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Settlement Behaviour of Deep Fill For Housing Development, Niddrie, VIC

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SETTLEMENT BEHAVIOUR OF DEEP FILL FOR HOUSING DEVELOPMENT VALLEY LAKE, NIDDRIE, VICTORIA

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1 INTRODUCTION

This paper describes our experience of processing and placing about 2.4 million cubic metres of stockpiled overburden fill into a former basalt quarry in Niddrie, Victoria.

The project encompasses many geotechnical challenges including the development of a strategy to engineer a fill platform using material varying from high plasticity basaltic clays to weathered basalt rock with boulders up to 2m in size. Critical to the residential housing development is the settlement behaviour of the engineered fill, particularly with regard to the performance of shallow footings founded on a fill thickness of up to about 35m.

At the time of preparation of this paper about 85% of the 2.4 million cubic metres of the stockpiled fill has been processed and placed back into the former quarry since the commencement of the project in April 2002. Settlement monitoring in some parts of the project commenced in July 2002. An overview of the trends of the settlement data so far is provided later in this paper.

The site is located on the western side of Steele Creek, a tributary of the Maribyrnong River, and is approximately 1.5km south of the Essendon Aerodrome. The site is 10km north-west of Central Melbourne, accessed via the Calder Freeway. Figure 1 below is an aerial photography of the site taken in 1989.

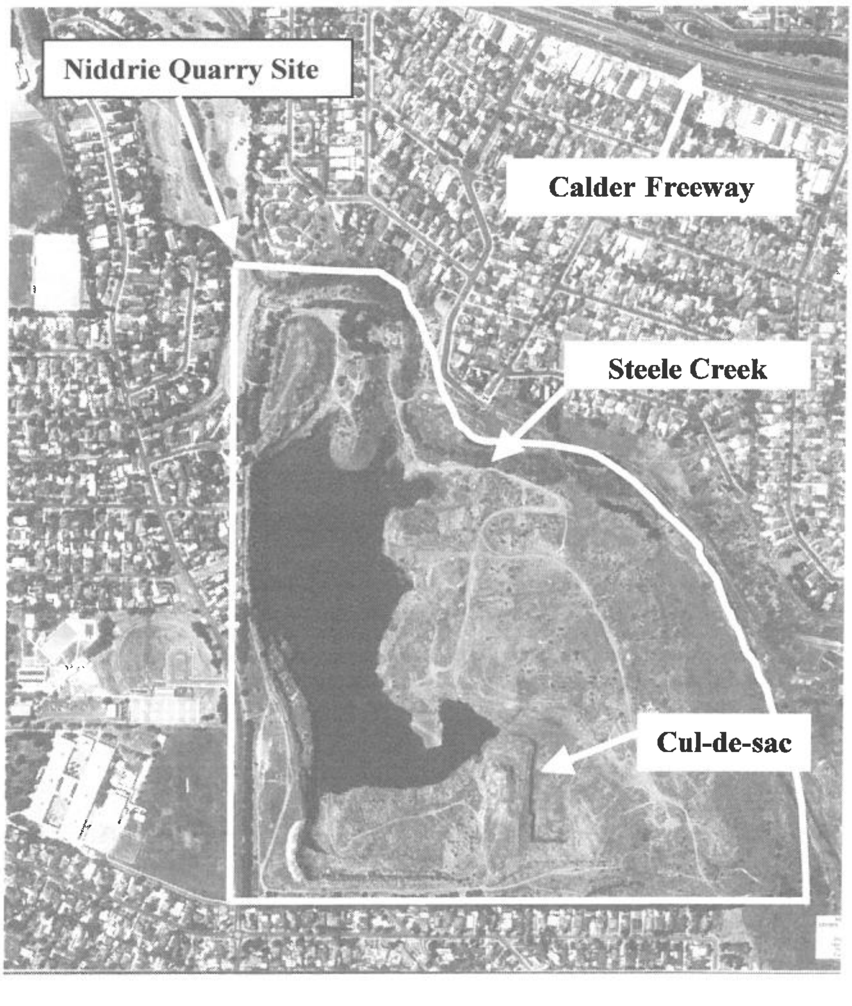


Figure 1 Aerial Photograph, 1989

2 DETAILS OF THE OLD QUARRY

The former Niddrie Quarry site covers a total area of approximately 48.4 ha, and of this the quarry hole is approximately 11 ha. The depth of water in the base of the quarry, prior to the development earthworks, was up to about 8m. At the completion of the quarrying operation about 2.4 million cubic metres of waste overburden material had been left around the edges of the former quarry hole in stockpiles up to 30m thick. Along the western edge of the quarry lake is a sheer basalt rock face, approximately 30m to 40m high. Existing residential properties are located some 10m to 20m from this western edge of the quarry hole. Figure 2 below shows a view of the old quarry hole looking south, just prior to the commencement of the earthworks.

Figure 2 View South

3 GEOLOGICAL SETTING

The surface geology of the quarry site is Quaternary age basalt known as the "Newer Volcanics", which has been established to be up to about 50m thick within the quarry area. This basalt overlies thin irregular Tertiary age deposits which in turn overlies Silurian age sedimentary mudstone, siltstone and sandstone, being the bedrock for the Melbourne region.

The basalt rock in the quarry is considered to comprise three distinct rock types. From the surface the profile comprises an ash like tuff, then weathered vesicular basalt and beneath is the massive columnar basalt which was the target for the quarrying operation. A variable thickness of residual basaltic clays of high plasticity were also found to overlie the weathered basalt rock in some parts of the site.

The stockpiles around the site generally contained the residual clays and the more weathered basalt rock overburden materials.

4 DEVELOPMENT PROPOSAL

In late 2000 the Urban and Regional Land Corporation (URLC) purchased the Niddrie Quarry site. After considering a number of options the URLC developed a vision for turning the existing disused quarry into a vibrant and modern housing development. This project is considered to be Australia's largest ever quarry rehabilitation project.

The URLC proposal is for a residential development whilst keeping approximately 30 percent of the site as open space. The key principles for the development include:

- Retention of Niddrie Lake
- Rehabilitation of the Steele Creek environment, abutting the east boundary
- Retention and reuse of materials on-site
- Minimal importation of materials

Plans have been developed for a total of 431 lots. This includes 376 conventional residential lots generally on the southern and eastern portions of the site. A number of medium density lots and a number of superlots for apartment development will also be made available. Figure 3 below shows a schematic plan of the proposed development.

Figure 3 Proposed Development Plan

The URLC, in consultation with their design team, assessed the critical aspects of their proposed development and how they might be addressed. Through various stages of planning and refinement of ideas, it was proposed to backfill the quarry, in part, using only the existing overburden materials and grading the surface of the fill down to the lake. The lake will be filled naturally by groundwater, and will form the centrepiece of the development.

5 GENERAL DESIGN PHILOSOPHY FOR ENGINEERED FILL

The design surface profile for the residential development was prepared in consideration of;

- The amount of available fill;
- The aesthetics of the site topography (in particular the need to maintain the lake as the prime focus);
- The maximum practical surface grades that could be tolerated;
- Maximising the area of residential lots founded on natural ground.

6 GEOTECHNICAL INVESTIGATION AND TESTING PROCESS

6.1 ASSESSMENT OF THE FILL MATERIALS

A number of geotechnical investigations of the materials in the fill stockpiles have been undertaken by Golder Associates and various other parties over the past 15 or so years. The fill material varied across the stockpiles but generally consists of a mixture of clay, sand and gravel, with basalt cobbles and boulders ranging in size generally up to about 2m maximum dimension.

Borehole investigations were inappropriate given the nature of the fill. Early investigations prior to the URLC purchase of the site involved test pits and trenches using large excavators. However, the maximum test pit depth was about 7m compared to a stockpile depth of up to 30m in parts.

Supplementary investigations were performed by Golder Associates and involved the excavation of test pits up to 16m deep. These investigations were conducted to allow the project team and potential earthworks tenderers to physically observe the materials to a greater extent than previously. The supplementary test pits were to a much greater depth than previously investigated and consequently the percentage of the stockpile investigated in terms of its thickness was significantly greater than all previous investigations, (that is, 60% compared to about 20% previously).

In summary, the fill materials encountered in about fifty test pit excavations across the various fill stockpiles typically comprised an average of about 35% to 40% of oversize material (ie. > 100mm particle size). A wide gradation of particle sizes was observed ranging from silt/clay to sand, gravel, cobbles, boulders and rock pieces up to 2m in size. In the main the fill stockpile material was described as a Clayey Sandy Gravel with cobbles and boulders throughout.

6.2 STRUCTURAL FILL MATERIAL TYPES

In consideration of the general nature of the available fill materials on the site, and of the type of residential development proposed, different fill zones were defined. For low rise residential areas where buildings will be supported by the fill, it was considered essential that at least the top zone of the fill comprise a well compacted high quality engineered fill. This is the zone in which excavation works for roads, services, retaining walls, building footings, batter slopes and other related excavations will be performed. This fill needed to be of a perceptually higher quality than the underlying fill. Material placed in this zone was designated as Type A Fill.

The limits of grading adopted for the Type A Fill are defined as:

- Maximum Particle size of 100mm.
- Not more than 30% exceeding 50mm particle size.
- Not more than 15% less than 0.075mm particle size.

This gradation was assessed visually during placement and by sampling and sieve testing.

Beneath the Type A Fill a coarser grade of fill was allowed. The material class for this zone was designated as Type B Fill with a nominal maximum allowable particle size of 600mm. The Type B Fill cannot be tested for compaction by conventional methods due to its coarse grading, so compaction of this material was judged predominantly by visual assessment and verification that the specified method placement had been strictly adhered to. The method specification established was based on the results of compaction trials performed prior to the commencement of the works. The low tolerance on clay content in this zone was for the purpose of reducing the potential for long term consolidation settlement.

The limits of grading for the Type B Fill material are defined as:

- Maximum Particle size of 600mm.
- Not more than 25% exceeding 300mm particle size.
- Not more than 15% less than 0.075mm particle size.

The material gradation was assessed visually during the placement and spreading process. It was also considered important that the compacted Type B Fill be free of voids to minimize the potential for the migration of fines due to subsequent saturation.

There are several areas in the development where higher level medium density housing is proposed. In such areas it is considered unlikely that the buildings will be able to be founded directly on the engineered fill due to their higher footing loads and the associated risk of excessive differential settlement. In these areas a third type of structural fill was specified. This fill is designated as Type C Fill.

The Type C Fill was designated to have a nominal maximum particle size of 200mm. This maximum particle size was derived in consultation with piling contractors so that conventional piling methods could be used to penetrate the fill in order to found piles on the natural ground beneath. The Type C Fill was placed under a method specification similar to Type B Fill. However, on the whole, the Type C Fill has been testable using conventional compaction testing methods.

The limits of grading for the Type C Fill are defined as:

- Maximum Particle size of 200mm.
- Not more than 30% exceeding 50mm particle size.

This grading of the Type C Fill was assessed during placement visually, and by sampling and sieve testing.

The Type C Fill may also comprise predominantly clay, as some long-term consolidation settlement of this zone could be tolerated, given that the building will be supported on piles and the maximum thickness of Type C fill to be placed is less than 10m. The clay fill had to be utilized somewhere on the project, and its potential for adverse impact as an engineered fill was considered least in this fill zone.

6.3 TRIAL PAD CONSTRUCTION

Prior to the commencement of earthworks a trial compaction pad was constructed to allow the project team and potential tenderers to observe the processes of blending, conditioning, placement and compaction of the engineered fill. The trial pad was used to demonstrate a method of construction which would be suitable and acceptable for the bulk earthworks project. It was a possibility that the successful tenderer for the bulk earthworks contract may propose alternative methods to those used in the trial fill. However, the trial operation was to provide tenderers with a basis to assess the aims and requirements of the earthworks design.

Different processes were trialed in the spreading, mixing, compaction and moisture conditioning of the fill materials. Variations were made in the layer thickness and the amount of compaction applied. Assessment of the trial pad was based on:

- precise level survey of a grid of points across the pad with levels taken after every second roller pass;
- visual inspection of slots excavated through each lift of the pad to observe the material grading, voidiness and compactness throughout the layer;
- sampling of the fine fraction of the material (<19mm) and testing for moisture content compared to Standard Optimum Moisture Content;
- proof rolling of the surface of each lift to check stability. A total of 3 lifts were completed during the trial.

In conclusion, the preferred placement method as a result of the trial was:

- placement of the Type B Fill in two nominal 0.5 m thick layers using tracked machinery;
- moisture conditioning the minus 19mm fraction to between SOMC to 3% DRY of SOMC;
- rolling at the top of the combined 1m thick lift with a minimum of 8 passes of an 18 tonne vibrating smooth drum roller or equivalent.

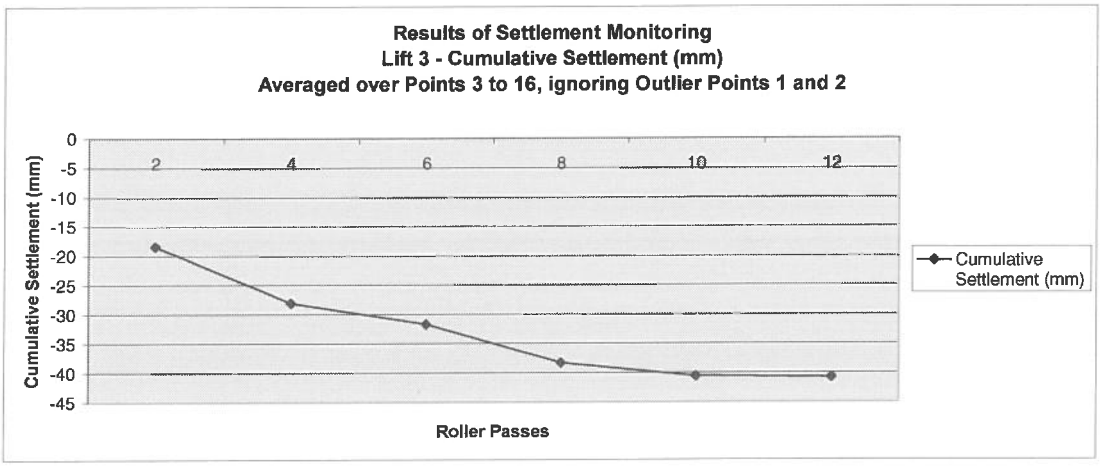
This placement method was altered following the award of the contract. The successful contractor undertook further trials which resulted in our accepting an alternative placement method that is:

- placement of Type B Fill in two nominal 0.5 m thick layers;
- moisture conditioning the minus 19mm fraction to between SOMC to 3% DRY of SOMC;
- rolling each 0.5m layer using a static multi-wheeled 825C Compacter with a minimum of 4 passes of each 0.5m layer to achieve a maximum 1m thick lift.

Figure 4a shows the trial pad with settlement points marked by paint. Figure 4b shows the adopted spreading and compaction method.

Figure 4a Trial Pad **4b Fill Placement and Compaction**

Figure 5 is an example of the results of settlement monitoring of one lift of the trial pad. The results demonstrate that further settlement of the 1m lift was negligible once 8 passes of the vibrating roller was reached.



Roller Passes	Cumulative Settlement (mm)	Cumulative % Complete
2	-18	45%
4	-28	69%
6	-32	78%
8	-38	94%
10	-41	99%
12	-41	100%

Figure 5 Trial Pad Settlement Monitoring

7 STRUCTURAL FILL DESIGN

7.1 SETTLEMENT CONSIDERATIONS

In general terms, the more densely compacted fill is, the lower its compressibility, or tendency to settle under its own weight or under an applied load. However, high levels of compaction are achieved by control over the spreading, moisture conditioning and compaction process.

If a reasonable minimum relative compaction is not achieved the potential exists for collapse settlement due to migration of material into voids, or as a result of saturation. The consequences of such settlement if it occurs after development would be serious. Similarly, if the fill contains materials that may decompose or dissolve, unacceptable settlements may occur. Selection of suitable sources of fill was therefore very important.

For predominantly granular fill, as exists for the majority of the fill materials on the site, which is subject to a reasonable level of compaction, the rate at which settlement occurs will diminish over time. Subject to an acceptable delay between fill placement and subsequent development this diminishing rate of settlement can be used to advantage in selecting the level of compaction applied. The higher the achieved relative compaction in the fill, the less delayed settlement that will occur and therefore the sooner an acceptable rate of settlement will be achieved.

Predicting the amount and rate of settlement of fill is difficult, especially where variable fill materials are used. Laboratory studies on expected typical fill materials can assist. However, for deep fills, with coarse rock included, settlement monitoring of the completed fills is considered to be essential in order to obtain an understanding of the performance of the as-placed materials as it relates to the timing of planned development.

In consideration of the long-term settlement of the fill and the recommendations given in the Australian Standard AS 3798 "Guidelines on Earthworks for Commercial and Residential Developments", minimum compaction levels for the Type A and Type C Fills were selected. The acceptance of the compactness of the coarser Type B Fill was based on the method specification established as a result of field trials. The adopted compaction limits and maximum layer thicknesses for each structural fill type were as follows:

Table 1 Compaction Limits

Structural Fill Type	Minimum Dry Density Ratio (in accordance with AS1289.5.4.1)	Maximum layer Thickness (Compacted)
Type A Fill	98% Standard	0.3m
Type B Fill	Not Applicable	1.0m (2 x 0.5m)
Type C Fill	95% Standard	0.5m

It should be noted that:

- Settlement of the Type A, B and C Fill materials could not be accurately assessed prior to placement due to the placement method being adopted, particularly for that of the Type B Fill where up to 0.5m thick lifts were adopted.
- The settlement is influenced by the composition of the Type B Fill, in particular the proportions of boulders, cobbles, gravel, sand, clay and silt in the fill material.
- The settlement is expected to be influenced to some degree by groundwater conditions. It is anticipated that some increased settlement of the fill material will occur when it becomes saturated, as the groundwater level recovers over time.
- The amount of settlement is influenced by the thickness of the fill material.

Confidence in the expectation that the rate of settlement should be sufficiently small to allow release of some lots within a relatively short time after completion has been increased following the trial fill pad constructions, the stockpile investigations undertaken, the nature of the Type A, Type B and Type C Fill placed so far and the preliminary settlement data.

7.2 THICKNESS OF TYPE A FILL

During design development it was considered that the upper surface of the engineered fill profile would require more stringent production and placement requirements.

The upper zone of the fill profile is where all future works will be undertaken. This includes the construction of roads, services, retaining walls, building footings, battered slopes and other related excavations. For this reason it was considered that the Type A fill needed to perceptually be of a higher quality and therefore was a factor in assessing the required thickness of Type A fill.

In addition to the above it was considered that a thickness of higher quality fill at the surface would act as a bridging layer over the potentially lesser quality Type B Fill.

Taking into consideration the above factors, the design allowed for a typical thickness of 5 m of Type A fill. In certain areas of the site where the batter slopes are steeper than typical and benching of the fill is required to reduce surface grades, the thickness of Type A fill is to be 6 m thick.

Where Type A Fill is to be placed directly over a prepared natural subgrade its thickness may be less than 5m. There are also other examples where it was not considered critical that a full 5 m depth of Type A be placed. These areas included those beneath the retaining walls at the edge of the lake and beneath the polishing ponds. Some building areas have also had a reduction in Type A Fill were the finished grades are not steep and benching is not required. At these locations the minimum thickness of Type A Fill will be either 2 m or 3m.

7.3 RESIDENTIAL FOOTING DESIGN

It is intended that footing design for house lots on the engineered fill will be assessed in accordance with Australian Standard AS2870-1996, Residential Slabs and Footings-Construction. The Standard allows for controlled fill lots to be reclassified from Class P sites in accordance with accepted engineering principles and certain criteria. We anticipate that the lots will be reclassified to at least Class H sites which are defined as sites having a characteristic surface movement (y_S) in the range of 40 mm to 70 mm. The structural fill material, and in particular the Type A Fill, will comprise cobbles up to 100mm in a matrix of gravels, sands and some basaltic clays. An allowance of about 20 mm of surface movement may need to be provided for the potential soil reactivity (volume change with moisture content variation) of the high plasticity basaltic clay in the matrix of the fill material. However, it is noted that because the Type A Fill will have less than approximately 15% fines (clay/silt), this allowance should be more than adequate. Hence, to remain within a "Class H site classification" the amount of further differential movement to be tolerated by a house footing system would need to be less than 50 mm. That is, up to 20mm associated with shrink/swell movement and up to 50mm associated with ongoing total and differential settlement of the fill.

The assessment of the achievement of these criteria will be based on the rate and magnitude of settlement measured at the monitoring points both during the construction phase, for points within the fill, and following the completion of the main earthworks contract via top of fill movement measurements.

7.4 SETTLEMENT MONITORING

Settlement plates have been installed progressively as the fill has been placed. A total of sixteen monitoring installation locations have been established. Eight of these locations have two separate plates, one at a level of about 10 m above the base of the fill and a second plate at the top of the Type B Fill (underside of Type A Fill).

In addition to the settlement plates installed during fill placement, a greater number of surface settlement points will be installed immediately following completion of the works.

Settlement plates are to be monitored at the following frequencies.

During construction: Weekly readings
Post construction: Fortnightly readings for initial 3 months.
Readings monthly thereafter

7.5 SETTLEMENT AT THE INTERFACE BETWEEN THE FILL AND NATURAL GROUND

The differential settlement will be higher on lots where there is a transition from natural soils and rock to fill material. Hence, the time lapse before release of these lots is expected to be greater.

The amount of settlement will depend on the thickness of fill material and the slope of the transition from fill to natural. Sharp interfaces with deep fill will incur greater differential settlement across this zone.

To reduce the effects of differential settlement at these sharp interfaces, the top edge of the natural ground has been battered back at a grade of 1H to 1V for the upper 3 m. This will create a transitional effect on the settlement differential. This aspect will be specifically assessed as part of the fill settlement program, with building lots in such areas only being released once the acceptable settlement criteria has been met.

8 RESULTS OF SETTLEMENT MONITORING SO FAR

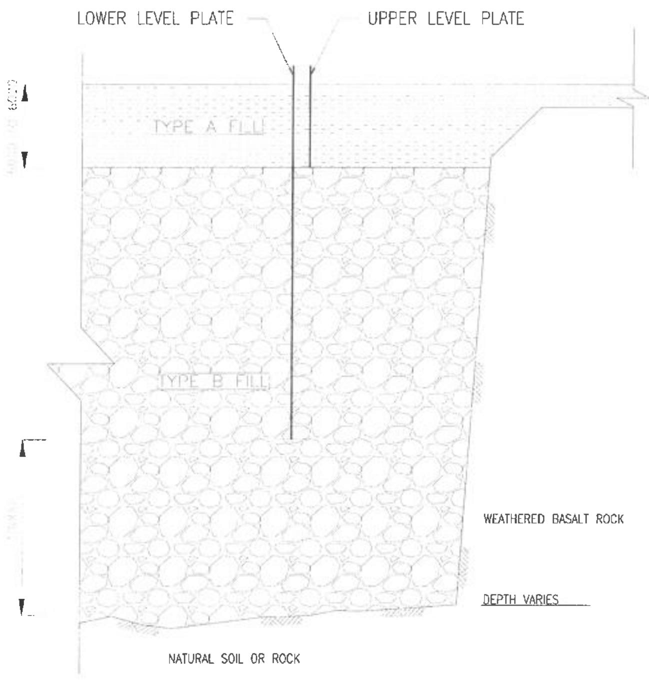
Filling on the project occurred first in an area known as the Cul-de-sac (Refer to Figure 1 for location). This was an area of the quarry that was mined late in its life and had minimal overburden across its base and a floor above the groundwater table.

five settlement monitoring devices have been installed in this area so far. These include three lower level plates, (SMP-01 to SMP-03) and two upper level plates, (SMP-04 and SMP-05). A summary of some of their details is presented in Table 2. The locations of these devices and a typical cross section showing the configuration of the plates are presented in Figures 6 and 7 below.

Table 2 Settlement Monitoring Plate Details

Settlement Monitoring Point	Date Installed	Level of Plate RL (m) AHD	Natural Floor Level RL (m) AHD	Thickness of Fill beneath Plate (m)
SMP-01(Lower)	25 June 2002	36.32	25.64	10.68
SMP-02(Lower)	16 July 2002	35.79	25.81	9.98
SMP-03(Lower)	30 July 2002	36.99	26.10	10.89
SMP-04(Upper)	6 Nov. 2002	50.61	25.75	24.86
SMP-05(Upper)	17 Oct. 2002	50.77	25.71	25.06

Figure 6 Cul-de-sac Settlement Monitoring Plate Locations



TYPICAL CROSS SECTION - SETTLEMENT PLATES

Figure 7

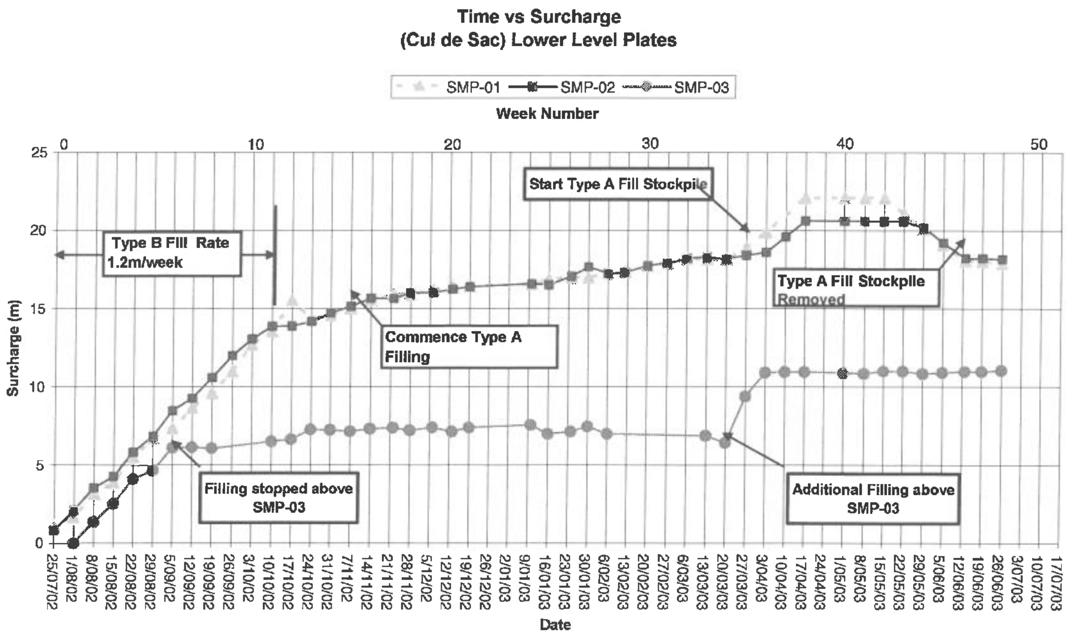
Figure 8 Upper and Lower Monitoring Plates with Temporary Type A Fill Stockpile

Lower Level Plates

Settlement Monitoring Plates, SMP-01, SMP-02 and SMP-03, lower level monitoring plates, were installed in the Cul-de-sac once the thickness of Type B Fill had reached about 10 m at each position.

Following installation, filling above the plates continued at the rates shown on the Time versus Surcharge Plot below.

Plot No.1

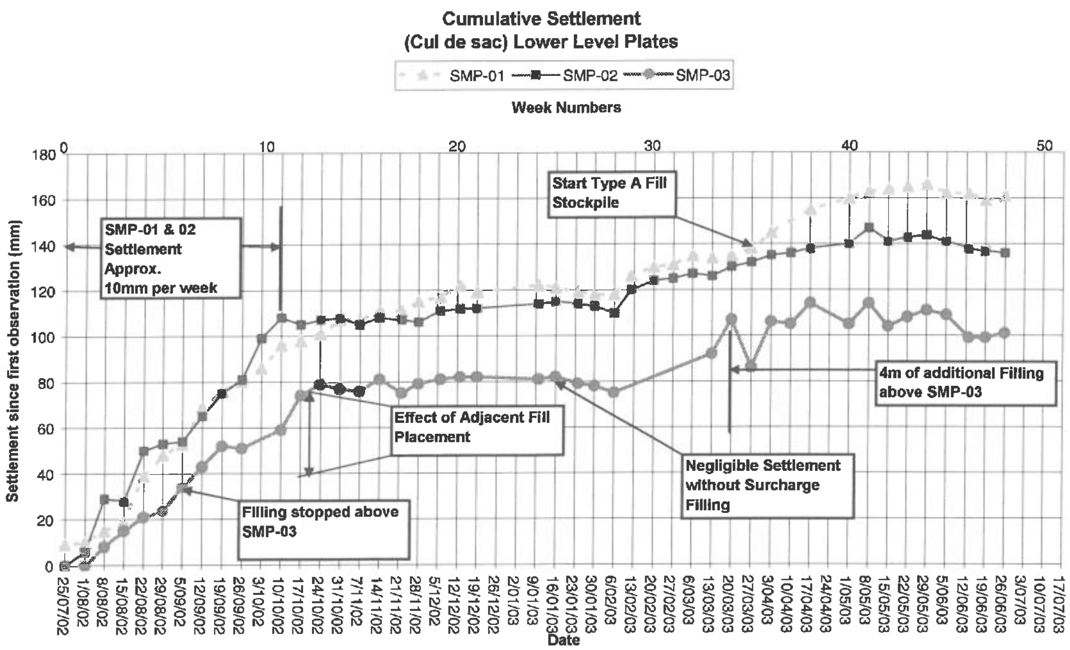


Points of note on Plot No 1 include:

- Filling continued at a relatively fast rate for the first 11 weeks (to 10/10/02), a rate of about 1.2 m per week.
- SMP-03 was located near the edge of the fill cell for the Cul-de-sac. At about five weeks after its installation fill above the plate had reached about 6 m. Following this time no further fill was placed above the plate until about the 20th March 2003 when a further 4 m of fill was placed over a 2 week period as a consequence of the abutting cell construction. No further fill was placed above this plate for the following 12 weeks (Weeks 36 to 48).
- Between about Week 11 and Week 15 the rate of Type B fill placement reduced. Only about 1 m of filling was placed in this period.
- On about the 7th November 2002, the placement of Type A Fill commenced in the Cul-de-sac. Its rate of placement was relatively slow compared to that for the Type B Fill. The thickness of Type B fill at the locations of SMP-01 and SMP-02 was about 25 m.
- About 3 m of Type A fill was placed between Week 15 (7/11/02) and Week 35 (27/03/03), a period of 20 weeks.
- Due to site constraints, on about Week 35 (27/03/03), Type A Fill was temporarily stockpiled in the Cul-de-sac area to a height of about 4 m for a period of about five weeks.
- SMP-02 was located at the edge of the Type A Fill stockpile and hence its impact on settlement was equivalent to about 2 m of surcharge.
- The Type A fill surcharge was removed by Week 47 (12/06/03).

Plot 2 below shows the cumulative settlements of SMP-01 to SMP-03 in the Cul-de-sac. The settlements reflect compression of the 10 m thickness of Type B fill beneath the plates as a consequence of the self weight of this zone and the added surcharge of fill above.

Plot No.2



Points of particular note on Plot No.2 include:

- The settlement rate of SMP-01 and SMP-02 mirrors the fast placement rate of Type B Fill above in the first 11 weeks. The average settlement rate was about 10 mm per week.
- Settlement of SMP-03 was less than SMP-01 and SMP-02 but continues at a steady rate until Week 12. Although Type B fill was not placed directly above SMP-03 after Week 6, its settlement was influenced by the load spreading effect of the adjacent placed Type B Fill.

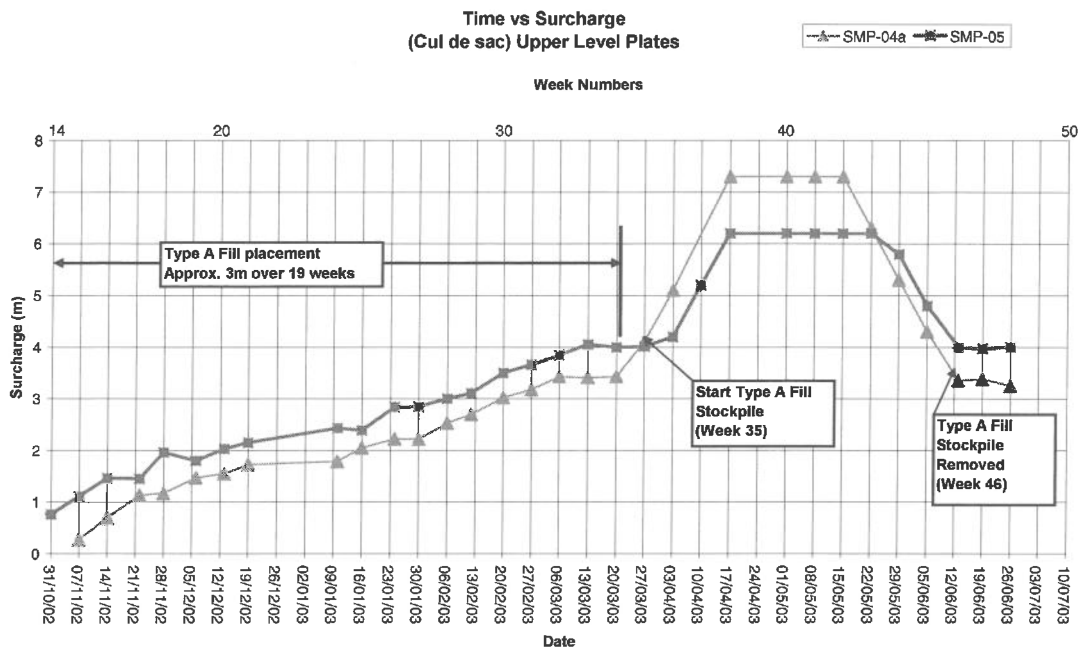
- Settlements of SMP-01 and SMP-02 were between 25 mm and 35 mm for the period Week 11 to Week 35, during which time about 4 m of additional fill was placed.
- Settlement of SMP-03 was negligible between Week 12 and Week 30 when no fill was placed in its vicinity.
- The impact of the Type A fill stockpile on SMP-01 was to increase settlement by about 25 mm, with about 5 mm of elastic rebound on its removal.
- The impact of the Type A fill stockpile on SMP-02, due to being at the edge of the stockpile was less with about 15 mm additional settlement but still resulted in a rebound of about 5 mm.
- The addition of 4 m of fill over SMP-03, between Weeks 34 and 36 resulted in about 20mm to 30 mm increase in settlement.

Upper Level Plates

At the locations of SMP-01 and SMP-02 the upper level Settlement Monitoring Plates SMP-04 and SMP-05 were installed respectively. These plates are located at the top of the Type B fill, at the interface of the Type A and Type B fill, and have about a 25m thickness of fill beneath them.

Plot No 3 below presents the Time versus Surcharge plot for SMP-02 and SMP-05.

Plot No.3

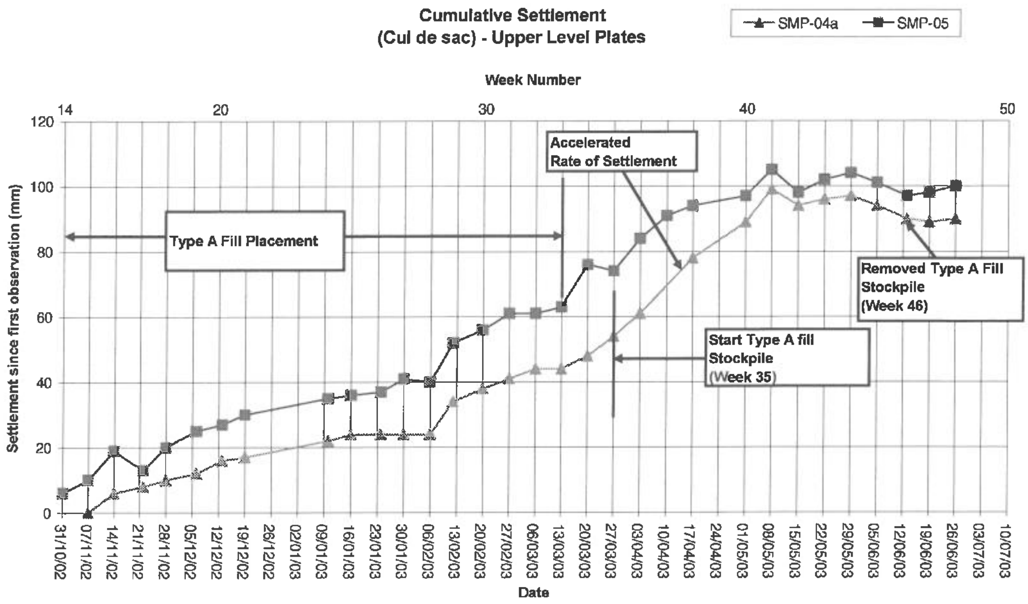


. Points of note on Plot No. 3 include:

- About 3 m of Type A fill was placed above these upper level plates during the period Week 14 (31/10/02) to Week 33 (13/03/03).
- The temporary Type A Fill stockpile was about 4 m thick at SMP-04 and about 2.2 m thick and SMP-05.

Plot No. 4 below shows the cumulative settlements of SMP-04 and SMP-05 in the Cul-de-sac. These settlements reflect compression of about a 25 m thickness of the Type B Fill beneath the plates as a consequence of the self weight of this zone and the added surcharge of Type A fill above.

Plot No. 4

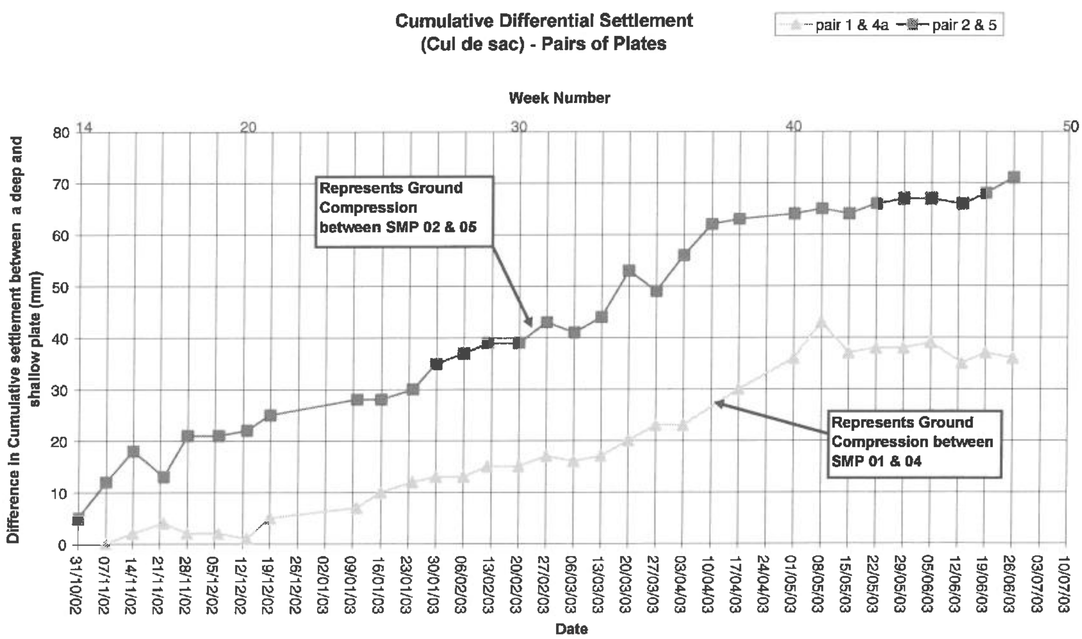


Points of particular note on Plot No 4 include;

- The total settlement of SMP-04, between Week 14 and Week 42, was about 90 mm.
- Removal of the temporary stockpile by Week 46 indicates a rebound of SMP-04 and SMP-05 of about 5mm.
- SMP-05 showed a similar amount of settlement to SMP-04 but slightly higher at 100 mm over the 34 weeks since installation.
- The rate of settlement of SMP-04 accelerated markedly during the period that the Type A fill stockpile was being placed.

Plot No.5 shoes cumulative differential settlement between the pairs of settlement monitoring plates. These plots represent the compression of the fill between the upper and lower plates.

Plot No.5

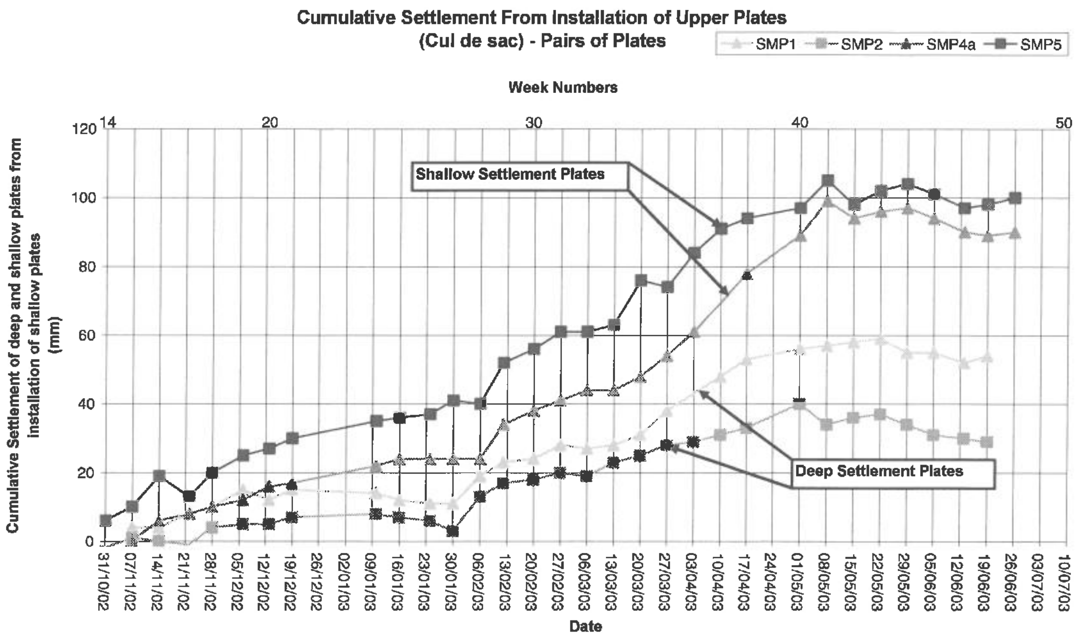


Points of particular note include:

- The compression of the fill between SMP-01 and SMP-04 was only about 40 mm compared to about 70 mm for the fill between SMP-02 and SMP-05. The reasons for the 30mm difference between these pairs of plates is uncertain. It is presumed to be associated with differences in the compressive nature of the materials between each location.
- Compression of the ground between the upper and lower plates has been small to negligible since Week 40 (0 to 5 mm).

The following Plot No. 6 shows the cumulative settlements over time of both the upper and lower plates, but only since the upper plates were installed in about November 2002. As would be expected, the deep settlement plates showed a lesser amount of settlement over this period compared to the upper plates, that is, 30mm to 60mm compared to 90mm to 100mm respectively.

Plot No 6.



8 CONCLUSIONS

At the time of this paper the bulk earthworks contract for the project has been running for approximately 15 months and about 85% of the 2.4 million cubic metres of fill has been placed. The adopted processes and methodologies for the placement of the various fill types have proved satisfactory. The preliminary settlement data has indicated that:

- Compression of the bottom 10m of fill occurred at a rate of about 10mm per week whilst fill above was being placed at a rate of about 1.2m per week.
- Settlement of the lower plates slowed significantly when the rate of surcharge fill placed above slowed.
- When fill placement above a plate had stopped, negligible ongoing settlement of the plate occurred over a measuring period of about 12 weeks. This indicates the fill response to be predominantly elastic.
- Placement and removal of the temporary fill stockpile indicated a generally immediate elastic settlement and rebound response of the fill for both the upper and lower plates.
- The total measured settlement (compression) of the 25m thickness of fill at the location of SMP-01 & 04 was about 250mm, and at SMP-02 & 05 was about 240mm, (ie. Approx. 1% of the fill thickness). It is noted that this includes only the measured settlement of the fill after the plates were installed.

The preliminary settlement data suggests that because of the predominantly granular and well engineered nature of the fill that estimated long term total and differential settlements of the fill should be sufficiently low enough to allow relatively early release of the lots for residential building construction.

Figure 10 Photograph in January 2003 - View South

9 REFERENCES

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