INNOVATIVE COST EFFECTIVE METHODS FOR RETROSPECTIVE REMEDIATION OF EXISTING UNCONTROLLED FILL AND FOR ACTIVE PLACEMENT OF NEW CONTROLLED FILL



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ABSTRACT: Uncontrolled fill, commonly encountered in mining, land development and transport infrastructure, is inherently variable Construction on such material typically requires ground improvement to enhance stability, stiffness and bearing capacity. Conventional treatment relies on bulk re-excavation and controlled re-compaction, an approach that can be costly and time intensive. Similarly, achieving controlled fill (e.g. Level 1 in accordance with AS3798-2007) typically demands continuous supervision and testing, which can constrain construction productivity.

This paper presents two case studies demonstrating alternative, performance-based approaches.

The first case study involves retrospective remediation of a poorly controlled fill at a former quarry proposed for commercial and industrial warehouse development. Existing fill was characterised using boreholes and in-situ testing including Grizzly Dynamic Probing Super Heavy (DPSH) instrumented penetrometer and Multichannel Analysis of Surface Waves (MASW) geophysical testing. Impact Rolling was then undertaken to densify the fill in situ. Roller pass count and settlement monitoring results were reviewed. A grid of DPSH tests validated achievement of minimum 98% Standard Compaction across the full depth, identifying localised zones requiring remediation. This approach substantially reduced excavate-and-replace works while providing quantifiable assurance of performance and substantially enhanced the site's value.

The second case study outlines an alternative methodology for achieving AS3798 Level 1 controlled fill during residential land development. Rapid bulk earthworks of 2-3 m cut to fill is to be supervised to check stripping and to control material type and in-situ moisture prior to Impact Rolling, followed by DPSH compaction validation. The method will deliver substantial savings in time and cost while maintaining compliance with key performance requirements of AS3798.

Keywords: Uncontrolled fill, compaction, Dynamic Probing, DPSH, Impact Rolling, mining, land development, infrastructure

INTRODUCTION

This paper presents a performance-based alternative to conventional excavation, replacement, and intensive Quality Assurance testing to remediate uncontrolled fill to controlled fill and an alternative approach to achieve controlled fill with rapid bulk earthworks and thick layer Impact Rolling. The approach combines targeted investigation, in situ densification, and verification to provide engineering assurance with reduced cost, time, haulage, and carbon impact (Power et al. 2026).

WHY FILL VERIFICATION REMAINS A PRACTICAL AND COMMERCIAL CHALLENGE

Fill verification remains difficult because variable materials must be assessed using limited, indirect tests. Uncontrolled fill may vary in density, moisture, composition, stiffness, and inclusions, while even controlled fill remains vulnerable to placement variability, weather, operator performance, and testing limitations.

Conventional controlled fill, by way of example in accordance with guideline Standard AS3798-2007, nominates a set of observations to verify materials, insitu moisture, layer thickness, roller passes, roller performance and more, together with minimum testing requirements. When validating remediated existing fill (Case Study 1), these requirements need to be addressed in accordance with sound engineering principles. When validating rapid, thick layer impact rolled active fill placement (Case Study 2), the key elements of controlled fill noted above can be met, but in a way that differs from the implied sequence of observations and testing in guideline StandardAS3798-2007.

ALTERNATIVE PERFORMANCE-BASED COMPACTION AND EARTHWORKS VERIFICATION

Rather than relying solely on density and moisture compliance supplemented by skills-based human observations, the proposed alternative methodologies integrate process control with performance outcomes including largely automated real time stiffness, settlement control and roller pass count monitoring with close to 100 % coverage over the whole area, integrated with compaction interpretation from DPSH testing.

IN-SITU DENSIFICATION BY IMPACT ROLLING

Impact Rolling – often referred to as High-Energy Impact Compaction (HEIC) and Rolling Dynamic Compaction (RDC) – uses heavy 3, 4 and 5 sided impact rollers pulled by tractors at 10-16 km/h (Figure 1).

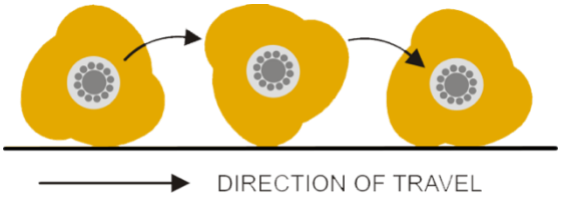


Figure 1 – Schematic of the Impact Rolling Concept

As the non-circular roller rotates, it imparts energy to the soil as it falls to compact the ground and densify the fill in place, typically improving ground to depths of about 1.5 m to 4 m, subject to material, insitu moisture conditions and whether the material is pre-existing fill or freshly placed fill (Scott et al, 2021). Impact rolling can reduce excavation, imported fill, rework, and program delays.

VERIFICATION OF IMPROVEMENT

Density improvement is verified using Intelligent Compaction Measurement pass-count mapping (Figure 2), induced settlement (Figure 3) and ground response (Figure 4), as well as Dynamic Probing Super Heavy (DPSH) (Figure 5) or Variable Energy Dynamic Probing (VEDP) (Figure 6) penetration profiles, both calibrated with Nuclear Densometer (NDM) testing. This combination enables both area-wide traceability and depth-based validation to Standard or Modified compaction.



Figure 2. Impact Rolling Pass Count Measurement

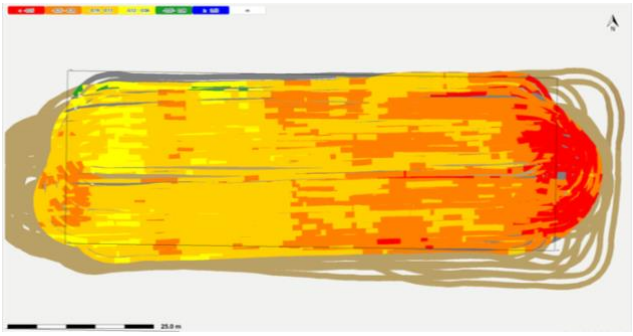


Figure 3. Impact Rolling Settlement Measurement

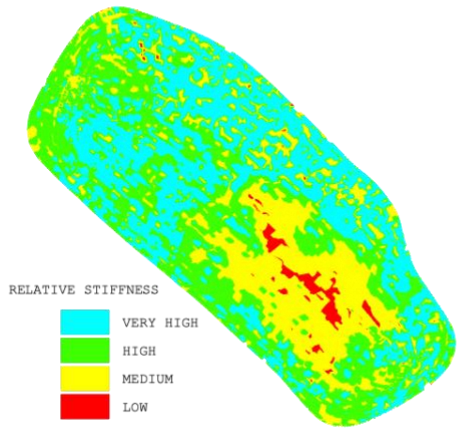


Figure 4 - Impact Rolling Ground Response Measurement



Figure 5. Dynamic Probing Super Heavy (DPSH) - Grizzly



Figure 6. Variable Energy Dynamic Penetrometer (VEDP) - Panda

Importantly, the method can identify under-compaction due to excessive insitu moisture in any layers throughout the full depth fill profile.

CASE STUDY 1 – RETROSPECTIVE REMEDIATION OF EXISTING UNCONTROLLED FILL - FORMER QUARRY REDEVELOPMENT FOR COMMERCIAL / INDUSTRIAL WAREHOUSE CONSTRUCTION

A former quarry with up to 6 m of uncontrolled fill was treated using impact rolling, DPSH testing (with initial NDM calibration), and targeted replacement of non-compliant zones.

Non-compliant fill after impact rolling was identified by DPSH testing and remediated by excavation, drying, replacement and compaction by conventional methods, together with Level 2 NDM testing in accordance with AS3798. The entire fill area was then given an additional 20 impact roller passes to reduce potential for post-placement differential settlement. Impact rolled and conventionally placed remediated fill was tested using a 20 m x 25 m grid of full depth Grizzly DPSH tests.

Figure 7 and Figure 8 show the calibration of DPSH tip resistance with Standard Density Ratio based on NDM tests in impact rolled fill co-located for level and proximity to the DPSH probe for results at Optimum Moisture Content (OMC) (Figure 7) and up to about 2.5 % wet of OMC (Figure 8), the dominant insitu moisture range for the fill. Figure 9 shows back-calculated calibration of DPSH tip resistance within excavated and conventionally placed reworked fill with GPS located Level 2 NDM results within a 2 m radius of the relevant DPSH probe.

Adopted acceptance values of Grizzly DPSH tip resistance for complying compaction were 3.5 MPa , relaxed to 2.5 MPa for fill confirmed by auger drilling and field assessment to be approaching 2.0-2.5 % wet of OMC. The two different data sets show essentially the same correlation between DPSH tip resistance and Standard Density Ratio for the dominant insitu moisture regime. The relationships are statistically significant, with R^2 values in the range of about 0.75.

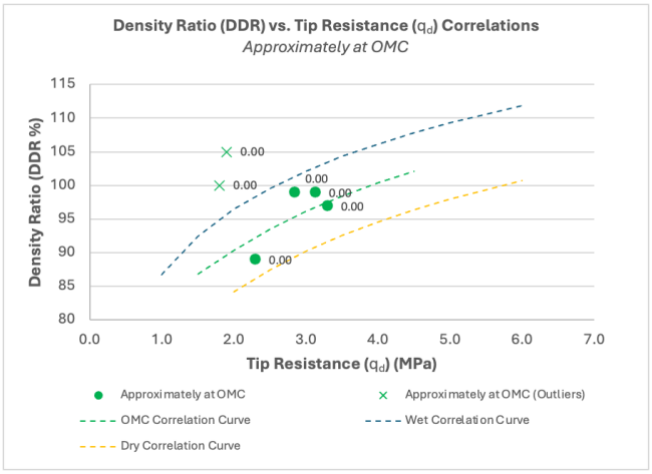


Figure 7. Approximately at OMC Correlation

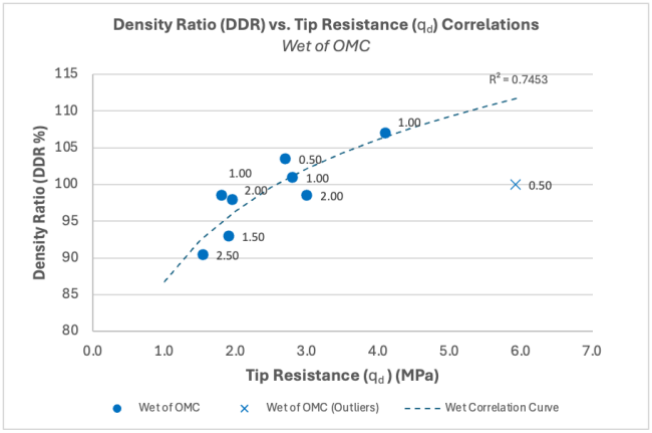


Figure 8 - Wet of OMC Correlation

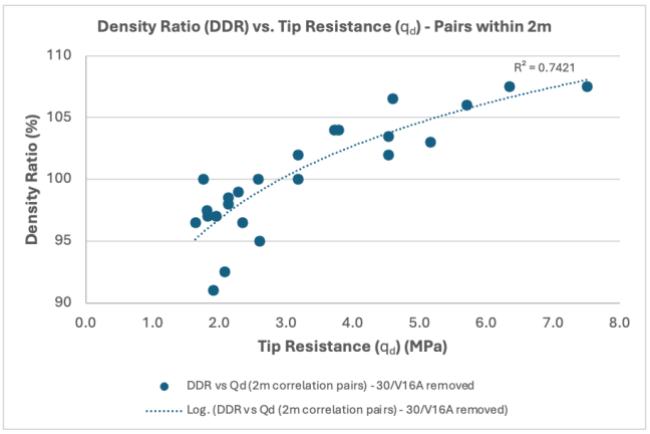


Figure 9. Replacement Fill Statistical Correlation - Pairs within 2 m

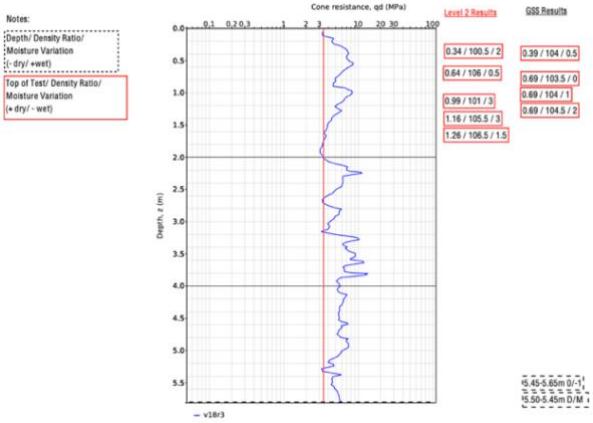


Figure 10 - DPSH Sounding Plot with Compaction Control NF P94-063

CASE STUDY 2 – ACTIVE PLACEMENT OF NEW CONTROLLED FILL

A bulk earthworks project to place up to 6 m depth of controlled fill within a 5.0-5.5 hectare area of former sand extraction for a proposed multi-lot residential development. This project had a delayed start and is in progress now at the time of writing.

Geotechnical constraints include variable base conditions including very stiff to hard clays to loose natural sands, some areas of uncontrolled backfilling and the need to transition into steep batters on 3 boundaries. Available site won materials include stockpiled dirty (silty) sands and sandy clays of low to medium plasticity and natural sands. Insitu moisture content ranges from about 5-6 % dry of OMC for some sands to 5-7 % wet for some stockpiled sands and clays.

Impact rolling was adopted by the project design team to de-risk adverse post placement settlement issues due to variable base conditions, the presence of loose natural sand in some cut areas and in transitions to existing steep cut batters formed in loose natural sands on boundaries.

The program nominated an initial rapid bulk fill operation of typically 2-3 m depth of cut to fill to create a uniform surface for impact rolling, with compaction validation using a grid of DPSH tests, followed by a further 3 m of conventionally placed and conventionally tested controlled fill using imported materials.

After it was pointed out that DPSH testing alone would not meet sufficient key elements of AS3798-2007 to be assessed as controlled fill, the following hybrid methodology was agreed:

- Consider the site in terms of:
  - Area 1: predominantly in cut to remove existing fill materials for reuse in Area 2 and 3, with loose natural sands likely to be encountered in some areas at design excavation level
  - Area 2: generally underlain by very stiff / hard clays, as identified by prior boreholes and Grizzly DPSH tests
  - Area 3: underlain in part by very stiff / hard clays and in part by loose sands, some which maybe backfill to former workings
- Strip Area 2 to expose very stiff / hard base clays, proof roll using a loaded Moxy truck, assess suitability to receive fill and strip boundary batters to expose natural soils, as initially identified by prior boreholes and Grizzly DPSH tests
- Strip Area 3, identify areas of natural or fill sand, investigate, consider insitu improvement by impact rolling or excavate and replace conventionally. Impact roll entire Area 3 base after localised reworking to de-risk from potential hidden prior workings
- Provide insitu moisture profiles within Area 1 to assist the contractor to manage target placement moisture within the range of +/- 2.0 % from OMC when filling Areas 2 and 3
- Bulk, rapid cut to fill from Area 1 to Area 2 and from Area 1 to Area 3, using a CAT 825 compactor to spread and compact in layers progressively, with sufficient inspections by an experienced Geotechnical Engineer to record laterally consistent fill materials and complying insitu moisture, and with some sampling for laboratory testing to validate the target insitu moisture content range and some NDM testing to validate target compaction being met / closely met. Specifically, the compactor is to step bench into existing natural cut batter and compact over the cut fill interface, progressively moisture conditioning the natural soils before being covered and compacted
- Impact rolling at target rapid bulk earthworks level in Areas 1 to 3, review Intelligent Compaction Measurement data including roller pass count, settlement and ground stiffness to verify uniform impact roller response and uniform likely terminal compaction
- Undertake a grid of full depth Grizzly DPSH tests initially calibrated against GPS located NDM tests carried out during rapid fill placement. Investigate potential low anomalies by auger drilling and sampling to check material and insitu moisture and check test by NDM potential anomalies accessible via carefully excavated test pits to a max 1.5 m depth
- Validate complying fill (Areas 2 and 3), natural soil (Area 1) and fill over natural soil at existing boundary cut batters in Areas 2 and 3 to meet the key elements for controlled fill as defined in AS3798-2007 and to be suitable to receive a further 3 m of controlled imported fill to be placed and compacted conventionally to final site level. Validate exposed surface after excavation in Area 1

CONCLUSION

Performance-based verification provides a practical, economical pathway for managing fill risk while maintaining defensible engineering assurance. Target compaction for both studies is 98% Standard within a moisture content range of +/- 2.0% from OMC.

For Case Study 1, the methodology involved significant prior sampling to check insitu material and moisture conditions and calibration with carefully co-located Grizzly/NDM tests and back calculation of Grizzly and GPS closely located NDM tests within areas of locally conventionally reworked fill for further calibration of compaction and moisture conditions.

For Case Study 2, the methodology is assessed to meet all key and implied elements of guideline standard AS3798-2007 for controlled fill, although not in the sequence or manner implied by the guideline standard. Importantly, the standard already provides for compaction assessment by alternative means using either cone tipped (DCP) or blunt tipped (Perth Sand) portable penetrometers calibrated against NDM. The Dynamic Probing Super Heavy (DPSH) - Grizzly (Figure 5) and Variable Energy Dynamic Penetrometer (VEDP) - Panda (Figure 6) offer significant improvement as both use over-sized sacrificial tips to overcome excessive rod friction which adversely affects DCP and Perth Sand Penetrometer results below depths as shallow as 0.75-1.0 m.

Impact rolled and tested fill can reportedly be half to one-third the cost of conventionally placed and tested fill (Power et al. 2026). The methods described in this paper combine prior DPSH investigation, moisture assessment (Case Study 1) and moisture control (Case Study 2), field supervision, laboratory MDD/OMC testing, Intelligent Compaction Measurement and DPSH validation to confirm uniform deep compaction, identify anomalies and deliver controlled fill outcomes with reduced cost, program risk and delivery burden.

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NF P94-063 Soils : investigation and testing - Compaction quality control - Constant energy dynamic penetration test method - Principle and method for calibrating penetrodensitographs - Exploitation of results – Interpretation.