REDUCING HAUL ROAD MAINTENANCE COSTS AND IMPROVING TYRE WEAR THROUGH THE USE OF IMPACT ROLLERS

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Abstract

Manufactured and further developed in Australia over the last 21 years, the “square” Impact Roller has found a variety of applications in various parts of the world. Employing the well-established principles of rolling dynamic compaction, the Impact Roller densifies the ground to significant depths, without excavation or removal, allowing the retention of materials that may otherwise be considered unsuitable as engineered or controlled fill. It also facilitates the improvement of weak ground, either natural or man-made, breaking concrete and rock, and compressing waste. Broons now manufacture four models of the Impact Roller, all with solid modules, and two designed specifically with the mining sector in mind.

In the mining industry, the potential benefits of the “square” Impact Roller have become apparent in recent years, and the Impact Roller is providing a significant contribution to tyre life management. Applications at mine sites in general comprise the construction or improvement of haul roads, the “rubbilising” of surface rocks and the generation of a low permeability cover or capping.

With existing haul roads, where weakness in the subgrade results in on-going surface deformation, the deep penetration of the impact wave facilitates the densification of subgrade materials without excavation. Proof-rolling of subgrade areas before placement of haul road construction layers provides a denser more uniform subgrade and can identify weak zones early. Construction of new haul roads, or the rectification of haul road grades and cross-falls, can be efficiently carried out with an Impact Roller – the high speed and deep compaction effect facilitates the use of thicker layers and coarser particle sizes to achieve high quality haul roads quicker.

The rubbilising feature has been put to good use on tip heads, to improve the running surface for dump trucks, particularly in the turning areas, as well as in pit floors where loose or protruding rock can damage tyres or cause unnecessary mechanical stress - the high speed and production rate of the Impact Roller means it can complete work in key areas quickly.

1. Introduction.

Broons Hire (SA) Pty Ltd manufactures the “square” impact roller in South Australia and modifications and improvements have been made over the years, particularly to cater for specialised situations such as mining applications.

The concept of rolling dynamic compaction dates from some decades ago, although the extent of potential applications has expanded significantly since the 1980s. Case studies presented in papers available on the Broons website, at www.broons.com (link to Technical Publications) illustrate the wide-ranging opportunities that the impact roller provides for cost and environmental benefits through this approach to ground improvement.

2. Background.

South Africa pioneered the early development of impact rolling as it is applied today, although some of the earliest uses of impact to densify the ground include Roman foundation rammers and Chinese swinging weights dating from the Middle Ages or earlier. The mid-20th Century saw the development of dynamic compaction by French engineers, employing a relatively free-falling mass.

The potential advantages of in situ deep compaction using a mobile dynamic compactor were recognised by the 1930s, and a Swedish designer patented a towed impact roller of hexagonal cross-section in 1935. About 20 years later, the South Africans took up the concept. The approach to the treatment of collapsing sands by direct, controllable impact led to the manufacture of the first full-size impact roller, a 7t concrete cube towed by a bulldozer, which caused serious difficulties for the towing unit and the driver. This was followed by a 5-sided towed unit, with springs that absorbed some of the horizontal component of force, as well as other different shapes and masses.

Further development continued and, in the mid-1970s, a 4-sided impact roller was patented, with a torsion bar springing system that evolved into the 4-sided towed impact roller employed today. Broons Hire (SA) Pty Ltd introduced this unit into Australia in the mid-1980s under licence, and since 1985 it has been manufactured in Australia and progressively improved by Broons.

The unique control system harnesses the horizontal thrust created by the falling non-circular mass, and utilises it in conjunction with the kinetic effects resulting from the high travel speed, to maximise the energy delivered to the ground. The 1.5m "square" section steel module is completely filled to form a solid a mass, and four models of the Impact Roller are currently available (see Table 1).

Model	Module Mass (t)	Module Width (m)	Details
BH-1300	8	1.30	Standard unit
BH-1300HD	11.5	1.30	Heavy module
BH-1300MS	8.5	1.30	Includes Broons registered mine specification wear package
BH-1950MS	12	1.95	50% wider with the registered mine specification wear package

Table 1: Current Models of Broons "Square" Impact Rollers

The module is drawn in its frame by a suitably configured and powered towing unit at a speed of 10 to 12 km/h. Generally, agricultural tractors have proven to be the best and most reliable for towing Broons Impact Rollers. Figures 1 and 2 illustrate the shape and configuration of the "square" impact roller.

Figure 1: The "square" impact roller.

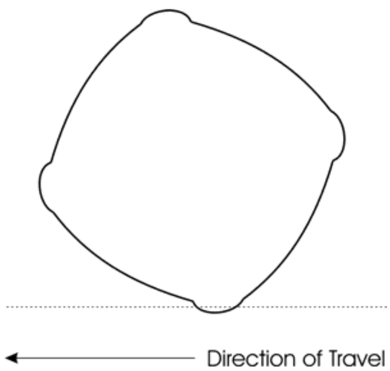

Figure 2: Cross-section of the "square" module.

From its earliest conception, the civil engineering potential of rolling dynamic compaction was evident and the South African trials demonstrated that impact rolling could have an effect to 1m or more, far deeper than any conventional static or vibratory roller. Impact rolling was found to be suitable for a wide variety of materials and was far less dependent on the material's moisture content to achieve the desired improvement. The impact roller's ability to equalise the density gradient across a site, developing a more uniform soil "raft", lends itself to a wide variety of applications, some of which are described in the case studies that follow. Depth effects have been verified to 3m or more in field studies, dependent on the material types, moisture conditions, depth of the water table and other factors.

3. Range of Applications.

Many and varied applications have been undertaken over the years, following on from the early work on collapsing sands and coal stockpiles. Applications have broadened over the last two decades and impact rollers are now used for the in situ densification of existing fill, such as on former industrial land or brownfield sites, raised land and landfills, mine haul roads and bulk earthworks. The principle common to all is the reduction in the volume of air voids in the impact rolled material. However, apart from improving the relative density of the material, this has the added effect of a general reduction in the material's permeability, a factor that has been utilised in the agricultural industry. Impact rollers can be used in semi-arid areas to achieve a stiffer more uniform subgrade using less water during compaction and with little control on subgrade moisture content - this is a particular feature of impact rolling attractive to its application in Australia's agricultural sector.

Other non-engineering applications are the "rubbilising" of rock on open-cut mine waste tips to reduce abrasive tyre wear, and the improvement and construction of haul roads. The mining applications are discussed further in the following sections.

In addition, the increasing use of surface mining or milling equipment in hard rock quarrying, in lieu of drill and blast techniques, presents an opportunity to induce fracturing of the surface layers with the impact roller before extraction, improving production rates up to three fold. Similar procedures can be followed for the demolition of concrete pavements on roadways and airfields.

4. Haul Road Improvement and Reconstruction.

Following on from its innovative use in the reconstruction of rural roads in Australia, the impact roller has been used on a number of mine sites for haul road upgrading. One major problem with haul roads is localised or more widespread failure due to poor subgrade conditions. The major benefit of the impact roller is that the subgrade can be improved from the surface, without the need to remove any material. The surface layers are broken up under impact rolling allowing the impact wave to penetrate deep into the subgrade, densifying most types of subgrade materials, and leaving the surface ready for treatment to place and compact the new wearing course material.

The effect of impact rolling on the subgrade is clearly shown in Figure 3, in which the Dynamic Cone Penetrometer (DCP) test results on the centreline of a South Australian road are correlated with California Bearing Ratio (CBR). The improvement in the subgrade zone from 0.3m to about 0.7m has manifested itself within 12 passes of the "square" impact roller.

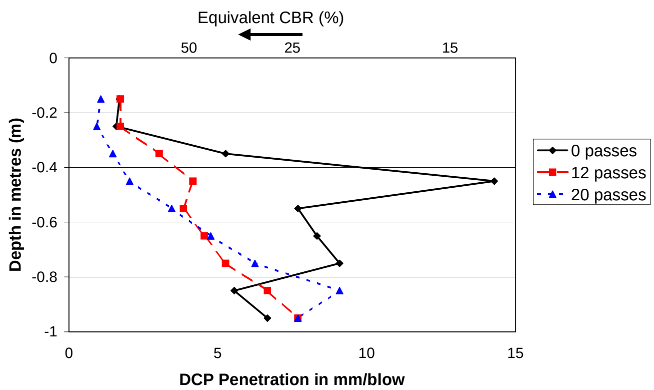

Figure 3: DCP test results for road reconstruction project.

5. Haul Road Construction.

As a “proof roller”, prior to the construction of a new haul road, the impact roller can be applied to the subgrade to improve its density and uniformity, as well as to identify soft-spots that can be rectified well before pavement materials are placed, thereby greatly reducing the risk of future subgrade problems. Although the impact roller actually disturbs the top 100mm or so due to the kneading and shearing effect as the module travels over the surface, its real compactive effect penetrates to at least 1m, the critical zone for heavy duty pavement subgrades.

The benefits of the impact roller to haul road construction lie in the potential that is offered to compact thicker layers quicker, and also to utilise materials with larger particle size. Conventional rollers have a realistic depth of compaction of only 200-500mm, depending on the size and drum mass of the unit, and this restricts the acceptable particle size. Over-size materials are discarded in most cases, or further crushing is required before the materials are placed for compaction.

The impact roller can deal with layers of 500mm thickness or more, allowing larger particles to be included. As with most compaction materials, moisture conditioning improves the compaction effect, and this also applies in the case of the impact roller. The impact roller is not a finishing roller, and there is always the need for final trimming, watering and rolling with conventional plant to achieve the running surface.

6. Rock “Rubbilising”.

The mining sector was an early advocate of impact rolling to reduce the incidence of spontaneous combustion in coal stockpiles, a use that still continues in South Africa today. In Australia, the “square” impact roller has been utilised or trialled on numerous mine sites to reduce tyre damage resulting from protruding or surface rocks.

Impact rolling on the tip head to “rubblise” the rock has the effect of breaking down larger sharper rocks, with an associated reduction in abnormal tyre wear. The trucks drive up onto the tip head and then turn through 180° and reverse to the edge to dump the load. During turning, the truck tyres are particularly prone to damage from protruding hard sharp rocks. A similar phenomenon occurs in loading areas or on pit floors, where truck traffic is concentrated, and where rocks can cause abnormal tyre wear. The Broons BH-1300MS and BH-1950MS “square” impact roller modules have been specifically modified for such mining applications.

Figure 4: The impact roller and a dump truck on a mine waste tip.

7. Production of Low Permeability Cover.

Other applications of the Broons “square” impact roller on mine sites has included the construction of tailings dams, to compact the cover or capping over waste rock cells and to re-form former flood plain surfaces with a low permeability capping

These applications are generally driven by environmental factors, including water quality, acid mine drainage, and EPA conditions for flood plain re-establishment, amongst others. Using the impact roller to obtain deep compaction in effect also reduces the permeability characteristics of the material. Trials are often required to ascertain the site-specific aspects and beneficial effects of impact rolling, to establish the preferred layer thickness or optimal number of passes. The choice of appropriate testing protocols during trials, and before, during and after impact rolling, related to the specific end uses and site conditions, is an area that Broons can assist, particularly in the preparation of or comment on engineering specifications.

8. Conclusion.

Rolling dynamic compaction has been proven to be effective for the deep compaction of materials in a variety of earthworks applications, as well as for non-engineering uses. While the "square" impact roller is acknowledged by many as a significant contributor to the fleet of construction equipment, there remains a minority who are yet to be convinced. There also remain others who are yet to be convinced about potential benefits to the mining industry.

Truck tyres form one of the single largest cost items for mine operators. The impact roller's use to rubbilise rock, particularly where haul trucks are required to turn sharply on dumped spoil that includes protruding or loose rocks, is already established as a component of tyre management at some mines.

Poor road surfaces cause rock spillage from loaded trucks, posing a major hazard to following vehicles and a significant risk of tyre damage. Improved haul roads have the obvious outcome of reducing abnormal tyre wear, but will also result in less stress on mechanical systems and consequential reduction in the cost of maintenance and spares.

Low permeability cover to waste tips reduces water percolation through waste rock, so reducing the occurrence of acid mine water or other hazardous or unacceptable discharges. The compaction effect of the impact roller to produce a denser more uniform and low permeability cover offers a significant environmental advantage. In a similar manner, areas such as former flood plains that have to be re-constituted after mining has passed, can be capped in thick layers and compacted with the impact roller to satisfy stringent environmental demands.

In the future, we are likely to see impact rollers used for intermittent or long-term spells on all of these types of mining applications, and possibly in as yet unexplored uses. Apart from their benefits in earthworks and compaction, the Broons "square" impact rollers are becoming a significant consideration in the development of tyre management procedures.

Appendix.

Broons Impact Rollers have been, or are being, utilised on mines dealing with the following ore bodies and in the listed geographic regions (1985-2006):

Ore types: Iron ore, coal, gold, zinc.

Geographic locations: The Pilbara (WA); the Bowen Basin (Queensland); the Hunter Valley (NSW); gold fields in WA, NSW, Indonesia and New Zealand; South Australia, other regions of Queensland and WA.

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