

A PERSPECTIVE ON ROLLING DYNAMIC COMPACTION RESEARCH COLLABORATION BETWEEN INDUSTRY AND ACADEMIA

Derek Avalor

Broons Group, South Australia

ABSTRACT

In the three to four decades since the Broons Group (formerly Broons Hire) introduced the 4-sided “square” impact roller into Australia in the mid-1980s, collaboration between industry, including consulting and contracting, and universities has been strong. This paper is a personal view on how this collaboration has developed and progressed over time. The paper outlines aspects of historical collaboration between the industrial and academic sectors when it comes to rolling dynamic compaction (RDC), or impact rolling. It is, however, within the last 18 years or so that there has been an acceleration of this collaborative effort. In summary, modelling and numerical studies have been carried out Adelaide and Sydney Universities; physical installations and site studies at Adelaide University; and testing techniques at Adelaide and Monash Universities. Most of these activities have involved the RDC suppliers and contractors, to some extent. The results of these efforts have included the construction of scale model test beds, instrumented ground treatment pads, undergraduate and post-graduate projects, including PhD theses, and numerous published collaborative case study papers. While RDC has provided a fresh and relatively un-researched topic for academic activity, the collaborative research activities and the interest of academics has assisted industry with development and marketing of the technology. Several aspects of the extensive collaboration between industry and academia are addressed, covering a broad view of the topic. In particular, the research initiatives, undergraduate and post-graduate research topics and co-authored technical papers resulting from this collaboration are highlighted.

1 INTRODUCTION

Drawn non-circular modules or polygonal compactor weights have been utilised for ground compaction for a long time. “Impact Rollers” describes the compactor, and various acronyms have been applied to this form of compaction device. The author prefers the generic term Rolling Dynamic Compaction (RDC) to describe the technology. More information on the history and development of these devices can be sourced in several of the papers in Section 7, and it is not the intent of this paper to repeat such information.

2 RDC IN AUSTRALIA

The first impact roller arrived in Adelaide, South Australia, in the mid-1980s. A seemingly ungainly beast, it was required to be towed by a large agricultural tractor. The 4-sided impactor received various nicknames, such as the “square thumper”, referencing the module shape, and the “kanga-roller” due to the unusual movement of the module’s linkage arms that protrude above the frame as the unit progresses. Broons’ original impact roller is shown in Figure 1.



Figure 1: The first Broons impact roller, pictured on site in Australia in 1985

Since those days, Broons has manufactured dozens of impact rollers at its factory in Adelaide. The range of models has been expanded to suit various applications. Figure 2 shows two current models with their more modern tow tractors.



Figure 2: More recent models of Broons 4-sided impact rollers

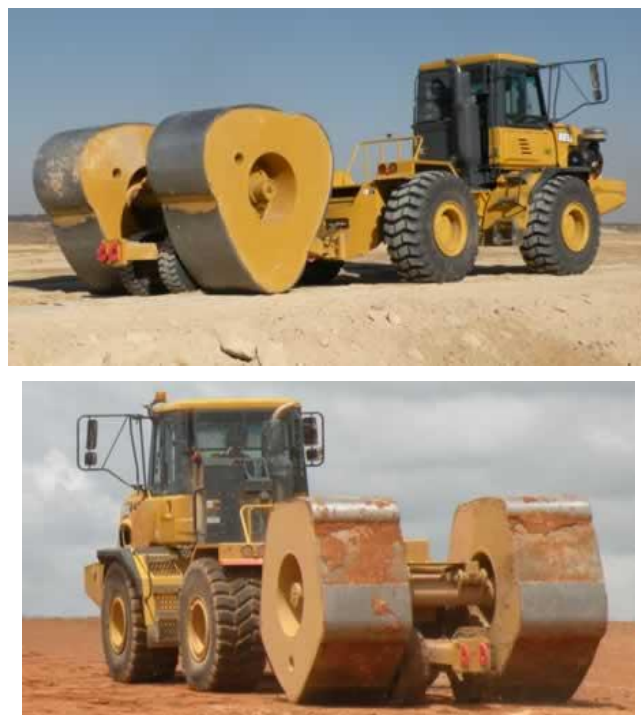


Figure 3: 3- and 5-sided impact rollers

The acceptance of RDC technology was slow to emerge. Early collaboration was between industry, in the form of Broons as the manufacturer and supplier of impact rollers, and geotechnical consultants who wanted to ascertain the capabilities of the machine. Two of Adelaide's leading geotechnical consultants at the time, Charles Fitzhardinge and Peter Mitchell, embraced the advent of RDC. They and others prepared reports on behalf of Broons, highlighting aspects of RDC that were innovative and addressed the effects of the compaction effort.

In the early 1990s, three- and five-sided dual module impact rollers were introduced into Australia by Landpac (see Figure 3). These units have complemented the RDC fleet of options and they have also stimulated the collaboration process.

The principle of all these impact rollers is similar. As the non-circular module is drawn forward, friction on the base causes the module to flip over its leading edge and then fall to impact the ground surface. These units are towed at a significant speed, generally at between 10 and 15km/h, which adds a kinetic component to the energy of the impact.

3 PROJECT CASE STUDIES

In the author's experience, case studies that relay actual project information are most informative in addressing the capabilities of impact rollers and the application of RDC. Many of these projects are referred to in detail in the documents listed in Section 7. Other references address the practical use of RDC and the range of applications. There are many research-oriented publications, and these are discussed in more detail in Section 4. It is now common to encounter papers at Australia and New Zealand Conferences on Geomechanics, at international conferences and published in prestigious technical journals.

As is evident from the range of references in Section 7, RDC has stimulated wide-ranging interest both from the perspective of sharing practical information and case studies, as well as from the detail of academic research that has ensued.

4 RESEARCH PROJECTS

The construction of scale model RDC units has resulted in an array of research projects in recent years. Sydney University has a 1:10 scale model of a 3-sided dual module RDC unit, while Adelaide University has a 1:13 scale model of a 4-sided impact roller. Both were developed collaboratively and have been used for several research projects. They are illustrated in Figure 4. The models are suspended from an oval track, a section of which passes over a container into which soil can be placed, with instrumentation, and compacted each time the roller passes.

Full scale field projects have also been instrumented to generate research data. The soils, both in the laboratory and in the field, have been instrumented with a variety of settlement and pressure gauges, and high-speed photography has been used to capture the movement of the module. Finite element methods are employed to analyse the RDC process.

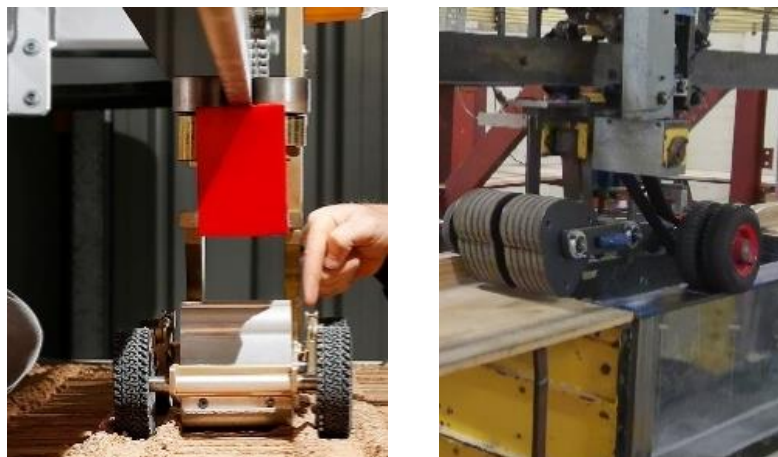


Figure 4: Laboratory scale models at University of Adelaide (left) and University of Sydney (right)

4.1 UNDERGRADUATE THESES AND MASTER'S DEGREES

There have been several Master's theses and undergraduate theses or projects over the last 12 years. Table 1 lists a selection of these from the Universities of Sydney and Adelaide.

Table 1: Master's and Undergraduate Theses and Projects.

Year	Research Topic	Project Type	Student Name/s
2010	The influence zone of the impact roller	Honours	Thomas Bierbaum, Robert Lane, Jessica Piotto, Thomas Treloar
2011	Effectiveness of the impact roller	Honours	Nicole Mentha, Simon Pointon, Aidan Symons, Penelope Wrightson
2012	Effectiveness of the 4-sided 8-tonne impact roller	Honours	Dapeng Liu, Christopher Smith
2014	Investigating the Effects of Rolling Dynamic Compaction Using a Reduced-Size Model	Honours Thesis	Zhongyan Yu
2014	Quantifying the effectiveness of the 4-sided impact roller with operating speed	Honours	Gianfranco Canala, Christopher Gauro, Jackson March, Richard Strapps
2015	Development and analysis of a 4-sided scale model impact roller	Honours	Mark Haywood, Gerard Peters, Samuel O'Dea, Thomas Schwarz
2015	Comparing 3- and 4-sided impact rollers	Honours	Stefan Chenoweth, Jordan Colbert, Julianne Saw, Ross Vince
2015	Dynamic Effects in Soil – Dynamic Compaction	Master's	Rajaratnam P
2016	Investigating the effectiveness of one of the impact roller's key physical characteristics; the mass of the roller	Honours	Thomas Muecke, Keegan Steele, Samuel Brown, Dan Nguyen
2017	Field comparisons between impact and conventional circular drum rollers	Honours	Benjamin Chau, Zixi Deng, Chi To Lai, Yuhao Yan
2018	Measuring the influence of rolling dynamic compaction	Honours	Theodore Balomenos, Vanda Lucas, Adam Sedgley, Samuel Whalley
2018	Assessing the efficacy of rolling dynamic compaction in the laboratory	Master's	Wen Dong, Yanzhang Chen, Junfei Bian
2019	Assessing the effectiveness of rolling dynamic compaction in the laboratory	Honours	Melanie Fragoulis, Antonio Labbozzetta, William McPherson, Nicholas Sierros
2019	Examining the applicability of similitude in the physical modelling of soil dynamic compaction	Master's	Pawel Dawidowski, Duo Lei, Chaowei Zhang
2021	Comparing 1:13 scale and full-scale impact rollers	Honours	Georgia Groves, Vanessa Lamarre, Jesse Nichols, Finn McGown

4.2 DOCTORAL DEGREES

Two PhDs have been awarded at Adelaide University on the topic of RDC in recent years. Research for a third PhD is in progress at the University of Sydney.

Tharanga Ranasinghe (2017) developed predictive tools to forecast the effectiveness of RDC, noting the absence of rational means to estimate the degree of densification or the extent of the influence depth by RDC in different ground conditions. This work developed robust predictive models to forecast the performance of RDC by means of the artificial intelligence (AI) techniques in the form of artificial neural networks (ANN) and linear genetic programming (LGP). The study focussed on the 8-tonne 4-sided impact roller and the AI-based models incorporate databases consisting of in situ cone penetration test (CPT) and dynamic cone penetration (DCP) test data obtained from many RDC ground improvement projects. Distinct sets of CPT and DCP models for each of ANN and LGP were developed, resulting in a recommendation for the most feasible approach to predict the effectiveness of RDC in different ground conditions with respect to such test

data. A series of mathematical formulae were developed for practical application to provide preliminary estimates of the density improvement in the ground based on the subsurface conditions and the number of roller passes.

Brendan Scott (2020) explored the uncertainty regarding the capabilities and limitations of RDC, the underlying objective of this research being to quantify the ground response of the 8-tonne 4-sided impact roller, using full-scale field trials and bespoke instrumentation to capture the ground response. Towing speed and depth of improvement during field tests were compared to several published case studies. Equations were developed for the prediction of depths that can be achieved for both the improvement of in situ materials and the compaction of thick layers. The in-ground response measured using buried earth pressure cells (EPCs) and accelerometers enabled key parameters to be quantified, including the energy delivered to the soil by RDC.

At the University of Sydney, Yuxiao “Johnny” Li (2021, in preparation) is currently completing the numerical simulations in advance of submitting his PhD thesis. He has focussed on the paucity of engineering models to predict soil behaviour in different conditions. His thesis presents the investigation of sand particle movement during RDC with a 3-sided compactor using the university’s 1:10 scale model in the laboratory. Settlements at different depths and cone tip resistance were measured to determine the increase in soil density. A high-speed camera was adopted to capture images so that the displacements of the sand particles could be determined using the particle image velocimetry (PIV). Numerical simulations are being conducted to investigate the effects of moisture content and the water table.

5 CONCLUSION

There has been a high degree of collaboration between industry and academia in the field of impact rollers or RDC, evidenced by over 50 documents listed in Section 7. This illustrates the collaborative efforts in Australia over the last 20 years or so. Missing from this list are older publications from the development phase of impact rollers and the early years in Australia, as well as papers from overseas publications and conferences, including from South Africa and the United Kingdom. From the range of research projects and published papers, it is clear that there is and has been a strong collaborative approach to the subject of rolling dynamic compaction and impact rollers in Australia.

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