Case History: Waterproofing Lining System at Penny's Bay

Project:	Inspiration Lake, Hong Kong Disneyland
Type of work:	Waterproofing Lining System
Location:	Penny's Bay, Hong Kong
Client:	Civil Engineering and Development Department, HKSAR
Project Consultant:	Maunsell Consultant Asia Ltd.
Design Consultant:	Scott Wilson, Binnie & Meinhardt
Main Contractor:	China State Construction & Engineering Corp.
Main Contract Period:	October 2001 to May 2005
Installer:	G and E Company Ltd.

Introduction

The Inspiration Lake is a major part of the development of Hong Kong Disneyland. It serves the purpose as a water recreation activity centre, an irrigation facility, a landscape feature, a micro climate cooling mechanism and as part of the regulating measures to the overall site drainage system.

The site is developed from reclaimed land off exclusive Penny's Bay about 10 km (6.2 miles) from the Hong Kong International Airport. Land reclamation work was completed between May 2000 and December 2002. A 10 m of surcharge was placed over the lake area for 18 months to encourage settlement consolidation prior to lake excavation formation. The lake is 13 hectares (130,000 m^2 or 1,300,000sq ft) in area, 1.5 km (0.9 miles) in perimeter, 8 m (26 ft) maximum depth encircled by 1:3 side slopes and with an artificial island. Around side slope lye, the lake edge where amenities and gardens were designed. In this surrounding, there are 13 aquatic planters, a 70 m (230 ft) retaining concrete boat quay, a 50 m (164 ft) spillway chamber (controlling water level at +7.5 mPD), two water inlets collecting surrounding run off from five catchments channels into two sedimentation basins (designed to dissipate energy when water enters the lake and to trap dirt) thereby clean water

overflows into the lake, one fresh water inlet (where water is fed to maintain a low water level at +6.5 mPD), one irrigation outlet, two gazeboes, an invert drain, an ornamental fountain and a waterfall. A flexible lining was used as the waterproofing system.

For reason that the site was reclaimed with marine sand fill, any leakage of the flexible lining would represent rapid water loss. It would also lead to seawater contamination when high tide finds its passage through the liner. The material durability, installation attentiveness, construction control, work supervision, control quality assurance testing and commissioning are crucial to system integrity.

The Lining System

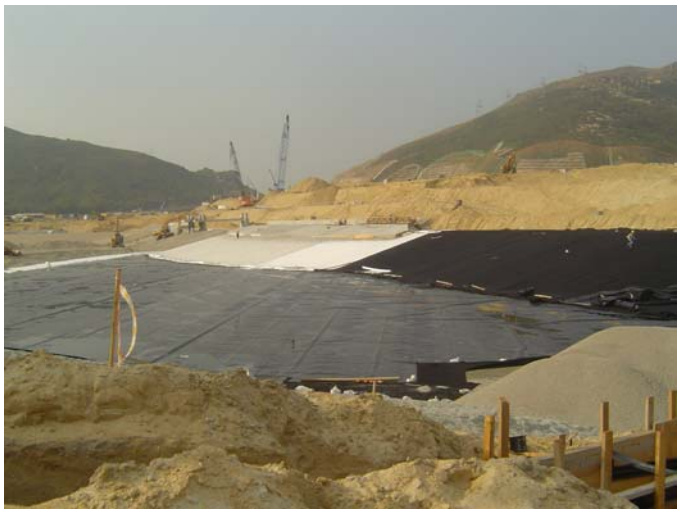
Preliminary choice of lining material was discussed around November 2001 with the design consultant engineer. Installation and site logistics were run through in January 2003 with project resident consultants. Method statement and shop drawings were finalized in May 2003. Lining work was completed between August 2003 and March 2004. The design adopts the use of 1.5 mm (60 mils) HDPE geomembrane, textured for the side slope and smooth for the bottom, with protection geotextiles on both sides of the geomembrane.

Over the excavation profile, the subgrade was prepared with a 300 mm (12 inches) layer of compacted 10 mm (0.4 inch) aggregate. This gives a rigid working base and a good drainage layer to relieve water from tidal effect. The lining system was ballasted by another 300 mm (12 inches) layer of 10 mm (0.4 inch) aggregate and, on top, a 400 mm (16 inches) layer of 200 mm rockfill. Lake edges are massive concrete structure constructed over the lining system.

Liner terminations along the lake edge were primarily welding to concrete embeds. Exotic details were taken at interface where liner terminated on the outside of lake edge parapet wall but turned onto the inside of concrete structures along the boat quay and spillway at different levels.

The Material

High density polyethylene (HDPE) was chosen largely because of its reliable weldability, cost effectiveness and readily availability. GSE HDPE geomembrane was selected as the liner. Non woven needle punched geotextile was essential to cushion HDPE liner against sub-base, ballast material and concrete structure. Special procedure was taken to manage construction traffic damage when placing 200 mm (8 inches) of aggregate over geomembrane. Amoco style 4516 was chosen as underling geotextile because of its outstanding resistance to seawater and Bonar SNW600 was chosen as cover protection because of it unique thickness and its heat reflective characteristic thereby minimizing geomembrane wrinkles. GSE Studliner was used as concrete embed along the outer side of parapet wall where welding connections are above the water level and GSE Polylock was used in watertight locations below the water line.



The Installation

The invert of the lake bottom excavation was +1.80 and that of lining system is +2.1, below the high tide at +2.5. Ingress of water was evidenced during initial profile excavation. Presence of water imposed a major installation problem. Two measures were taken to keep the area workable, 1) to carry out all work during the low tide period and during the dry season and 2) to pump down of the water table. Work was then scheduled from autumn 2003 when tidal change advantage was observed and before spring rainy season in 2004. A temporary drainage channel was formed along the center line of the lake bottom following the floor gradient towards a sump about 4 m x 5 m x 1.5 m deep where a series of 3", 6" and 8" submerging pumps were operated throughout the installation.

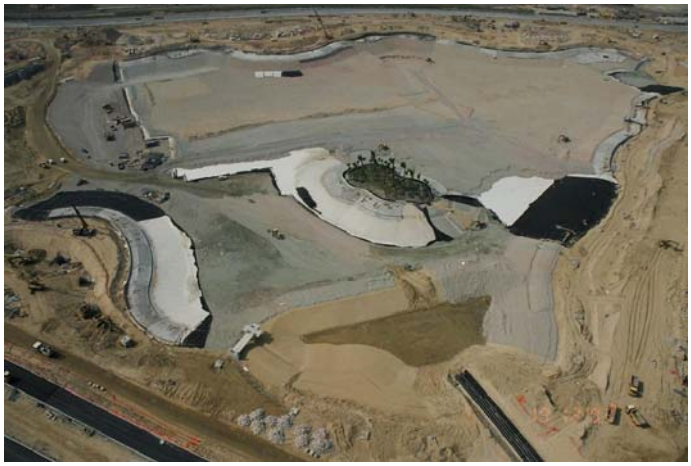
Lining work had to be in phase with the excavation following the lake edge clockwise, from low ground to high attitude. With the temporary drainage system and a high draining subgrade, water ponding unexpectedly occurred in many incidents. Sacrificed geomembrane was used to get the welder running on dry surface. From light precipitation, dew and moisture, water accumulated on the liner easily (under a very gentle gradient of less than 1:300), which then drained towards the working areas. As work progressed, this surface run situation became more prominent. This was much too obvious when pumping activities intensified when surface run were all collected to the sump instead of sipping under the subgrade. In many instances, squeegee and sandbags were used to divert surface water away from seaming area.

Extra standby resources were implemented when the pumping system was eventually dismantled to complete the lining. Formation, sandbagging, laying of geosynthetic, extrusion welding, testing and backfilling were to be completed within 4 hours before the ground water built up.

Vertical concrete joint at the boat quay retaining structure was vulnerable to leak. A concrete embed (Polylock) was fabricated to enable the liner to conceal the CJ up to the water level. Along the lake edge, concrete works on lined area posed high risk of damage. Spacer and special protection were introduced to cushion formwork in contact with the liner. The heavy needle punched performed well in this respect.

A minimum construction traffic protection layer of 1,000 mm limited earthwork inefficiency. To limit excessive wrinkles caused by daily temperature variation, lining work had to be slowed down to maintain minimum exposure.

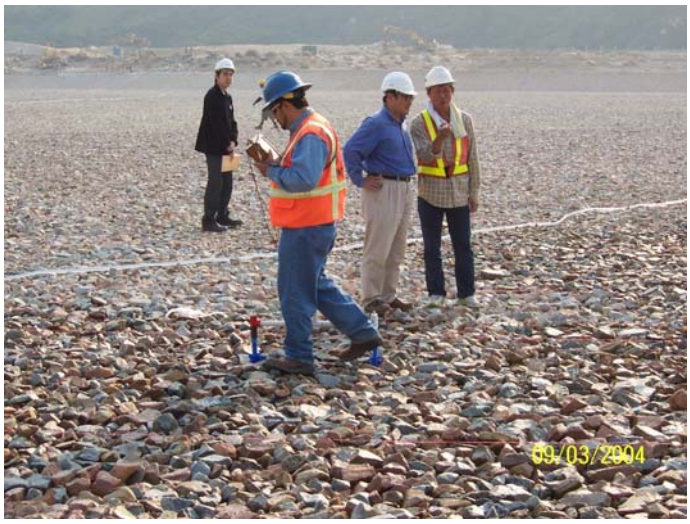
The custom sizing detailing of lining material to fit the lake edge curvature and aquatic planter irregularity were labor intensive. Extrusion welding around the 1.5 km (0.9 mile) lake edge was time consuming and painstaking.



The Commissioning

Upon completion of the liner, considerable rainfall was recorded. At the same time, water loss, in excess of evaporation, was reported. With the awareness of possible installation and construction damage, a leak location survey was commissioned beyond that of the project control quality assurance requirement. This technology which employs electric signal to detect liner puncture was first applied in Hong Kong. A specialist contractor, Leak Location Services, Inc. from USA, provided the service over a two weeks period in March 2004. With 700 mm of granular material separating the probe and the liner, water was continuously sprinkled during the scanning to ensure electric path optimum sensitivity. Three locations of damage up to the size of about 300mm x 600mm were found and the necessary repairs were performed. Subsequent resurvey of each repaired area indicated positively.

The lake requires half a million cubic meter of water and it took about 8 weeks to fill it up. Fresh water was introduced through the portable water inlet between February and April 2005. The design water level is a +7.5 m during dry season and +6.5 m during the raining season. Inspiration Lake was officially opened to the public on August 16, 2005.



The Overview

Careful planning and the possibility of using the best seasonal effect helped to follow project program. The challenge comes from the field operation. Geosynthetics and membrane lining are specialized engineering work unfamiliar to most of the contractor staffs and the engineers. Doubtfulness, misunderstandings and sometimes embarrassments were experienced throughout the beginning of the installation. Whether it was quality or standard of work, interpretation of testing results, details to welding operation, perception of integrity evaluation etc., we were very pleased that Geosynthetics expert, Mr Leo Overmann, was able to offer expertise on lining technicalities. Disneyland Hong Kong celebrated its grand opening on September 12, 2005.