WICK DRAIN APPLICATION FOR ONE DIMENSIONAL CONSOLIDATION, GULF HARBOUR MARINE VILLAGE, WHANGAPARAOA

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SUMMARY

During the summer of 1994/95, approximately 80,000 metres of geosynthetic wick drains (Colbond® EX1000) were installed at the Gulf Harbour Marine Village, Whangaparaoa. This was undertaken to accelerate the consolidation settlement of large areas containing up to 9 metres depth of soft to very soft estuarine and alluvial deposits overlying sandstone/siltstone bedrock at depth. This paper outlines the site geology and geotechnical considerations of the project, together with assessing predicted versus actual performance.

INTRODUCTION

Situated on the southern side of the Whangaparaoa Peninsula, some 45 minutes drive north of Auckland City, Gulf Harbour is one of the largest subdivisional developments in New Zealand. Apart from considerable residential development, it involves the extension of an existing marina and construction of a new boat harbour, marine village and town centre situated around a canal development, hotel, international 18 hole golf course and man-made lakes for irrigation.

As part of the marine village/town centre development, extensive areas of underlying saturated estuarine deposits needed to be rapidly consolidated to allow for programmed construction of residential/commercial buildings within six to eighteen months of the completion of preload earthworks and to reduce the liquefaction potential of the substrata.

Final design levels for the marine village allowed for approximately 2.5 metres depth of compacted clay filling ("structural blanket filling") with varying depths of additional preload to accommodate expected settlement.

SITE INVESTIGATION AND GEOLOGY

Extensive investigations involving machine drilling and sampling, trial pit excavations and cone penetrometers (CPTs), combined with a detailed geological assessment, review of similar projects overseas and extensive laboratory testing was undertaken throughout 1992 and 1993 as part of the marine village project. Strata beneath the marine village area were categorised into five types as outlined below:

(i) Wind blown sand deposits - loose, fine and uncompacted, up to 1.8 metres thick, with scattered bands of shell.

(ii) Estuarine silts - soft to very soft, generally non-plastic to slightly plastic with some sand, shell and organic inclusions. Shear strengths ranged between 6 and 22 kPa, Mv and Cv values averaging 1.21 m^2/MN and 7.6 m^2/year respectively under loadings up to 60 kPa.

(iii) Alluvial silts and/or highly weathered residual Waitemata Group soils - soft to very stiff, non-plastic to very plastic orange/brown/blue/grey/green clayey silts and silty clays up to 5 metres thick. Average Mv and Cv values were 0.37 m^2/MN and 60.3 m^2/year respectively, shear strengths ranging from 18 to greater than 140 kPa.

(iv) Underlying Waitemata Group sandstone/siltstone - very weakly to well cemented, weak to strong, dark grey alternating sandstone and siltstone with unconfined compression strengths from 2 to 25 MPa.

(v) Construction spoil fill - originating from the original marina construction. End tipped or hydraulically pumped, loose, mixture of sands, silts, sandstone and shells.

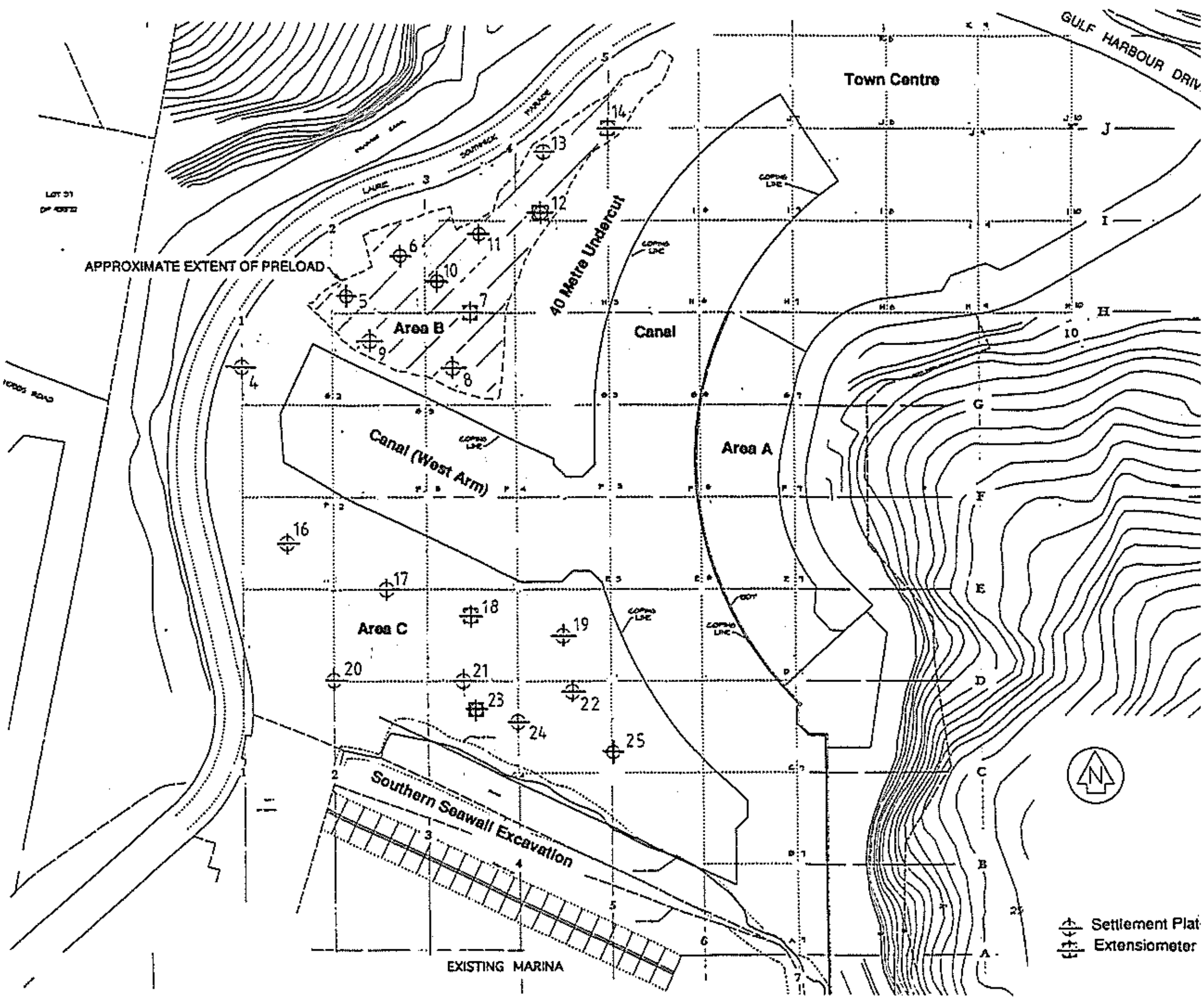

Figure 1: Layout Plan of the Gulf harbour Marine Village

DEVELOPMENT PROPOSALS AND REMEDIAL OPTIONS

Final development levels for Areas B and C, on the western side of the proposed canal (refer Figure 1), called for approximately 2.5 metres depth of clay filling to be placed over up to 9 metres of type (ii) and (iii) soils. Preliminary scheme proposals for these areas indicated that they were likely to contain two to three storeyed residential buildings and related services, resulting building loads being limited to around 20 kPa by means of raft foundations and careful foundation design.

In order to provide suitable conditions for such development, several remedial and construction options were considered, including:

(a) Deep compaction: This option was discounted due to the very soft and non-granular nature of many of the substrata. It was felt that the compactive effort would have been largely wasted in pushing aside the soft materials rather than providing compaction.

(b) Full Removal of Soft Strata: This option was utilized for one area of the development known as the 40 metre undercut (refer Figure 1), to ensure good foundation conditions for programmed building within a short period, in case preload settlements did not proceed as quickly as expected. It was considered too expensive for large-scale use.

(c) Partial Removal of Soft Strata: The partial replacement of some soft materials with better quality engineering filling was not considered adequate due to the long-term effects of consolidation settlement within remaining strata, particularly in relation to the provision of services and roading accessways.

(d) Foundation Piling: Piling without addressing long term services settlement was considered inappropriate. Additional complications would have been created by negative skin friction acting on the piles.

(e) Wick Drains: As previously shown, the compressibility of types (ii) and (iii) soils was high. Initial calculations showed that some areas could take up to 18 years to reach 90% of total primary consolidation. However, with the provision of vertical wick drains and 1 to 1.5 metres of preload filling (plus structural fill) it was calculated that this consolidation could be achieved within 6 months over Area B and 12 to 18 months over Area C depending upon wick drain spacing.

Finalised wick spacings were 1.7 metres on Area B with 2.2 metre spacings used on Area C. As works progressed it became apparent that Area C could not be preloaded as quickly as expected and spacings were reduced to 1.7 metres to provide for more time flexibility when full preload was achieved.

CONSTRUCTION

For the Gulf Harbour contract, COLBOND® CX1000, 100mm wide, 6mm thick, wick drain was selected. As with similar synthetic wick drains, it contains a stiff, porous drainage core wrapped in a heavy duty, fine-pored filter membrane, the stiffness of the core being relied upon to provide a competent vertical drainage path, while distorting as settlement occurs.

Installation of the wick drains commenced in mid November 1994 and continued as required until mid January 1995 on Areas B and C. Placement of the drains was carried out using a 27 tonne hydraulic excavator installing two drains simultaneously at the desired spacing on a wide weed bucket.

After installation, the drains were linked together with additional Colbond® laid out on the surface to form a drainage network. Collector drains approximately 300mm deep at 24m centres were constructed over the area, into which the wick drain network was fed. The entire area was then covered with a 300mm to 500mm deep sand layer (Type (i) soil) to help provide a drainage blanket and also to prevent damage from earthmoving machinery.

Along with the installation of settlement monitoring instrumentation, certified filling was won from the nearby boat harbour excavation and other site borrow areas and placed on the affected areas between January and June 1995. Subsequently, as preload material became available from the nearby southern seawall excavation, it was placed throughout June to August 1995 on Area B. However, due to deteriorating weather conditions, certified filling and preload works were not able to be completed during the 1994/95 earthworks season.

SETTLEMENT MONITORING

Prior to filling, 20 settlement plates and 4 vertical magnetic extensiometers were installed on the site in the locations shown in Figure 1. Although expensive and difficult to install, the extensiometers were expected to provide better quality results than the settlement plates especially in establishing differing settlement rates of Type (ii) and (iii) soil. Settlement monitoring was subsequently carried out on a fortnightly basis, commencing in late November 1994. Vertical extensions to the monitoring devices were constructed as, firstly certified filling and later preload filling were placed.

RESULTS

Results available at the time of preparation of this paper, indicate that on the whole, both the rate and degree of consolidation settlements occurring in the field are comparable with the predicted results.

Of the twenty four settlement monitoring points installed, five have been either temporarily or irreparably damaged, while a further two have been buried beneath a topsoil stockpile for much of the time. However, results from the remaining sites show that, in the ten months since the commencement of monitoring on Area B, maximum settlements have been in the order of 550 mm, at extensiometer plate 7, the predicted settlement having been in the order of 500mm in this locations for 55 kPa certified fill loading plus 45 kPa surcharge loading. In addition, the settlement curves relating to settlement plates 10 and 13 indicate that much of the primary consolidation has already occurred in the few months since the completion of preloading.

Area B			PLOT		
Plate 10			Sink	Rate	
N729,116.83	E302,159.88		Total mm	mm/day	Fill RL
	Total Days	Plate RL			
6/1/95	0	0.417	0		
24/3/95	77	0.279	138	1.79	2.97
4/4/95	88	0.270	147	0.82	
11/4/95	95	0.261	156	1.29	3.50
8/5/95	122	0.238	179	0.85	3.50
14/6/95	159	0.218	199	0.54	3.50
24/7/95	199	0.178	239	1.00	4.26
7/8/95	213	0.170	247	0.57	4.70
21/8/95	227	0.161	256	0.64	4.70
4/9/95	241	0.160	257	0.07	4.70
18/9/95	255	0.158	259	0.14	4.70
3/10/95	270	0.156	261	0.13	

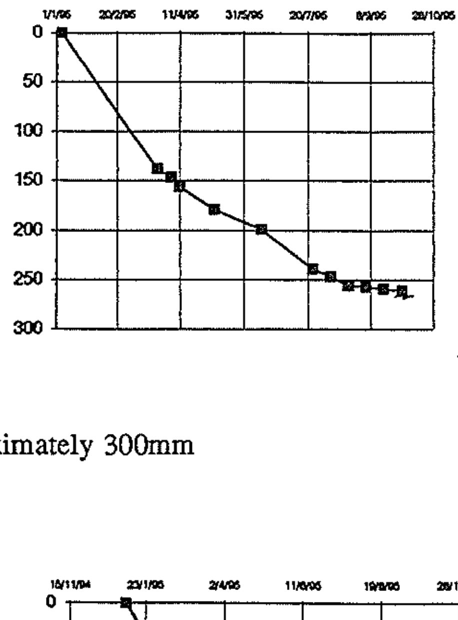

Plate 10: Total Predicted Settlement Approximately 300mm

Area B			PLOT		
Plate13			Sink	Rate	
N729,185.32	E302,227.68		Total mm	mm/day	Fill RL
	Total Days	Plate RL			
6/1/95	0	0.378	0		
4/4/95	88	0.203	175	1.99	
11/4/95	95	0.197	181	0.86	3.00
8/5/95	122	0.166	212	1.15	3.20
14/6/95	159	0.127	251	1.05	3.60
24/7/95	199	0.092	286	0.88	4.17
7/8/95	213	0.083	295	0.64	4.30
21/8/95	227	0.080	298	0.21	4.30
4/9/95	241	0.079	299	0.07	4.30
18/9/95	255	0.079	299	0.00	4.30
3/10/95	270	0.076	302	0.20	

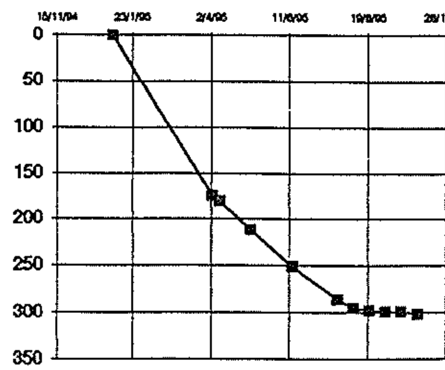

Plate 13: Total Predicted Settlement Approximately 300mm

Given the large degree of error generally associated with consolidation settlement prediction, these results have shown an encouraging degree of consistency and in some areas, settlement has occurred at a faster rate than expected. Several reasons have been mooted for the faster than expected settlements. Firstly, Mv and Cv values were conservatively used for calculations, rather than MH and CH. In addition, horizontal sand lenses within the natural deposits. are likely to have provided shorter drainage paths than those used in design. Thirdly, the lowering of the general watertable as a by-product of the adjacent canal excavation and construction works would have allowed for more rapid consolidation.

Consolidation monitoring of the site will continue during the removal of surcharge and the construction of buildings, services and accessways. This is due to commence on Area B in March 1996. However, as filling and preloading was not completed on Area C during the 1994/95 earthworks season, further work will need to be undertaken during the 1995/96 season to achieve the required settlements.

CONCLUSIONS

During the construction of the Gulf harbour Marine Village, the use of vertical wick drains in conjunction with preloading to achieve rapid consolidation settlements has been found to be both effective and economical in conditions of soft, wet estuarine silts and clayey silts, overlying competent bedrock at shallow depth. As a result, development times have been reduced, enabling construction date targets to be achieved and resulting in faster capital returns for the developers.

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