

Use of the Impact Roller in Site Remediation and Preparation for Heavy Duty Pavement Construction

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Abstract

The 5.5 hectare site of the former Bunnerong Power Station at Port Botany, New South Wales, has been remediated, capped, and prepared for future industrial/commercial land use.

When the power stations were demolished in 1979 and 1987, demolition spoil was used to backfill the larger underground pits and structures, and for general site levelling. As a consequence of this backfilling and of prior site usage, the near-surface subsoil contained old footings and substructures, and areas of hydrocarbon and asbestos contamination, and was in an unknown and variable state of compaction. Sydney Ports Corporation purchased the contaminated site in late 2001, with the intention to remediate the land to a condition suitable for the development of the land as port related industrial use.

The adopted remediation strategy was, after hydrocarbon remediation, to largely leave the remaining contaminated materials in-situ, to cap the area with inert weathered sandstone fill with a minimum of disturbance of the subgrade, and to subject the capping and the underlying subgrade to rolling dynamic compaction using a Broons BH-1300 “square” impact roller.

To assess the overall geotechnical characteristics of the completed works without intrusive investigation of the capping and the potentially contaminated subgrade, extensive testing was carried out using the Heavy Falling Weight Deflectometer (HFWD). The HFWD is usually used on completed pavements, and some modifications to the testing and interpretation procedures were necessary to cope with the weaker “pavement” of weathered sandstone fill at Bunnerong.

The Paper presents the results of the testing programme and final evaluation of the capping and subgrade using the HFWD. The quality and quantity of data associated with subgrade preparation and the use of the HFWD provides a degree of confidence in the ground conditions for the possible future designers of heavy-duty pavements at this site.

1 Introduction

This Paper describes civil engineering and earthworks carried out as part of site remediation works at Bumborah Point Road, Port Botany on behalf of Sydney Ports Corporation (SPC).

The site was previously occupied by parts of Bunnerong Power Station, which was demolished in two main stages in 1979 and 1987. Sydney Ports Corporation purchased the contaminated site in late 2001, with the intention to remediate the land to a condition suitable for the development of the land as port related industrial use.

The key elements of the civil engineering and earthworks carried out were:

- Stripping of vegetation to expose a subgrade of either natural soils, fill or demolition rubble;
- Proof rolling of the exposed subgrade and remediation works associated with soft patches or buried structures encountered;
- Placement of a high visibility marker layer;
- Placement and conventional compaction of the lower 300mm of a capping layer followed by impact rolling and deep compaction with the Broons BH-1300; and,
- Placement, compaction and testing using the Falling Weight Deflectometer of a final capping layer of varying thickness to produce a design interim landform and temporary drainage scheme.

The Contractor for the site works was Ward Civil and Environmental Engineering (Wards), and the design and supervision of the works was by URS Australia Pty Limited (URS) on behalf of Sydney Ports Corporation (SPC).

2 Importation of fill

VENM (virgin excavated natural material) sandstone rock and a small quantity of shale were imported from ten sites in the Sydney Metropolitan area.

Each fill material was natural or processed material which was required to be well graded and to comply with the following general requirements:

Test Method	Property	Requirement
AS 1289.3.6.1	Material Passing 200mm	100%
	Material Passing 63mm	75-100%
	Material Passing 0.075mm	>10%
AS 1289.6.1.1	Soaked CBR, material compacted to 95% DDR, 2% dry of OMC	>5%

The Contractor had difficulty sourcing material with greater than 10% fines and it was agreed that this aspect of the specification would be relaxed. Grading curves of the materials supplied have been provided in Section 5.3.

The CBR tests were carried out in the laboratory on recompacted material and the results are presented in Section 5.2.

3 Placement of fill

After the site had been cleared of surface vegetative matter, the ground surface on which fill was to be placed was proof rolled, using two passes of a single smooth drum self propelled roller with a minimum static mass of 15 tonnes, travelling at a speed of approximately 2 km/h. Proof rolling was used to identify any visually detectable soft areas in the subgrade.

Any material which was soft, visibly deformed, unstable, required treatment or deemed unsuitable was excavated and replaced with compacted granular fill, or filled with stabilised sand in accordance with the requirements of the Technical Specifications to “make good” the surface.

Subsurface concrete pits, slabs or other structural elements encountered during the site works and proof rolling were demolished sufficiently to allow them to be filled by leaving the demolished materials in situ and backfilling the voids using stabilised sand mix of 20:1 sand:cement, with immersion vibrators being used to assist in the filling of the voids.

3.1 The Marker Layer

The high visibility marker layer was green or orange Bidim A14G geotextile. It was placed over the proof rolled subgrade and beneath the capping layer in areas that had been assessed to be impacted by asbestos. The purpose of the marker layer was to identify the base of the capping layer, below which further control measures would need to be implemented if undertaking deeper excavation in the future. The marker layer has no geotechnical or drainage orientated design purpose. Details of the protocols required if disturbance of the marker layer is required are included in a site Management Plan prepared by URS.

The marker layer was placed following completion of proof rolling and any geotechnical remedial works as described above, and prior to the placement of the capping layer.

3.2 300mm capping layer

Spreading and compaction of the lower part of the capping and filling layer was done in a single lift of 300mm nominal compacted thickness. The lift was pushed out over the top of the proof rolled surface and marker layer so no compaction equipment came into contact with the proof rolled surface. Care was taken to prevent disturbance of the proof rolled surface, and hence avoiding potential asbestos contamination of the general fill layer. In fact, the fill was mostly pushed out and compacted over the marker layer initially in a nominal 150mm initially to secure the marker layer to the proof rolled surface. This action was closely followed by pushing out and compacting further material to the required thickness (a nominal 300mm level after compaction).

Fill materials from the imported fill sites were generally placed directly to the required areas by delivery trucks and pushed out over the marker layered surface using either a Cat D7 Bulldozer or Drott 959. From observation onsite, delivery trucks did not appear to have difficulties trafficking to any areas of the site.

Conventional compaction of this 300mm layer was generally by a Cat 815 Compactor or 15 tonne pad foot vibrating roller with moisture addition as necessary. The compacted surface was then smooth drummed rolled for approximately 5 – 7 passes by a vibrating roller of minimum static mass 15 tonnes. No formal specification for this initial compaction of the 300mm layer was imposed by the Contract, the main aim being to prepare the sandy capping to a condition where it could be impact rolled without the risk of direct disturbance of the underlying subgrade by wheel ruts or impact depressions.

Impact rolling the designated areas of the site was carried out as described in Section 4.2 following placement and compaction of the initial 300mm capping layer.

3.3 Final capping layer

Following completion of all the works and submission of all information required in relation to the impact rolling, a final filling/capping layer was placed over the site. This layer was specified to be a minimum of 150mm thick after compaction, but in reality was up to 600mm in some locations to achieve the required interim landform, with the material being pushed out and compacted in nominal 150mm layers. A final survey was provided which contours the actual difference between marker layer level and final surface level for the capping placed.

The final capping layer was placed using conventional construction equipment as described above for the 300mm capping layer, to meet the specification required of a Dry Density Ratio (Standard Compaction) of at least 98%, at a moisture content in the range 60% to 90% of Standard Optimum.

The finished surface level was finally graded to within +/- 50mm of the interim landform plan to achieve the specification of “no local ponding of runoff on the final surface”. The final contour survey of the finished “as built” levels of site was provided by the Contractor.

3.3.1 Impact rolling

Following the placement and compaction of the 300mm capping layer to the required specification, rolling dynamic compaction or impact rolling was conducted on the capped areas of the site. Impact rolling has been successfully used for a wide variety of ground improvement applications (Avalle, 2004).

3.3.2 Method

The chosen method of improving the confidence level of the overall quality of the existing in-situ fill, subsurface structures and natural materials was to use rolling dynamic compaction.

On the basis of the specified total potential energy input of 240 kJ/m², the Contractor adopted 30 passes of a Broons BH-1300 impact roller. A grader was used to “smooth” the compactor indentations and tyre tracks in the running path of the impact roller every few passes.

On advice from Broons, the adopted procedure for each sub-area being treated was for the impact roller to travel in progressive clockwise, then anti clockwise, patterns in north-south and east-west directions at a constant speed of approximately 12 kilometres per hour. Figure 1 shows the site during impact rolling.



Figure 1: Impact Rolling in progress at the Bunnerong Site.

The Contractor conducted surveys of the site at the completion of the marker layer, and following completion of the impact compaction works on the 300mm capping layer.

Observation of the surface before and after impact compaction suggested that a maximum of about 50mm reduction in surface level generally occurred during the process.

As detailed in Section 6, falling weight deflectometer testing of the compacted surface was carried out at the completion of impact rolling.

3.3.3 Limits of impact rolling

3.3.3.1 Exclusion Zones

To reduce the possibility of damage resulting from the impact rolling, alternative compaction procedures were directed in the vicinity of potentially sensitive infrastructure, including sewerage lines and a stormwater culvert within the site, and the Australian Customs Service X-Ray machine building and Eastern Suburbs Memorial Park cemetery wall structure on adjoining sites. The Contractor subcontracted GDK of North Parramatta to conduct vibration monitoring for the course of the impact rolling work.

Before any impact rolling was conducted, a trial was set up for the vibration monitoring to record maximum peak particle velocities, with the triaxial sensor of the vibration monitoring equipment at set distances from the impact roller. Based on the results of the trial and the GDK report, the exclusion zone distances for impact rolling were set as follows:

- Sewer lines – 10 metres each side
- Stormwater culvert – 10 metres each side
- ACS X-Ray machine building – 3 metres from ACS boundary fence
- ESMP cemetery wall structure – 5.5 metres from the wall

Vibration monitoring was continued throughout the impact rolling activity. On one occasion the vibration monitor warned of a breach of the peak particle velocity constraint for a sewer line on the site and as a consequence the exclusion zone for the sewer line was increased to

15m. Within the exclusion zones conventional compaction was carried out as described above in Section 3.2 and 3.3 for the 300mm and final capping layer.

4 Site data

4.1 Contract areas

For convenience the site was split into Contract areas as follows:

- Contract Area A - housed the main structures of former Bunnerong Power Station;
- Contract Area D - provided access to the site for rail transport and housed a railway weighbridge and some outhouse buildings; and,
- Contract Area E - housed the former outfall canal from the former PowerStation to the outlet at the far north of the site.

4.2 Site observations

An overlay plan of the Former Bunnerong PowerStation assisted in establishing links between anomaly results and various structures from the former PowerStation layout. Observed locations of various subsurface pits, concrete structures and features were recorded during the works.

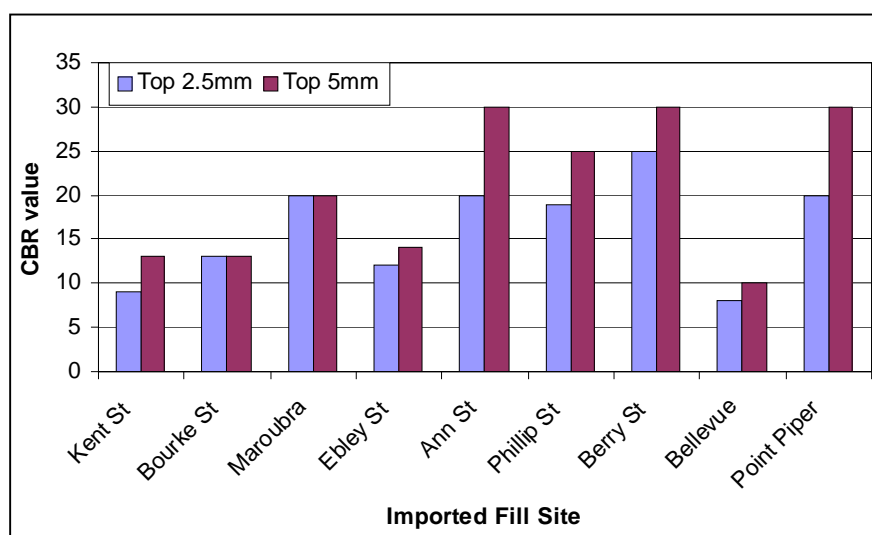
5 Geotechnical test results

5.1 Compaction tests

The compaction tests carried out on the final layer by the Contractor showed that dry density ratios achieved were typically 99%-108%.

5.2 CBR tests

The results from the laboratory CBR tests for each of the 10 fill sites carried out by the Contractor are presented below (Graph 1).

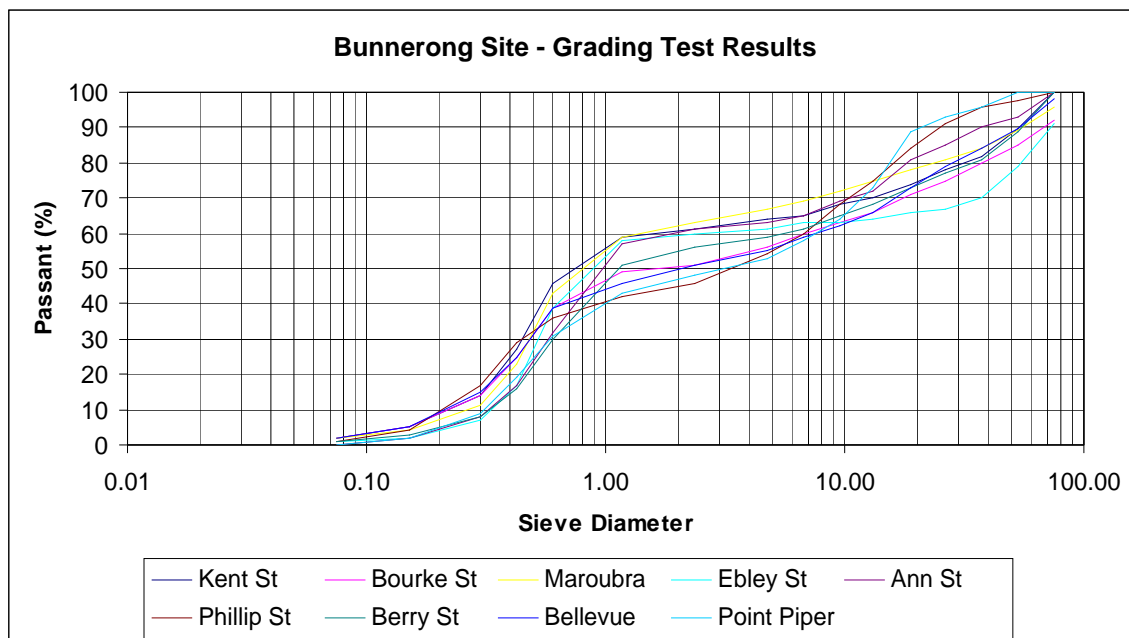


Graph 1: Summary of CBR Test Results for each fill site.

Note that the CBR testing was carried out in the laboratory, on samples compacted to 95% DDR, 2% dry of optimum, as part of the specification requirement for fill material.

5.3 Grading tests

The results from the grading tests carried out by the Contractor are presented below (Graph 2). Grading curve results are displayed by the graph for locations scattered across the site by the location of each fill site's material.



Graph 2: Grading Curves for each fill site.

6 Heavy Falling Weight Deflectometer (HFWD) testing

6.1 The equipment

In-situ testing of the compacted capping and underlying fill at the site was carried out using a “heavy” falling weight deflectometer (HFWD) operated by Pavement Management Services Pty Ltd.

The HFWD is a trailer-mounted device which uses a falling weight to apply a load to the surface of a pavement, with the resulting pavement vertical deflections being measured by an array of transducers. The test data is analysed using a two-layer elastic model to assess the elastic moduli which give the best fit to the load/deflections measured at each point.

The HFWD can also be interpreted to produce data which is analogous to the Benkelmann Beam test for pavement deformation characteristics. The HFWD test rig is shown in Figure 2.



Figure 2: HFWD Test Rig at Bunnerong Site.

6.2 The testing

The testing was carried out in three phases, as follows:

6.2.1 Phase 1:

Parts of the site (namely Area A) at this time tested had been effectively completed as follows:

- nominal 300 mm capping placed and impact rolling completed;
- nominal 150 mm final layer placed and compacted with smooth drum vibrating roller.

The areas tested in other areas (namely Areas D and E) on this occasion had only been partly compacted. These results have therefore not been taken into account in the assessments presented below.

6.2.2 Phase 2:

Parts of Areas A, D and E.

Compaction had been completed at all test locations but final surface preparation had not been completed. Some areas were subjected to impact rolling, with the remaining areas having been compacted with conventional rollers only as described in Section 3, due to their proximity to underground services.

6.2.3 Phase 3:

Parts of Areas A, D and E.

Compaction had been completed at all test locations and bitumen seal laid in places. Some areas were subjected to impact rolling, with the remaining areas having been compacted with conventional rollers only as described in Section 3, due to their proximity to underground services.

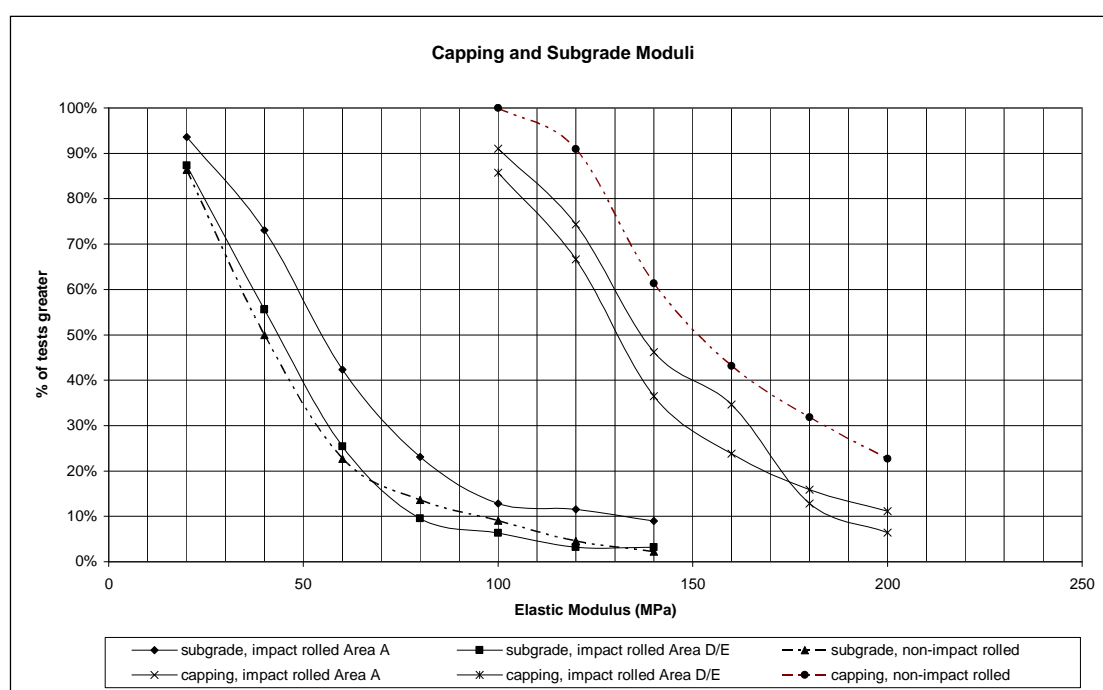
6.3 Analysis

The results have been combined, scrutinised, and grouped for analysis as follows:

- impact rolled parts of Area A
- impact rolled parts of Areas D and E
- all non impact rolled areas (i.e. parts of Areas A, D and E)

6.4 Results and interpretation

The interpreted elastic modulus data is summarised in Graph 3 below, where the y ordinate plots cumulative percentage of tests with a modulus greater than the x ordinate value. This is therefore a simplistic “confidence level” plot: for example, for the non impact rolled areas, the modulus for the subgrade at 75% of locations was at least 25 MPa, and at 50% of locations was at least 40 MPa.



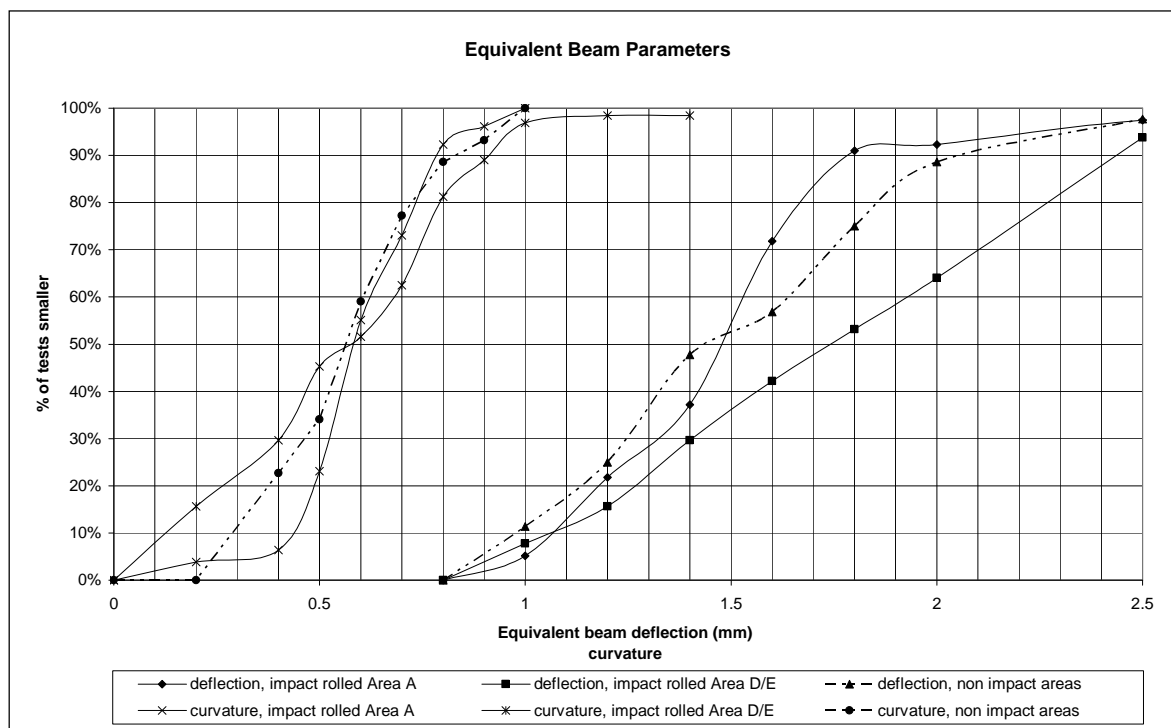
Graph 3: Capping and subgrade layer moduli test results.

The means and standard deviations for the inferred moduli are given in Table 1.

Table 1: Inferred Moduli Data.

		Area A impact rolled	Area D/E impact rolled	Non impact rolled areas
Capping	Mean (MPa)	143	138	168
	Std Dev	36	44	48
Subgrade	Mean (MPa)	67	48	49
	Std Dev	48	31	31
	No. of tests	77	63	43

In Graph 4 below, the equivalent Benkelman Beam deflections and curvatures derived from the HFWD tests have been plotted as cumulative percentage of tests smaller than the x ordinate value. While these parameters cannot be directly used for pavement design, they may be of assistance to designers in comparing the site with their experience of other sites and conditions.



Graph 4: Equivalent Benkelman Beam parameters.

6.5 Discussion

The HFWD testing was principally carried out to provide a semi-quantitative assessment of the general quality of subgrade across the site following capping with inert sandy fill, and impact rolling where practicable.

The deflectometer was seen as a means of economically carrying out non-intrusive tests at a large number of locations distributed across the site. The intention has been to obtain data which gives an indication of the range and variability of subgrade conditions likely to be encountered, to assist in the planning of future site usage and the design of pavements and near-surface footings. However, in the detailed design of such elements the test data in their immediate vicinity will need to be specifically reviewed, rather than simply relying on the broader statistical assessments presented in Graph 3 and 4.

It needs to be understood that deflectometer testing is usually carried out on existing flexible pavements to obtain parameters for assessment of available pavement life, or for the planning of preventative maintenance and the design of overlays. The surface on which the device impacts in these cases is very much stronger and more competent (typical CBR > 100) than the sandy material (typical CBR 15) used for the capping and final surface at Bunnerong. It was therefore necessary to operate the device at the lower limit of its impact force capacity to

avoid excessive penetration of the surface. Care therefore needs to be taken when extrapolating normal deflectometer analyses and correlations to the site's situation.

While there is no direct theoretical correlation between elastic modulus (which is a deformation parameter) and CBR (which is a strength parameter), the approximate relationship $E \text{ (MPa)} = 10 \times \text{CBR}$ is often used for subgrade evaluation. For the sandy capping material, where the moduli interpreted from the deflectometer testing were mostly in the range 120-170 MPa, this would infer a compacted CBR of 12-17, which agrees quite well with the laboratory test data summarised in Graph 1.

For the subgrade below the capping, most of the interpreted moduli are in the range 30-70 MPa, which would infer a subgrade CBR of 3-7.

7 Conclusion

The methods and geotechnical testing described in this Paper allowed the preparation of this site for future industrial/commercial land use by SPC.

The practice of proof rolling, using rolling dynamic compaction, and the fill placement techniques adopted allowed a degree of confidence to be gained in the underlying subgrade of the former Bunnerong Power Station site with minimal disturbance of the contaminated materials and the underground structures encountered during the works.

The geotechnical suitability of the resulting sandstone capping was further confirmed by the non-intrusive Heavy Falling Weight Deflectometer testing conducted, albeit with the limitations as discussed in Section 6.5.

8 Acknowledgements

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9 References

9.1 Australian Standards

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- II. AS 3798 Guidelines for Earthworks for Commercial and Residential Developments

9.2 Other documents

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