Case History: Polymeric Reinforced Fill Slope in NENT Landfill

Contract No.	EP/SP/12/92
Project Title	Development and Management of North East New Territories (NENT) Landfill Hong Kong, Phase 2 Site Formation
Client	Environmental Protection Department, Government of the Hong Kong SAR
Consultant	Black & Veatch Hong Kong Limited
Operator	Far East Landfill Technologies Ltd.
Independent Consultants	Halcrow Asia Partnership Ltd.
Earthwork Contractor	Rankine Engineering Company Ltd.
Construction Period	October 2005 – May 2007
Geosynthetics Supplier	Tenax International BV, Tenax Tianjin Plastic….
Geosynthetics Distributor	G and E Company Limited
Scope of Work	Reinforced Fill Embankment
Material	261,600 m^2 of Tenax TT045 SAMP (Primary Geogrid) 72,975 m^2 of Tenax TT060 SAMP (Primary Geogrid) 57,050 m^2 of Tenax TT090 SAMP (Primary Geogrid) 31,200 m^2 of Tenax LBO202 SAMP (Secondary Geogrid) 5,000 m^2 of HDPE Bodkin Bar (Bodkin Connection)

Project Description

A steep embankment bridging two hills was constructed by reinforced earth using polymeric geogrid as reinforcement. The purpose is to form an embankment over a valley to increase the capacity of the landfill. Reinforcement is applied on both faces of the embankment. At the east, the permanent exposed face incorporates a gravel cover layer to protect geogrid from possible hillside fire damage. The west face is temporarily covered by a 1.0 mm green textured HDPE geomembrane to keep off rain and to provide aesthetics until waste is collected. Dimension of the structure is as follows:

Height of Embankment	35 m (West face), 42m (East face)
Slope angle	68 degree both faces
Base length	300 m
Crest length	350 m
Base width	45 m
Crest width	6 m
Berm details	2 m wide concrete path (East face), 2 m wide path(West face), at 7 m vertical interval
Configuration	Layer 01 to 49 – TT045 SAMP (Layer 1 is the topmost layer of geogrid) Layer 50 to 62 – TT060 SAMP Layer 63 to 84 – TT090 SAMP Width – Across the entire base Vertical spacing of primary geogrid – 400 mm

Photo 01 - Preparing the Slope

Photo 02 – Laying of Tenax TT Geogrid

Wrap-around type of construction was adopted. The reinforcement width extends across the entire width of the embankment from west to east. To prevent unraveling and long term erosion protection, the use of steel wire mesh and non-woven geotextile were taken as soil retaining element. Secondary reinforcement was supplemented to enhance face rigidity. Selected fill material was specified to ensure required frictional characteristics.


Photo 03 – Laying of Tenax TT Geogrid (3)


Photo 04 – Laying of Tenax TT Geogrid (4)

Internal Stability Analysis

Internal stability analysis of the reinforced fill slope is based on Geoguide 6: Guide to Reinforced Fill Structure and Slope Design (2002) published by Geotechnical Engineering Office (GEO) of the Government of the Hong Kong SAR.

Internal stability is concerned with the integrity of the reinforced block. Failures due to rupture and pullout of the reinforcement are considered in the design. In checking against internal instability limit state, the use of partial safety factors is adopted to evaluate if the design loading is sufficient for the design resistance.

For tension in reinforcement, the total horizontal force to maintain a slope in equilibrium was determined by considering a sufficient number of potential failure planes to obtain the worst case for design by computing program SLOPE/W. The checking was done at each face with the same continuous reinforcement connecting the two wrap around faces. Loading on the west face includes the pressure from future waste build up.

The Material

Tenax TT045, TT060 and TT090 SAMP geogrids with short-term characteristics strength of 45, 60 and 90 kN/m respectively match the design requirement. The long term design strengths were taken from the endorsement certificate issue by the Geotechnical Engineering Office (GEO) of the Government of the Hong Kong SAR. A basic bi-directional geogrid was brought in as secondary reinforcement but no strength requirement has been allowed in the analysis.

Geogrids were manufactured at Tenax's facility in Tainjin, China. Four containerized shipments were delivered between December 2005 and September 2006. Quality control was primarily the conformance testing on short term strength and carbon black content. Standard factory QC program was adhered to. Each consignment was tested by CESI in Italy from random samples at factory and by independent laboratories, Castco Laboratory in Hong Kong and Precision Geosynthetics Laboratory in USA from site stock samples. All tests were of flying colors, none failed.

The Principal

Tenax geogrids, being chemically inert and having a high tensile strength and modulus are specifically produced for the reinforcement of soil. Soil and aggregate interlock within the geogrid openings, which confine the soil and limit its relative displacements and increase the soil's shear stress resistance. Soil compaction produces an interlock between the soil and both faces of the geogrid layer, thus it's necessary to reach a higher level of tension in order to overcome such an interlock and give rise to movement.

The Construction

Understanding the size of the embankment, a mock up was implemented to anticipate possible construction problems. At the same time, details of geogrid deployment, facing integrity, practicality of accessories and diligent earth work can be appreciated and worker training can be set. The trial take the form of a miniature of the final profile specially formed with two earth abutments. The mock up is 30 m length, 8 m height, same 68 and with one berm. It was completed between September to November 2005. The experience was well received.

Problems were still encountered in the actual construction. The proper sieve of fill material posted difficulty. Fill from adjacent cut were too fine to match the special fill envelope. A batching plant was set to provide the coarse from rock cut. The mixing became a major operation. To ensure proper compaction, testing to 95% at location close to the face was never possible. Layout of geogrid was also unmanageable since wrap back of continuous geogrid between two unparallel faces cannot be jointed by bodkin to the upper layer in the same straight alignment, tensioning became even more tricky. An extended wrap back length was calculated to take away the bodkin connection, allowing the wrap back to turn askew to the upper layer. The curvature of the embankment also sees layout complications. Geogrid cannot extend over the entire base width and has to be discontinued along these change or orientation. Temperature variation also distorted some of the straightness of polymeric geogrid (product from cold Tianjin expands extensively in subtropical Hong Kong). Extra packaging and proper storage helped to restore dimension variation.

The Overview

Reinforced earth construction brings in a simple technique to form large steep fill embankment. The landfill operator sees RE method as a viable solution to increase waste volume. The method is relatively simple to design and efficient to build. Existing fill material can be fully utilized. Substantial cost saving can be justified compared to reinforced concrete. With the steep slope, volume of fill is reduced and the space created is many folds.

Photo 05 & 06 – Eastern Face of Reinforced Fill Embankment

Photo 07 & 08 – Western Face of Reinforced Fill Embankment (Before and During Construction)