Proceedings of the 11th ANZ Young Geotechnical Professionals Conference – 11YGPC
Queenstown, New Zealand
25 – 28 October 2016

Design and construction of a commercial building on a closed municipal solid waste landfill in Takapuna, Auckland

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ABSTRACT

Ground engineering works on closed municipal solid waste landfills provide challenges beyond those related to construction on other brownfield sites within the urban environment. Design and construction of a multi-level commercial building on the closed Barrys Point landfill site in Auckland presented challenges for foundation design, durability, and mitigation of hazards (refuse, gas, and leachate) related to landfill material. Geotechnical inputs for the new building included deep-piled foundations and landfill gas protection measures. Engineering observation of construction for the gas protection measures was required to comply with stringent consent conditions. This paper describes challenges, during detailed design and construction of the new building, posed by the complex ground conditions on-site. The challenges included the development of pile installation methods that would not contribute to leachate migration, and construction of the passive landfill gas protection system. Permanent design features of the building includes deep-driven steel piles, and landfill gas mitigation measures entailing a specifically designed gas manifold system and a subfloor slab with high-density polyethylene (HDPE) geo-membrane to prevent ingress of landfill gas into the new building.

Keywords: solid waste landfill, construction, excavation, pile installation, leachate migration, landfill gas mitigation measures

1 INTRODUCTION

The four-storey commercial building (known as 3 Fred Thomas Drive), located inside the eastern margin of the former Barrys Point solid waste landfill in Takapuna, Auckland, is underlain by landfill material. The closed municipal Barrys Point landfill is managed by Auckland Council and authorised by a discharge permit held by the Council. Land development within the closed landfill site is relatively slow in comparison to its surrounding areas in the Takapuna suburb due to technical challenges and high expenses for construction on landfill. The location of the site is shown on Figure 1. The building has a ground floor footprint of approximately 1,350m^2, which consists of two specific areas (Areas 1 and 2). Area 1 (western half) includes a ground floor retail tenancy, whilst Area 2 (eastern half) is a parking area occupying the balance of the ground floor footprint.

Settlement of ground surrounding buildings has been observed on neighbouring properties, and ingress of high concentration landfill gas into the neighbouring structures (detected by landfill gas alarms installed) has historically been reported. The key objectives of the 3 Fred Thomas Drive development are to prevent damage to the building due to ground settlement and to eliminate landfill gas from leaking into the retail area.

Specific site investigations were undertaken in 2014 to define the site subsurface conditions for design of the deep pile foundations and the gas protection system. The investigations included geotechnical machine boreholes, environmental boreholes, and laboratory testing on soil and groundwater samples. Geotechnical challenges of this project involved the installation of driven steel H-piles to 30m depth on average, excavations of approximately 340m^3 into landfill material, and construction of a landfill gas mitigation system.

Construction of the new building was completed in April 2016. As part of the Auckland Council consent conditions, ongoing long term landfill gas monitoring is required to ensure there is no ingress of landfill gas to the retail area.

Figure 1. Location of the site (aerial photo sourced from Google Earth)

2 GEOLOGICAL SETTING

2.1 General Site Geology and Geomorphology

The geology of the site is Pleistocene materials (alluvial sediments) of the Puketoka Formation, overlying Waitemata sandstones and siltstone. The site and its surrounding area were used as a municipal solid waste landfill prior to the opening of the Auckland Harbour Bridge in 1959. Refuse landfill (depth various) was placed directly above the alluvial sediments. Limited information obtained from the Auckland Council closed landfill register indicated that a clay landfill cap may be in place.

The site is situated on the fringe of lava flows, which originated from the nearby Lake Pupuke. Highly compressible and soft Pleistocene age alluvial and estuarine muds and peats exist over the lava flows. During glacial periods of the Pleistocene epoch, sea level was considerably lower than present. The Shoal Bay stream, a tributary of the ancestral Waitemata River, initially cut down deeply into the underlying Waitemata Group. Pleistocene silts and peats were later deposited as valley fill, leaving alluvial terraces. The valley was flooded by the sea as it is today, during inter-glacial periods.

2.2 Subsurface Conditions

The subsurface conditions were confirmed by the specific field investigations. Refuse landfill was generally encountered to approximately 6.5m depth below existing ground surface. The clay landfill cap, to variable depths, was only encountered at some test locations, indicating the capping layer is not consistently placed across the site. Firm alluvial sediments of the Puketota Formation were identified beneath the landfill to approximately 30m depth, overlying alternating layers of completely to moderately weathered Waitemata sandstone and siltstone.

Laboratory testing was carried out for contamination on soil and groundwater samples recovered from the landfill layer. The high concentrations detected from the selected chemicals (i.e. sulphates, heavy metals, etc.) would pose severe corrosion on piles and risk to construction workers.

3 LANDFILL GAS HAZARD

Landfill gas alarms were previously triggered in the neighbouring properties due to ingress of landfill gas. In order to assess the landfill gas level within 3 Fred Thomas Drive, gas readings were recorded from the environmental boreholes on completion of drilling using a portable landfill gas analyser (GA5000). The gas readings indicated that the landfill refuse was still producing landfill gas. Landfill gas is considered a high level health and safety hazard. It could migrate into structures in numerous ways, including via minor cracks in the concrete slab and services. Accumulated landfill gas in a confined space may trigger an explosion or caused an asphyxiation hazard risk.

4 DESIGN PHILOSOPHY AND FEATURES

4.1 Pile Foundation and Installation Methodology

The landfill materials and firm alluvial sediments are compressible and have high settlement characteristics. Deep driven steel UC piles, founded within the Waitemata Group sandstones/siltstones, were adopted to prevent damage to the building due to ground settlement. Driven steel piles, in this instance, had the advantage that they could be constructed relatively quickly, significantly reducing drilling spoil from pile holes, and minimising cross contamination between the landfill layer and the natural ground. Main challenges encountered during development of the pile installation methodology included the collapse of the pile hole within the landfill layer, removal of the refuse obstructions during driving, and preventing leachate migration.

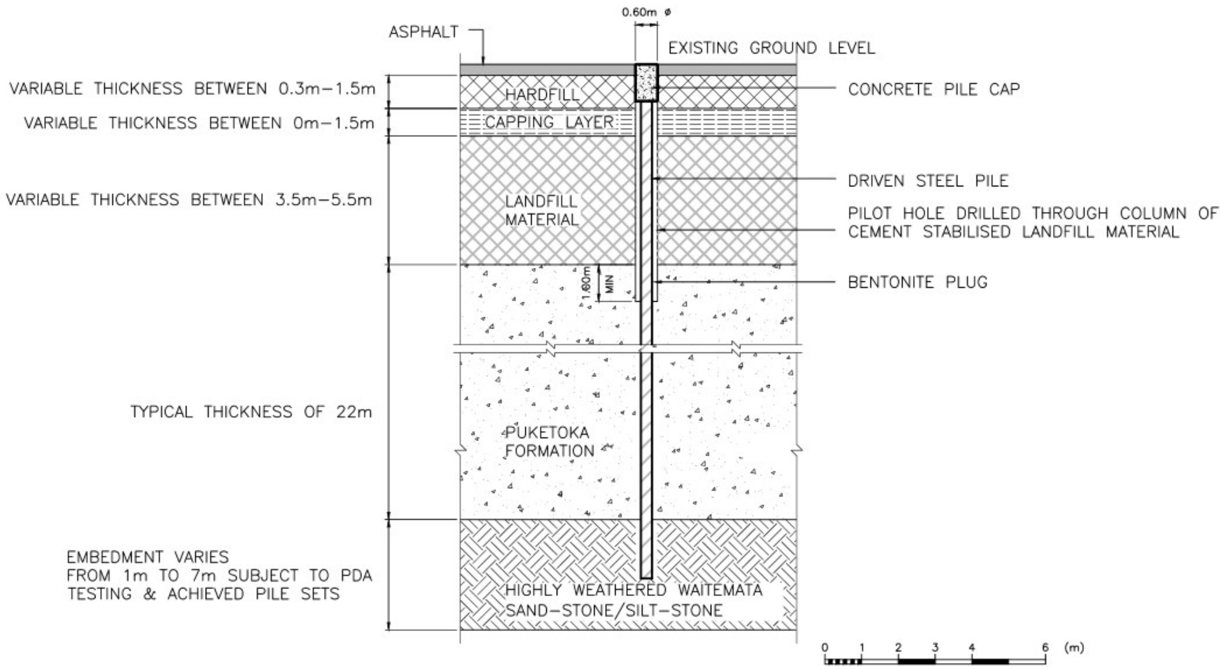

Figure 2. Typical pile cross section

In consultation with the piling contractor, an installation methodology combined of pre-drilling and driving was developed. All pile holes were pre-drilled to approximately 1m depth into the natural ground beneath the refuse (i.e. approximately 7.5m depth below the existing ground surface), and backfilled with low-strength concrete. This methodology not only provided a solution to the challenges, but also prevented both leachate entering the natural soils, and landfill gas escaping into the construction site. A smaller diameter pilot hole was then augered through the low-strength concrete to the bottom of the backfill. The steel H-pile was lowered vertically into the pilot hole, and driving commenced at 7.5m depth below ground surface. Figure 2 presents a typical pile cross section.

The foundation design involved 39 driven steel H-piles of varying size and length. The pile size ranged from 310 UC158 to 200 UC46, and extended to an average of 30m depth below the existing ground surface. All piles were connected by a network of ground beams to resist lateral loads. Pile corrosion was addressed by allowances in steel thickness for uncoated steel and coating protection systems.

The upper portion of each pile, approximately 10m in length was then painted with a high performance epoxy coating to provide protection against severe corrosion within the landfill layer. A minimum of 100mm cover of the low-strength concrete backfill was allowed around the steel piles over the pre-drilled depth to further minimise corrosion. In addition, pile driving analyser testing with CAPWAP analysis was undertaken on approximately 15% of the piles.

4.2 Landfill Gas Protection Measures

Results recorded during field investigations indicated the landfill refuse continued to produce gas. As the building and the Area 1 (retail tenancy) ground floor slab are supported on piles, ongoing settlement within the underlying landfill layer will potentially develop a void, allowing landfill gas to collect immediately beneath the building slab. Given the landfill gas hazard outlined in Section 3, it was important that a specifically designed passive venting system was constructed beneath the building to collect and discharge the landfill gas at safe locations.

The landfill gas protection measures beneath Areas 1 and 2 were designed differently. Area 1 includes a closed space retail tenancy (Area 2 is an open air car park building), hence, a more complicated passive ventilation system to fulfil the stringent consent conditions was required. This paper focuses on the design features of the Area 1 system.

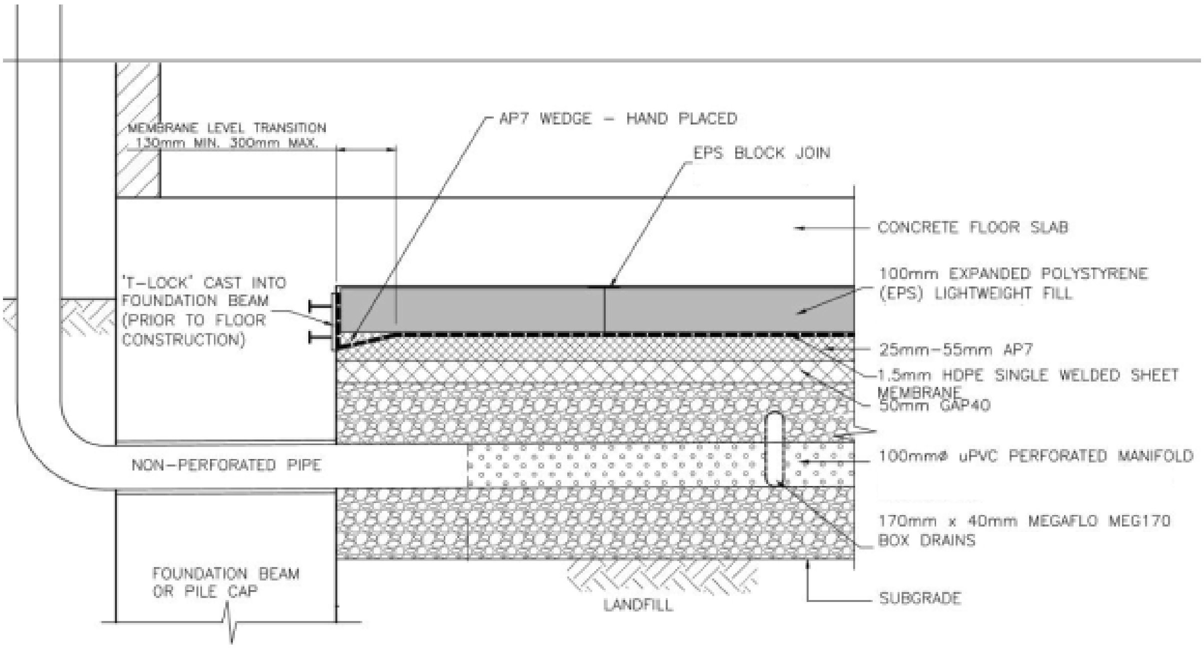

Figure 3. Typical details of Area 1 passive ventilation

Design of the Area 1 gas protection system includes a continuous subfloor passive gas collection network and an intact gas resistant HDPE membrane beneath the ground floor slab. The gas collection network consists of perforated manifold pipes, falling at a gradient of 0.5% towards vent stacks located between Areas 1 and 2. Box drains, connected perpendicularly to the manifold pipes at regular intervals, are incorporated into the design in order to maximise the area of influence. The manifold system is buried within a layer of granular materials, which provides a pathway for the landfill gas to migrate into the system. The landfill gas is directed and discharged via rotary ventilators on the building's roof. The HDPE membrane was placed above the granular layer. The membrane was designed to be welded to polyethylene brackets ('T-locks') that were pre-casted into the foundation ground beams. Figure 3 shows typical details for the gas membrane and subfloor passive ventilation within Area 1.

5 CONSTRUCTION

5.1 Excavation in Landfill

Floor levels were positioned to minimise excavation into the refuse. However, due to the highly variable thickness of the landfill cap (which is not consistently in place across the site), it was difficult to predict the volume of excavation into the refuse during ground works. Large amounts of refuse, consisting of bottles, glass, metal pieces, plastic, etc., along with a strong odour were encountered during site excavations – refer Figure 4(a) and (b).

Regular observations were undertaken by a Geotechnical Engineer during ground excavations, and geotechnical comments on the stability of trench excavation within soft refuse were provided. Where issues or conflicts arose between consented design and its constructability/excavatability, practical and cost-effective solutions were provided to the contractor.

(a)

(b)

Figure 4. (a) Excavation within landfill; and (b) Landfill refuse observed

As part of the consent conditions, personnel working in the landfill materials were required to wear chemical resistant gloves and overalls to reduce potential contact with contaminated materials. To further minimise the landfill gas hazard, personnel was also required to wear portable gas monitors at all time during landfill excavation and pile installation. Electric fans were positioned near the landfill excavation areas to provide ventilation during excavation. Excavated materials were removed off-site as soon as possible and disposed at a licensed waste facility. Any surface water or groundwater that came into contact with refuse was treated as leachate and was removed off site, under instructions of the Engineer, by a sucker truck.

5.2 Installation of Gas Manifold System and HDPE Membrane

The subgrade for the gas manifold system was prepared by removing all sharp objects on the surface and proof-rolling. On completion of the subgrade preparation the manifold pipes were assembled within individual foundation compartments (divided by ground beams). To accommodate the slight difference in size and shape of each compartment, the length and space of the drains and pipes were adjusted on-site, under the instruction of the Engineer. Figure 5(a) shows a typical alignment of an assembled manifold system, prior to placement of the granular venting layer. The top blinding layer was hand placed to ensure a smooth finishing surface for the HDPE membrane.

The HDPE membrane was installed by a specialist contractor under full time observation of the Engineer to ensure the manufacturers' requirements for the gas membrane were correctly adopted and the membrane was undamaged. Extrusion welding, a technique that 'glues' HDPE materials together by using hot polyethylene, was utilised to weld the HDPE membrane to the T-locks. Quality control, via spark testing (electrical current passed though copper wire to generate spark), was undertaken on completion of membrane placement within each compartment, to detect if there were any unsealed/damaged spots.


(a) *(b)*

Figure 5. (a) Gas collection network; and (b) Placement of HDPE membrane

It was noted by the Engineer that the membrane (which had been installed and tested) was regularly damaged by site personnel. Frequent repair (in conjunction with re-testing) of the membrane was time consuming and could reduce the performance of the gas membrane. Following numerous discussions with the site contractor, placement of blocks of expanded polystyrene (EPS) lightweight fill on top of the membrane was considered the most practical solution to prevent further damage – refer Figure 6(a). The lightweight fill blocks were closely butted and taped to further minimise physical contact with the HDPE membrane, as shown in Figure 6(b). Subsequently the HDPE membrane remained undamaged.


(a) *(b)*

Figure 6. (a) EPS fill on HDPE membrane; and (b) Closely taped EPS fill

6 CONCLUSION

The new multi-storey commercial building at 3 Fred Thomas Drive, Takapuna has been constructed on a closed solid waste landfill. The building is supported on driven steel H piles to approximately 30m depth below ground surface to prevent damage to the structure due to ground settlement. A specially developed pile installation methodology was adopted, and landfill gas protection systems were constructed beneath the building subfloor to prevent migration of leachate and ingress of landfill gas into the new building. Construction was completed in April 2016.

7 ACKNOWLEDGEMENTS

The author wishes to thank Arthur Amputch, Technical Director at Riley Consultants Ltd for providing information and technical support, and Smales Farm Management Ltd for permission to publish this paper.