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Construction of a large geogrid reinforced fill structure to increase landfill capacity

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ABSTRACT: Geogrid reinforced fill has recently been used to increase the capacity of a valley landfill in Hong Kong. A geogrid reinforced fill wall, 8 metres high, was constructed across the narrow opening of the valley to increase the landfill void space. Then the capacity of the landfill was substantially increased by the construction of a large reinforced fill embankment to fill a gap in the rim of the valley bowl. This reinforced fill embankment structure is 30 metres high and 300 metres long. This paper summarises the design of the embankment structure, the selection and quality control of the geogrids and fill material, and the facing details to prevent the outside face of the structure being damaged during a possible hillside grass fire.

1 INTRODUCTION

A solid waste landfill in Hong Kong, China, was designed in 1993 for a capacity of 40 million tonnes of waste. This landfill is now being operated and is about one third full. The landfill is lined to prevent the escape of leachate.

The landfill occupies a bowl shaped valley, which has a narrow opening at the downstream end leading onto a flat plain. The waste will eventually fill the valley, with a maximum depth of 140 metres. The rim of the bowl has a variable elevation, and in one location there is a 30 metre drop in the level of the top of the rim over a length of 300 metres.

1.1 *First use of geogrid reinforced fill to increase landfill capacity*

A geogrid reinforced fill wall, 8 metres high, was constructed across the narrow opening of the valley in 2003 and 2004 to increase the capacity of the landfill. This allows the placing of an extra 8 metres depth of waste across a large part of the 40 hectare landfill, which will increase the waste capacity by about 2 to 3 million tonnes.

This wall was formed with 80 kN/m and 120 kN/m uniaxial HDPE geogrids at a vertical spacing of 400 mm tied to concrete block facing units on the side of the wall facing away from the waste. The side of the wall facing the waste was formed with a geogrid wrap around arrangement, and was then lined with an HDPE geomembrane connected to the main landfill liner. The fill material was a silty sand obtained from within the landfill.

Placing of landfill waste against the wall commenced in 2007.

1.2 *Second use of geogrid reinforced fill*

The capacity of the landfill was again increased in 2006 by the construction of large geogrid reinforced fill embankment to fill the gap in the rim of the valley bowl. This structure is 30 metres high and 300 metres long, and again utilises excavated material from within the landfill. The geogrids have been placed in a wrap around arrangement.

The embankment was designed to withstand the lateral stresses from the waste, and it will be lined on the inside face to contain the landfill leachate. It is being monitored to determine settlement and lateral movement deformations.

The large reinforced fill embankment, which fills in the rim of the valley bowl, provides an interesting case history. This paper summarises the design, the selection and quality control of the geogrids and the fill material, and the construction of the structure. The outside face of this embankment structure has been designed to prevent the geogrids from being damaged during a possible hillside grass fire.

2 SHAPE OF THE EMBANKMENT

The embankment follows and fills the dip in the rim of the landfill. In plan it follows a variable curve. It is 30 metres high for over 200 metres of its length; the rest being a smaller transition towards the higher edges of the dip.

The sides of the embankment are 70° to the horizontal, with 2 metre wide benches at 7.5 metre vertical spacing. The top of the embankment is 5 metres wide, and the base about 40 metres wide on average.

3 DESIGN

The purpose of the embankment is to retain an extra 30 metres height of waste within the landfill.

Geogrid reinforced fill structures in Hong Kong are designed in accordance with the Guide to Reinforced Fill Structure and Slope Design (2002). With sides sloping at 70°, the embankment was designed in accordance with reinforced fill slope design.

The long term design strength of the geogrids was determined from tests for tensile strength, installation damage, durability and creep. Geogrid creep characteristics were determined at 30°C as Hong Kong is located within the tropics.

The waste loading on the side of the structure was accounted for by a slope stability analysis, whereby a series of potential slip surfaces from the top of the landfill through the embankment were analysed. The properties of Hong Kong waste have been reported by Cowland et al (1993).

It was decided that the lining of the side of the embankment facing the waste will not be carried out until the monitoring of the embankment shows that settlement has mostly ceased. It was also decided that the side of the embankment facing away from the waste should be designed to resist the occasional hillside grass fires that occur in Hong Kong.

3.1 *Fill material*

At the design stage, granular fill material was chosen to minimise the settlement of the embankment.

3.2 *Geogrids*

HDPE geogrids were chosen because of their better resistance to landfill leachate than geogrids made from other polymers.

The design resulted in uniaxial geogrids with three different ultimate tensile strengths being used. Geogrids with a strength of 90 kN/m were used in the bottom third of the embankment, 60 kN/m in the middle third and 45 kN/m in the top third. These geogrids were placed in a wrap around arrangement with a vertical spacing of 400 mm.

Secondary biaxial geogrids were placed between the main uniaxial geogrids to help maintain alignment of the embankment faces. These secondary geogrids were attached to the centre of each wrap around and had a penetration of 1 metre into the embankment.

A geotextile was placed inside the wrap around to keep the fill material in place.

Figure 1. Gravel facing for fire resistance.

Figure 2. Completed gravel facing.

3.3 *Lining*

The lining of the side of the embankment facing the waste, which will contain the leachate and gas in the landfill, will not be carried out until the monitoring of the embankment shows that settlement has mostly ceased. A temporary liner, 1 mm thick, has been placed on this face to protect it until the permanent liner is installed.

If some distortion of the face were to occur with the embankment settlement over this time, then it is thought that shotcrete could be used to smooth the face for the permanent lining.

3.4 *Resistance to grass fires*

In order to protect the side of the embankment facing away from the waste from the occasional hillside grass fires that occur in Hong Kong, a 100 mm thick layer of gravel was placed on this face. This was attached to the face using a steel mesh (see Figure 1).

The gravel is intended to keep the temporary heat of a moving grass fire away from the geogrids (see Figure 2). The thickness of the gravel was chosen based on the work of Austin (1997), and was confirmed with a rudimentary fire test.

It was recognised that the effect of fire on a reinforced fill embankment is unlikely to cause structural failure. The maximum tension in the geogrids is within the embankment, some distance from the faces, where the geogrids will be protected from fire.

Only the wrap around portion of the geogrid on the faces is likely to be affected by a fire. In this location, after settlement of the embankment, the geogrids are not in tension and their localised removal would not cause structural failure. However, the absence of this portion of the geogrid would cause a serviceability problem with time as the compacted fill material would start to escape from the face of the embankment.

Therefore, protection of the wrap around with a flexible gravel facing was thought to be prudent. It was thought that a shotcrete facing applied in the early life of the embankment would be too rigid and might crack as the embankment settled.

4 CONSTRUCTION

4.1 *Foundation*

Hong Kong soils are saprolitic in nature and relatively strong. During excavation for the base of the embankment, small areas of weaker soils were removed and replaced by a thin concrete foundation.

4.2 *Fill material*

The fill material was obtained from a nearby excavation within the landfill to increase the void space for waste.

The excavation was being carried out in a profile of saprolitic soils and igneous rocks. The saprolitic soils were encountered first in the excavation and some consideration was given to changing the design of the reinforcement to utilise these fine grained soils for the fill material. However, it was realised that the use of fine grained soils would increase the likelihood of unacceptable settlements of the embankment, especially if the fill became wet during placement.

It was then decided to use the igneous rock beneath. This was reduced in particle size as much as possible during the excavation blasting, and then the rock material was passed over a vibrating screen with a screen opening size of 40 mm. The material that passed through the screen was a remarkably consistent sandy gravel that was perfect for the construction of a reinforced fill structure.

4.3 *Geogrids*

In addition to the factory quality control of the geogrids, samples were taken on site for testing. These samples were tested for ultimate tensile strength.

Figure 3. Placing geogrids on a curved alignment.

Figure 4. Compaction and testing of fill material.

Interface friction tests were carried out for each of the three grades of uniaxial geogrids against the fill material in a large shear box.

Due to the variable curved shape of the alignment of the embankment, and the wrap around configuration of the geogrids at the faces, it proved to be an interesting exercise to place geogrids from one side of the embankment to the other (see Figure 3).

4.4 *Compaction*

The fill material was compacted using vibrating rollers. Heavier rollers were used in the centre of the embankment and lighter rollers near the edges.

Compaction control was achieved using a nuclear density gauge (see Figure 4). Due to the consistent nature of the granular fill, the required compacted density was consistently achieved.

In addition, this allowed a consistently good vertical alignment of the faces.

4.5 *Haul roads*

The construction of a 30 metre high reinforced fill embankment required considerable thought to be given

Figure 5. The embankment nearing completion.

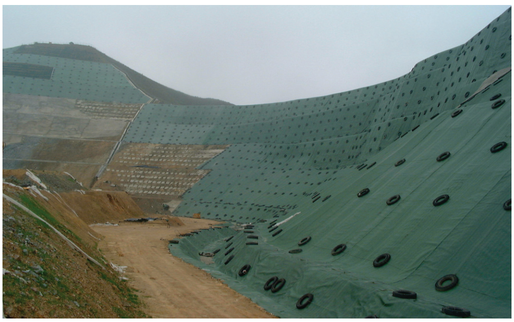

Figure 6. Completed reinforced fill embankment on the side facing the waste.

to how the fill material was to be transported to the narrow top without constructing another large temporary embankment alongside.

In addition, considerable thought had to be given to how the compaction equipment would be removed from the completed top of the embankment (see Figure 5).

4.6 *Safety*

Temporary scaffolding was installed on the faces of the embankment during construction to prevent workers from falling down the steep and high faces.

Permanent handrails are being installed on the benches on the side of the embankment facing away from the waste for the same purpose.

Figure 7. Completed reinforced fill embankment on the side facing away from the waste.

4.7 *Monitoring*

Monitoring of embankment movement has been carried out by standard surveying techniques. Due to the use of high quality granular fill, and good compaction during placement, very little movement has occurred.

5 CONCLUSIONS

The use of geogrid reinforced fill has proved to be a feasible method to increase the capacity of waste landfills in Hong Kong.

This paper has presented some practical aspects of the design and construction of a 30 metre high and 300 metre long embankment for this purpose. Figures 6 and 7 show the completed structure.

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