Impact Rolling in the Spectrum of Compaction Techniques and Equipment

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Summary Impact rollers have found increasing application over the last 20 years. In the area of bulk earthworks, however, their use has been limited and impact rolling is not referred to in AS 3798-1996. Although impact rolling works in a similar manner to conventional dynamic compaction, it is rarely referenced in guideline documents and is specifically excluded, for example, from BR 458, "Specifying dynamic compaction". This paper explores impact roller technology and experience, and discusses impact rolling within the spectrum of earthworks technology and ground improvement.

1. INTRODUCTION

Impact rollers were developed in South Africa many decades ago (Clegg and Berrangé 1971, Clifford 1976 and 1978). Over the last 20 years, since Broons introduced impact rolling into Australia and made the technology available internationally, the Broons BH-1300 "Square" Impact Roller has been used on more than 700 projects around Australia and overseas.

Impact rollers provide deep layer compaction, and within Australia, they have been utilised over a wide variety of applications. They have proven effective for many soil types and differing ground conditions, and many applications deliver both cost and environmental benefits (Avalle 2004a and 2004b).

On examination of AS 3798-1996, "Guidelines on earthworks for commercial and residential developments", one finds no mention of impact rolling at all. The table included in Appendix E of the standard, which is taken from the Caterpillar Performance Handbook, illustrates the suitability of certain compaction equipment for various fill materials from clay through sand to rock, and is, in essence, a useful guide to roller-material compatibility for various circular rollers. The lack of guidance offered in relation to impact rolling has resulted in geotechnical engineers and designers having to rely on product marketing documents and reported project experience. Specifications for impact rolling vary widely, as do testing protocols.

2. ROLLING DYNAMIC COMPACTION

The principles of conventional dynamic compaction apply to some extent to impact rolling, and it is sometimes referred to as 'rolling dynamic compaction'. Common to all impact rollers is the non-circular module, towed or self-propelled, that compacts as it rotates around a "corner" and "falls" to impact the ground (see Figures 1 and 2).

Figure 1: The "square" impact roller on a mine waste tip.

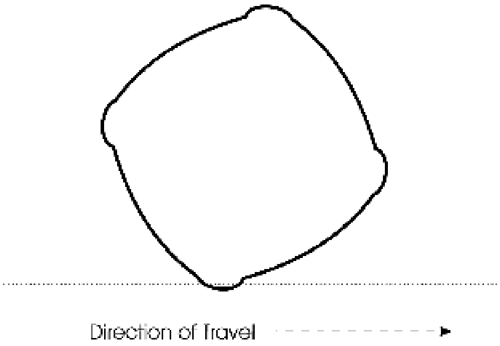

Figure 2: Cross-section of the "square" module.

The energy imparted to the ground by impact rollers is often considered as either potential or kinetic energy. While the maximum possible potential energy may be readily calculated using the module weight and the maximum "drop" height, this value may never be achieved in practice (except, perhaps on a flat hard surface) due to factors such as indentation into the ground surface at the "corner" of the module that reduces the "drop" height. In addition, dependent on the particular design, the module may not be in pure free-fall as there may be damping or spring acceleration effects.

The kinetic energy may be a more useful means of gauging an impact roller's output, as the angular velocity on impact can be computed, although taking account of spring acceleration or damping effects is quite complicated. However, converting this to an energy application rate is also complex because the module impact area is not constant, as it depends on the strength at the surface, and it is not continuous during application.

It is possibly attributable to these complications and the variance from conventional dynamic compaction that impact rolling is specifically excluded, for example, from the Building Research Establishment's BR 458, "Specifying dynamic compaction" (BRE 2003). CIRIA C572 (Charles and Watts, 2002), which deals with the engineering properties of treated ground, includes a process category termed "densification", under which dynamic compaction is included, as is "rapid impact compaction", a falling weight device (essentially a piling hammer) attached to a tracked excavator unit (BRE 2003). These documents reflect one approach in the UK to changes in methods of compaction and ground improvement.

3. EARTHWORKS AND PAVEMENT CONSTRUCTION

In terms of published guidance, the impact roller's use in earthworks and pavement construction has been limited due to a number of factors. Principal amongst these is the consequence of conventional earthworks practice that has been developed over a long period, utilising circular rollers of some form or another, relatively thin soil layers and an established testing regime. The absence of a mention of impact rolling in the Australian Standard for earthworks, AS 3798-1996, may also contribute to its restricted use.

However, there have been numerous pavement-related projects carried out over the years. Some of Broons' earliest jobs in the 1980s were for South Australian roads projects. In situ reconstruction of existing rural roads (see Figure 3) has been an on-going source of work for Broons over the years. Subgrade preparation for a variety of pavement applications continues to be undertaken, and some recent projects include a NSW container terminal (Davies et al, 2004), Adelaide Airport (see Figure 4) and the Port River Expressway (Avalle and Grounds, 2004).

Figure 3: Pavement reconstruction.

Figure 4: Adelaide Airport development.

While the applications listed in the above paragraph may not constitute "earthworks" to some observers, as ground improvement occurs in situ and there is generally no bulk movement of material, the preparation of the subgrade is a most important element in pavement construction and on most civil engineering projects. A key factor in the effective use of the impact roller for bulk earthworks and structural fill is to set an appropriate specification and establish a testing regime suited to the particular situation.

4. TESTING PROTOCOLS AND GOOD PRACTICE

Impact rolling has found application on clay soils, sand and dredged fill, gravels and crushed rock, rocky mine spoil and waste materials of various types, including refuse, industrial waste and building rubble. In other words, impact rollers can be used on the widest range of ground materials, although the depth of influence will vary significantly with the various materials. The upper 100-200mm or so is often disturbed due to the effect of the impact roller's shape and the main zone of densification is below that depth. Significant density and strength improvement is usually obtained to depths of 1-2m in clay soils and 2-3m (or more) in sands and waste materials, dependent on factors such as moisture content and groundwater conditions.

Fill materials may include large particles such as rock or concrete, they may be well or poorly graded and they may vary considerably over short distances (particularly in the case of waste materials). With such a wide range of possible material types and with the probable need to measure strength or density profiles with depth, the choice of a practical, appropriate and cost-effective testing programme is a challenge for most specifiers of impact rolling.

The following table (Table 1) summarises various categories of testing, monitoring and verification methods that have been applied to impact roller projects, in the author's experience.

Category	**Description**	**Comments**
Classification	Particle size distribution, Atterberg Limits, Emerson dispersion	Wide application, generally not suitable for heterogeneous fill with large particles
Continuous probe	Dynamic cone penetrometer (DCP), electrical friction-cone (CPT/EFC)	Provide output that may be correlated with CBR and strength
Conventional Fill Tests	Field density, moisture content, laboratory compaction (MDD, OMC) and California Bearing Ratio (CBR)	Roads and general earthworks; tests represent a very small proportion of the material treated; near-surface tests or excavate through compacted material
Geophysical	Continuous surface wave	Highly specialised equipment and interpretation
Ground response	Clegg Hammer, continuous deceleration measurements	Indicative of response to roller, inconsistent correlation with engineering parameters
Observation	Visual or audible evidence	Subjective, but proven by trial and error
Permeability	Permeability tests, infiltration tests	Useful in the agricultural sector, some tests can be difficult to perform
Settlement	Precise measurement of ground deformation	Simple and effective means of quantifying impact roller effect
Strength	Falling Weight Deflectometer (FWD), static and dynamic plate load tests	Specialised tests: produce load-deflection characteristics and soil modulus values

Table 1. Test methods in relation to impact rolling.

It is clear that the type of testing will need to relate closely to the particular application and the engineering requirements of the end product. However, as with most geotechnical situations, budget constraints will also generally apply, and the geotechnical engineer will need to make judgements, taking risk factors into account.

CIRIA C572 provides recommendations for good practice in the establishment of engineering parameters for poor ground that has been treated in some manner. These include improving the diagnosis of load-bearing deficiencies, improving the understanding of ground treatment effects, maintaining a linkage between ground treatment and footing design, developing quality management procedures for ground treatment and assessment, using testing techniques relevant to long-term performance of the treated ground, and the application of risk management. Most geotechnical engineers specifying impact rolling probably already follow these recommendations in one way or another, even if not consciously.

5. VISION FOR THE FUTURE

Impact rollers have found a place on the practical side of civil engineering earthworks, with increasing use in wider applications over the last 20 years. They often provide an alternative to conventional earthworks equipment and procedures, with both environmental and cost benefits.

It is the author's opinion that guidance documents should provide the engineering profession with the necessary tools to make appropriate judgements and decisions. Points of reference, such as the earthworks code, AS 3798-1996, should reflect best practice, and, where necessary, should be updated as technology develops and alternative options are offered to geotechnical engineers, designers and contractors.

6. REFERENCES

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