leachate. The gas content was considered a hazard so much so that the site, intended as Kwai Chung Park, was never opened to public. In addition, any concrete foundation built into the waste would have been susceptible to constant aggressive attack. Geosynthetics was introduced to mitigate environmental impact and to provide protection to viaduct concrete structures when excavation and construction began. This paper reviews the geosynthetics design, the material, the installation and the observable effectiveness eight years after completion.

Keywords: Geomembrane, geogrid, geotextile, geocomposite

INTRODUCTION

The Gin Drinker’s Bay landfill was formed by way of public dump back in 1960’s. At that time, environmental hazard was not a concern, let alone lining system. When the Airport Railway Express was conceptualized, the most feasible alignment was to have a section pass through the landfill, being the most viable location in between a cemetery hill on the North, the busy Kwai Chung Container Terminal on the South, the Kwai Chung Industrial area on the East and the Rambler Channel on the West. Other options would necessitate major re-routing and property relocations. Together with the natural elevation to cross the Rambler Channel, a decision was made to build the viaduct cutting through the landfill (figure 1). Kwai Chung Park Viaduct cost HK$300 million or USD 38 million (at 1995 value). The project kicked off in November 1994 and took 40 months to complete. Train was in operation in 1998 and a subsequent separated landfill restoration contract was implemented in 2000 to cap the entire landfill (picture 1).

SOLUTION

A capping system (picture 2) using geosynthetics was designed to encapsulate the exposed waste thereby reducing contact with the environment. The same system was extended to the pile caps and incorporated
into each pile. In doing so, the whole viaduct concrete structure was protected against leachate contact and any exposed waste as a result of excavation was kept away from external water, which would otherwise penetrate the waste and leach the contents into the groundwater. Adequate drainage and system stability was also put forward. Several different interconnected capping designs were adopted to cover the earthwork excavation and the concrete structure construction. The earthwork system covered the side slopes excavated from the crest of the landfill at +45 mPD to the railway formation at +20 to +25 mPD, in the shape of a mountain pass. The pile system referred to the protection of the pile caps and individual piles from the railway formation at +20 to +25 mPD level down to rock head at -10 to -36 mPD. The deepest pile had length in excess of 60 m. The platform system joined the capping and the pile system along the railway formation. A complete sealing was perceived.

**CAPPING SYSTEMS**

The earthwork system (figure 2; picture 3) included four layers of geosynthetics: a bottom layer of geocomposite to collect seepage of leachate and underground water, an intermediate layer of 1.5 mm thick textured LLDPE geomembrane to prevent water infiltration, another geocomposite to drain away any accumulation of water on top of the geomembrane and a top layer of geogrid to stabilize the capping fill material.

All geosynthetics were selected with sufficient strength and frictional characteristics to maintain stability across the 1:3 slope, which has a run of over 70 m. A one meter trench at the crest of the slope served as the only anchorage. The system had to have several important features: it needed a large degree of flexibility to accommodate soft waste settlement; it had to be effective in intercepting and draining water; it had to provide sufficient interface shear friction to prevent various layers of geosynthetic from sliding against each other; and it had to offer resistance to hold the capping fill material from sliding.

**Fig.2 Earthwork capping system**

The pile system (figure 3; picture 4) consisted of a double layer of 2.0 mm HDPE geomembrane. There were 52 piles of 2.20 m diameter and their depth varied from 30 m to 64 m. The internal lining layer had T-shape ribs (T-grip) on one side to ensure concrete bonding and the external lining layer had a smooth surface to minimize down drag resistance (negative skin friction). When soil settled, the membranes would slide against each other, minimizing damage to the concrete protection layer. There were 15 pile caps of various sizes. Underneath was a 2 mm smooth HDPE geomembrane extended to encase the underside and vertical face of the pile cap. Concrete embed was used at the termination. As such, all concrete structures were completely shielded.

**Picture 2 Kwai Chung Park Viaduct overview**

**Picture 3 Earthwork capping geosynthetics**
In between pile caps and the slope toe was the transition platform area. The capping system (figure 2; picture 5) here resembled the earthwork system except that both geocomposites were replaced by drainage crush rock layer. In this situation, any water collected by the geocomposites were drained and buffered in the crush rock layer. Geomembrane thickness was increased to 2.0 mm in view of a higher risk of construction damage. Separation geotextile was used to cushion the geomembrane. There was, however, no need of a geogrid on the level platform. Along the toe of the slope, the 1.5 mm textured geomembrane was welded onto the 2.0 mm smooth geomembrane on the platform. This completed the impermeable barrier.

The 15 pile caps were in straight alignment linking the Kwai Chung Terminal Viaduct on the East towards Rambler Channel Crossing on the West. At each project interface, the lining system was necessary to maintain full coverage. Here the pile cap became the crest of the capping system sloping down to the toe, the site boundary. Space constrain had called for the adoption of a geogrid reinforced slope at the West end. This was to allow space to build a maintenance access road across the slope face. A 65º slope gave an extra 3 m width, which would otherwise not be available with conventional fill construction method. The capping lining system was installed under this reinforced structure following the earthwork lining design but to different level and contour (figure 4; picture 6). Complication came at the lining layout along the transition where the upside capping lining merged with that of the downside at both the East and West project interfaces.
INSTALLATION

Pile double lining had to be pre-installed inside a permanent pile formwork. A corrugated tubular steel casing was taken as the permanent formwork to support the lining system. This had to be fabricated off site because of space congestion. Inside the casing, a 5 mm plywood lining was bolted onto the inside surface to receive the external HDPE liner. Tunnel rondelle was adopted to affix this liner. T-grip was then spot welded onto the external liner as temporary adhesion. A series of welding strength tests were conducted to determine method and location of welding. It was important to master the capability to hold the double lining in the formwork during transit and installation and yet to be able to disengage the two liner, effecting the negative skin function. Struts were sought to prevent detachment and collapse of double lining system during transit and storage. The maximum section length was 15 m for ease of handling and compliance to road transportation regulation.

The lined formwork was lowered down the bore hole inside the temporary casing section by section. While the lower section was tucked at ground level, the upper section was hoisted and secured for section jointing. Here, extrusion welding was applied on each layer of liner. An extension lip was allowed to facilitate this operation. Stiff and rigid 2.0 mm HDPE permitted good workability. A steel collar was then screwed on the formwork to protect the jointing and to keep continuation of formwork. Each section was repeated in similar manner to reach full length of the pile. Perfect alignment was necessary to slip in the steel reinforcement cage. Any deviation from close tolerance would mean liner damage. Guide shoes were incorporated to direct the cage run between gaps of the T-grip ribs. In doing so, the T-grip was kept from collapsing during concreting. High precision and dedicated work were crucial.

Installation of capping geosynthetics was carried out primarily manually whereby each type of geosynthetics were cut, laid, properly connected and tested, panel-by-panel and layer-by-layer. Access limitation forbade any use of heavy lifting equipment. Temporary stability of the lining system was a problem at the Rambler Channel end where liners were installed in full height of over 10 m at an angle of 65º against waste material. Concerns were raised as to the effect of overstressing and excessive wrinkling during backfilling. Efficient work sequencing was set to cut down lining exposure time, thereby reducing risk of instability.

At the platform, the challenge came from the geomembrane interfacing work. This was the last part of the liner work, which could only commence after the pile system was completed. Works were complicated when liner had to be spread out from the pile prior to the construction of the pile cap. Special work sequencing was thought of to minimize possible construction damage.

MATERIAL

A bi-planar geocomposite with double sided non woven geotextile fulfilled the design strength, transmissivity and frictional characteristics. A uni-directional HDPE geogrid met the need for long-term design strength to hold the fill material from sliding on the nonwoven geotextile surface of the geocomposite. A textured HDPE geomembrane of 1.5 mm thickness was chosen for use on slopes, which was selected for its flexibility and strength needed to accommodate settlement and its frictional resistant surface needed for slope stability. An HDPE concrete protection liner T-grip was selected for use as the internal pile liner. It is made from HDPE of a thickness of 2 mm and has T-shape interlocks on one side running along the length of the pile at 100 mm spacing. The material's strengths include its toughness, its resistance to waste and leachate, its flexibility in fabrication and the possibility of engaging guide shoes between ribs when installing steel reinforcements. An HDPE geomembrane of 2 mm thick was selected for the external pile liner as well as for the platform. It was of the same thickness and properties as the T-grip and can be welded on to the internal liner by extrusion welding. A polypropylene geotextile was applied without any problem. Its inertness to waste offered reliability; its thickness at 4.4 mm was an ideal cushion to protect the geomembrane; and its high flow characteristic provided a good drainage and separation application.

Internal stability calculation using partial safety factor method was used to verify the suitability of the HDPE uni-directional geogrid in the reinforced slope construction. A secondary geogrid was put to optimize
surface stability. The same cushion geotextile was used to retain soil from being washed out of the geogrid. No surface treatment such as plastering or vegetation was applied. The geogrid was left exposed to the environment since (picture 7).

CONCLUSION

At the time of installation, water running out from the geocomposite above the geomembrane along unfinished edges was noticeable after raining. Meanwhile, water was observed seeping out from the geocomposite below the geomembrane when rain subsided. This showed the desired drainage function and the geomembrane impermeability characteristics. During capping back-fill, no sliding of fill material had been encountered with the use of geogrid. Field and laboratory tests had demonstrated that Tenax TT201 SAMP geogrid had no significant strength reduction as a result of UV exposure.

The capping soil was 1.5 m thick and the slope face was subsequently planted with grass, seedlings and whips. Sliding had never been recorded (picture 8 & 9).

At the reinforced slope, very little deterioration to the exposed geogrid and geotextile were noticed. The slope stayed intact with no observable movement or distress. No differential settlement to the access road above the structure was noticeable.

To the pile lining, very little could be monitored. Inspection for possible lining damage prior to concreting was considered unsafe. From the record of concrete pour, consumption volume matched the anticipation. This indicated that there had been no concrete loss through the liner in the event damages had indeed taken place.

After Words

A request to re-visit the site in March 2005 was granted by the owner eight years after completion.

Vegetation was established quite well on all slope area, with some seedlings achieving over 5 m height. Full coverage of grass and ground cover were observed. The landscape appeared mature and no soil erosion or movement or settlement was noticed. All surface drainage did not show cracking and waterstop expansion joints remained intact. On the platform area, substantial settlements of up to 200 mm were seen at each end of the viaduct pile cap. One section of extrusion seam along the concrete embed where the HDPE geomembrane was welded onto the pile cap come off, signifying liner stayed integrity. Majority of the exposed seams were very strong and geomembrane was well protected by the geotextile against soil settlement down drag. No settlement was observed in all other area. Exposed geomembrane and geotextile did not show signs of deterioration. There was no heavy ponding or soil penning which were signs of geocomposite malfunction.

This project covered only part of the landfill affected by the construction of viaduct. The whole landfill underwent restoration subsequently two years after the viaduct was in service (picture 1). A lining system was
installed only at the top plateau leaving side slope surface drains to manage water infiltration. There was no continuity of lining systems in between the two phases of work. A drainage channel of about 2 m was allowed separating the two lining system to simplify the complexity of merging two systems. Trees were maturing on the slope in particular at the crest platform where the anchor trenches were. Structures constructed on slope such as access staircase and drainage channel did not seem to have dislocations. The geogrid did provide the sliding resistance.

Maintenance works are now primary horticultural in nature and drainage channel clearance. There was no leachate detection exercise until the whole landfill restoration work was eventually completed. The capping contractor has indicated little fluctuation volume of leachate. There were no observation wells within the viaduct vicinity. One could assume the same leachate quantity behavior. And surface drains were noticed to carry large quantity of water during rainy season. Information of gas monitoring shows insignificant amount. All these demonstrated satisfactory performance of the lining system.

The geogrid and geotextile in the reinforced slope were left fully exposed since completion. There seemed to be surprisingly little degradation (picture 7). Geogrid samples were taken for tensile testing in 2005, after a continuous seven years of UV exposure. The results showed a remarkable 97% retaining of short-term strength.

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REFERENCE

Civil Engineering Department, Hong Kong Government. GEO Report No.34, a Partial Factor Method for Reinforced Fill Slope Design.


