

# GROUND IMPROVEMENT OF LANDFILL SITE USING THE “SQUARE” IMPACT ROLLER

Derek L Avalor<sup>1</sup> and Robert W McKenzie<sup>2</sup>

<sup>1</sup> Technical Manager, Broons Hire (SA) Pty Ltd

<sup>2</sup> Senior Geotechnical Engineer, Chadwick Geotechnical Investigations Pty Ltd

## ABSTRACT

One third of a 2.2ha residential development site at Greensborough, Victoria, overlies an old refuse tip. The challenge for the development team was to engineer the site to a condition suitable for the proposed dwellings, maintaining a control on costs and achieving the specified environmental standards. After stripping the existing clay capping, leaving a thin cover over the waste, the site was subjected to ground improvement with the Broons BH-1300 “square” Impact Roller. Impact rolling continued until settlements became insignificant. Then a continuous capping was reinstated and the area surcharged. The suite of testing included settlement monitoring, intrusive and non-intrusive geotechnical tests before and after impact rolling, and vibration monitoring along the boundary with neighbouring houses. Ground improvement in this manner resulted in a cost-effective and environmentally sustainable solution.

## 1 INTRODUCTION

A property off Diamond Creek Road, Greensborough, Victoria, has been developed for residential use. Complex ground conditions and old buried waste were complicating factors. Innovative ideas were required to obtain a successful result.

## 2 SITE DESCRIPTION AND GROUND CONDITIONS

The site covers an area of approximately 2.2ha and forms part of a former basalt quarry. It is bounded by recreational land, a main road and residential properties. Quarrying took place from the early 1960s for about 10 years, after which the deepest part of the quarry was filled with domestic refuse and this was complete by the late 1970s (HLA-Envirosciences, November 2001).

Numerous site investigations were undertaken for the purposes of geotechnical and environmental assessment (HLA-Envirosciences, March 2002). No further review of environmental aspects is provided in this paper, other than to note the acceptance of all parties, including the Victoria Environmental Protection Authority and the local Council, for the on-site retention of all existing site materials.

Basalt had been quarried to the deepest depth in the central third of the site, and this area had been filled with refuse, observed to be about 3-4m thick, and capped with 2-3m of quarry overburden. Most of the site was covered with reworked quarry overburden, comprising silty to sandy clay with fragments of basalt. Significant settlement had occurred in the central part of the site, indicating the zone of buried waste (see Figure 1).



Figure 1. Panorama of depressed central area during preliminary site stripping.

Development plans required substantial re-levelling of the site surface, including filling in the depressed central zone and cutting from the higher natural ground, to facilitate the provision of roads and drainage. The ground conditions at

the time presented a challenge for the design of footings and pavements. Complete removal of the old refuse or a piled solution were both considered unacceptable options from environmental and cost perspectives.

### 3 PROPOSALS FOR GROUND IMPROVEMENT

Ground improvement was identified as the most appropriate method to facilitate the development. The initial option relied on heavy falling weight dynamic compaction over the refuse filled area to compress the fill, followed by compaction from the surface once the craters had been backfilled. However, the potential disadvantages of dynamic compaction included the mobilisation of additional heavy plant, penetration of the existing capping over the refuse, noise and vibration problems for nearby residents and their houses, and cost.

The option finally approved comprised the stripping and stockpiling of most of the existing capping over the refuse (leaving a minimum cover of 0.5m so that waste was not exposed at the surface) and the use of rolling dynamic compaction, or impact rolling, to densify the fill material. Impact rolling was accomplished using an 8t non-circular (4-sided or “square”) module towed in a frame by a 4-wheel drive tractor, a technique utilised for various applications around Australia for 20 years (Avalle 2004) (as illustrated in Figure 2). The work was carried out under an environmental management plan (Coffey Geosciences, April 2004).



Figure 2. Impact Roller at a Melbourne residential development site.

The excavated quarry overburden overlying the refuse was stockpiled and tested for suitability as final capping material. Impact rolling over the refuse filled area was controlled by surface settlement monitoring, with rolling continuing until “effective refusal” was observed, i.e. there was no further significant measurable settlement. “Effective refusal” was determined in this case by averaging the measured settlements over the whole area and observing the rate of increase on a plot of impact roller passes versus average settlement.

Other filled areas away from the buried refuse were also impact rolled. Subsequently, the capping over the refuse was replaced as engineered fill in the conventional manner. Natural soil sourced from the high part of the site was used to surcharge the capped refuse. Subject to the results of in situ tests and settlement monitoring, allowance had been made for the potential provision of geogrid reinforcement within the capping over the refuse filled area to reduce the risk of significant long-term differential settlements.

### 4 IMPACT ROLLING AND SETTLEMENT MONITORING

After accurately delimiting the extent of refuse fill utilising all previous data and additional trial pits, capping material over the refuse was excavated and stockpiled, leaving a minimum 0.5m cover over the waste (see Figure 3 – note the proximity of adjacent existing houses). Impact rolling was undertaken in May 2004 (Figure 4).



Figure 3. After excavation of the former capping over the refuse, prior to impact rolling.



Figure 4. Impact rolling underway.

Settlement monitoring was utilised to demonstrate the “effective refusal” specification. A total station was set up off the rolling surface and every few passes, the surface level was measured on a 10m grid, as illustrated in Figure 5.



Figure 5. Monitoring of surface settlement during impact rolling.

The results of the surface settlement monitoring showed an overall average settlement across the whole site of almost 120mm, with a maximum settlement of 492mm at one location and a heave of 42mm at another point. Figure 6 illustrates the overall average settlement, as well as the average settlement on five grid lines running across the site.

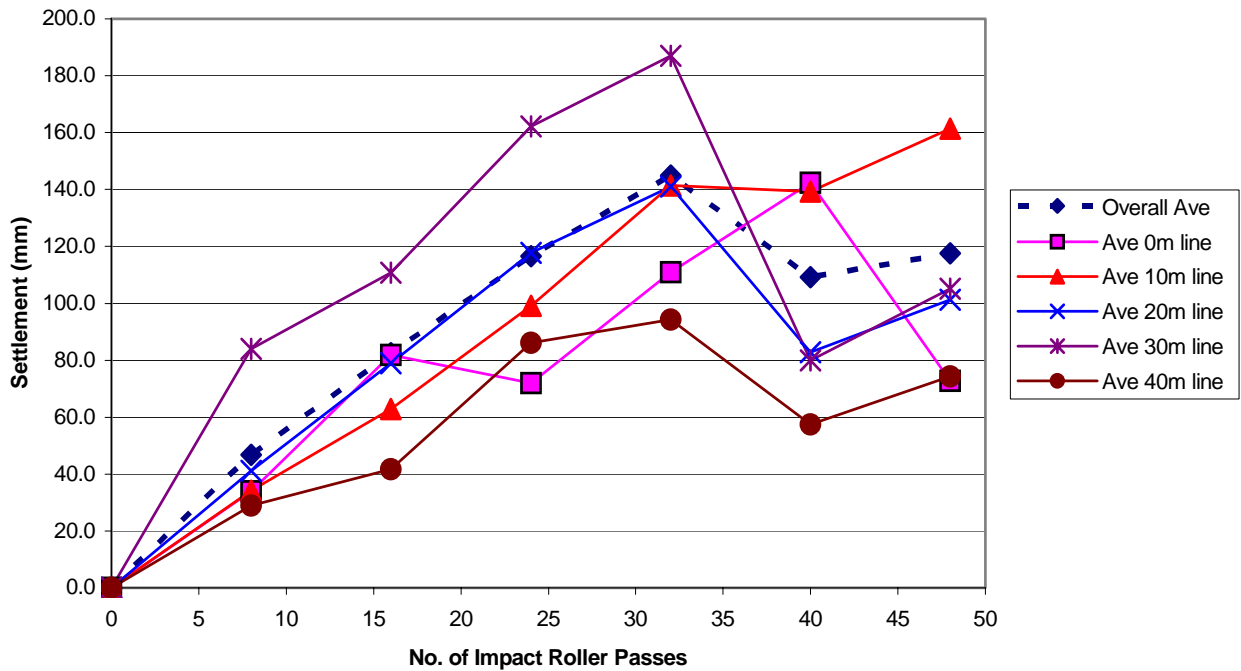


Figure 6. Average settlements occurring during impact rolling.

While the overall average settlement was used to verify “effective refusal”, the graphs along the grid lines illustrate the differing response across the refuse fill area. The apparent reduction in average settlement at some points on the graphs may be a “rebound” phenomenon reflecting the type of waste material, or it may reflect local heave and variations in the surface level at measurement points due to the impact rolling.

## 5 FIELD TESTING

### 5.1 BEFORE IMPACT ROLLING

The scope of field testing before impact rolling included trial pits and boreholes. Figure 7 illustrates drilling in progress over the refuse fill zone, with impact rolling in progress on the adjacent area of quarry overburden fill. Because of the granular and heterogeneous nature of the refuse, it was not particularly suited to Standard Penetration Tests, and only 3 were carried out, providing “N” values of 8, 23 and refusal in the seating depth.



Figure 7. Field testing over the refuse fill prior to impact rolling. Impact rolling in progress on peripheral fill.

Having defined the soil profile, geophysical tests were undertaken using the Continuous Surface Wave System (CSWS). These tests were repeated after impact rolling and the results are discussed in the next section.

## 5.2 DURING AND AFTER IMPACT ROLLING

On commencement of impact rolling, Terrock Consulting Engineers carried out vibration monitoring at the site boundary, particularly with respect to the nearby residences. The results are illustrated in Figure 8. Based on these results, it was concluded that the nearest residence was likely to experience a maximum peak particle velocity of 2-4mm/s for the isolated occasions where the impact roller approached the closest boundary (while working on the peripheral fill).

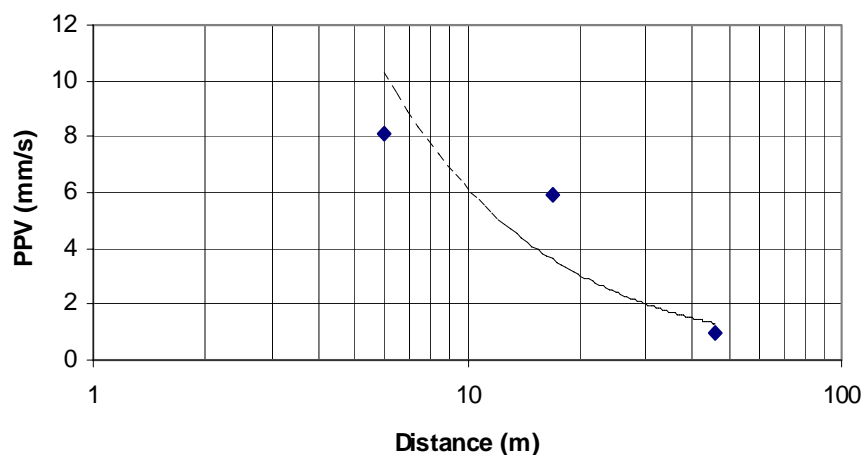


Figure 8. Maximum readings of peak particle velocity (PPV) due to impact rolling at the Greensborough site.

Geophysical non-intrusive tests by continuous surface wave methods (CSWS) were utilised to verify the ground improvement and produce profiles of modulus with depth. In contrast to traditional invasive methods, such as boreholes and cone penetrometers, CSWS is a relatively quick and cost-effective test. A single survey can be set up and carried out in about one hour and produces a stiffness depth profile with around 50 measurements.

The seismic control unit incorporates software that controls an electromagnetic vibrator, which is set oscillating at a series of fixed frequencies. The vibrator generates Rayleigh waves which travel parallel to the surface at a depth of around one wavelength. These surface waves are detected by a row of sensors or "geophones" and the velocity of the wave is measured. From this measurement the shear modulus is calculated using elastic theory. This stiffness measurement is assigned to a depth where the wave energy is a maximum. The system tests a zone encompassing the spread of geophones.

Output from these tests is a profile of modulus with depth, as illustrated in Figure 9. At this particular location, an improvement to a depth of approximately 2m is evident, including the upper capping zone and the refuse fill. The results of CSWS testing provide a non-intrusive response and are suited to assessing ground improvement and strength gain, in this case due to impact rolling. A more detailed examination and discussion of these results is to be presented in a separate paper (Bouazza and Avalue, 2006).

The evident strength gain enabled the design of the final capping to be completed without the requirement to include geogrid reinforcement, a significant cost saving to the developer.

Compaction of the capping over the refuse area (see Figure 10) was completed with conventional equipment to achieve at least 98% standard compaction and moisture contents within 2.5% of standard optimum. On average, the depth of the engineered fill was 2.07m. Further material was then placed over the refuse fill area to achieve design levels, and the eventual total thickness of material overlying the waste was 2.8-3.5m.

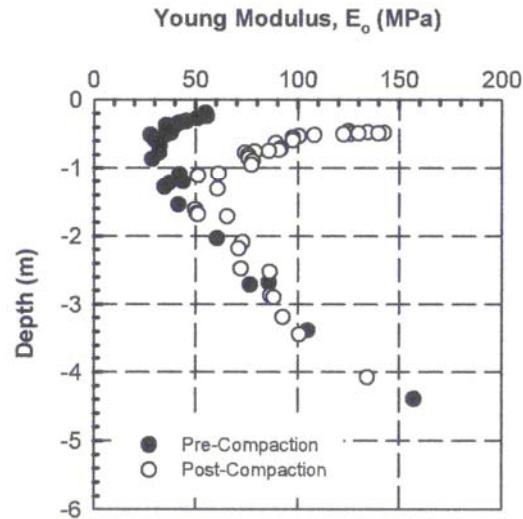


Figure 9. Typical output from CSWS testing at the Greensborough site.



Figure 10. Completion of the capping over the refuse area.

The refuse fill zone was further surcharged with a mound approximately 30m long by 5m wide by 1.8m high. Settlement pins, 2m long, were installed through the mound inside sleeves to prevent downdrag. Settlement monitoring of the pins was undertaken weekly for one month, relative to a site benchmark. The average settlement over this period was less than 2mm, with a maximum of 4mm.

Although the site classification remained Class P in terms of the residential footings code, AS 2870-1996, the ground improvement and controlled earthworks undertaken on this site enabled footing design parameters to be developed that will facilitate building construction on engineered design shallow footings. Figure 11 shows the site in the final stages of infrastructure preparation.



Figure 11. Earthworks, roads and drains nearing completion.

## 6 CONCLUSIONS

A geotechnically challenging site with a history of quarrying activity and waste disposal has been successfully prepared for residential development. A team comprising Broons, Chadwick Geotechnical Investigations and Roger G Bailey and Associates prepared an innovative solution. Site works involved the re-use of all site-won materials, the retention of all waste materials in situ, ground improvement using the “square” impact roller, a range of testing and monitoring protocols, and the reinstatement of a low permeability engineered capping over the site, resulting in a sustainable, environmentally acceptable and cost-effective solution.

## 7 ACKNOWLEDGMENTS

The authors extend their appreciation to their Client, the Fortunato Group; to the project designers, the Bonacci Group; and to the developers, Pacifica Corporate Developments, for permission to utilise technical data obtained during site preparation.

## 8 REFERENCES

- Avalle, D.L. (2004). Ground improvement using the "square" Impact Roller - case studies. 5th International Conference on Ground Improvement Techniques, Kuala Lumpur, pp. 101-108.
- Bouazza, A. and Avalle, D.L. (2006). Verification of Impact Roller Ground Improvement using CSWS Tests, (in preparation).
- Project Reports:
- November 2001, HLA-Envirosciences Pty Limited, Environmental Site Assessment, Lot M, Diamond Creek Road, Greensborough, on behalf of Pacifica Corporate Developments (Project No M1010/1&2).
  - March 2002, HLA-Envirosciences Pty Limited, Summary of Environmental Assessment, letter to Nillumbik Shire Council (ref. M1089/2).
  - April 2004, Coffey Geosciences Pty Ltd, Environmental Management Plan, Compaction Works in Area of Underlying Waste, 165 Diamond Creek Road, Greensborough, on behalf of Pacifica Corporate Developments (ref. E16146/1-AV).
  - April 2004, Terrock Consulting Engineers, Ground Vibration Test, Diamond Creek Road, Greensborough, on behalf of Roger G Bailey & Associates (ref. RBA-0401.doc).
  - May 2004, Chadwick Geotechnical Testing Pty Ltd, Inspection Report (Settlement Control and Capping Layers), on behalf of Roger G Bailey & Associates (Report No. GEN1509-4).
  - July 2004, Chadwick Geotechnical Testing Pty Ltd, Level 1 Controlled Fill Report, on behalf of Roger G Bailey & Associates (Report No. GEN1509-6).
  - August 2004, Chadwick Geotechnical Investigations Pty Ltd, Settlement Monitoring and Site Classification Report, on behalf of Roger G Bailey & Associates (Report No. GEN1509-8).