RailKonsult

Office of Rail Regulation

Further Assessment of Approaches to Improve Efficiency

Technical Appendix Number 9

Ballast Distribution and Redistribution Systems

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Executive Summary

This paper is one of a series commissioned by the Office of Rail Regulation in order to gain an improved understanding of the maintenance and renewal techniques used outside Great Britain. These reports have been produced as part of the PR08 process.

This report focuses on the use of ballast profile measurement systems to under-pin improved management of unloading and distribution of ballast techniques as used elsewhere in Europe and in North America.

During CP4 it is expected that traffic levels will increase and that further restrictions will force more track operations into possessions. This will mean that track access periods will become even further congested and that the ability to run ballast trains within them for the unloading of ballast will become more difficult.

Ballast unloading and distribution of ‘Top Stone’ to the correct profile is a process that all railway administrations have to undertake to ensure that their track infrastructure can run rail traffic safely. This is undertaken to redress deficiencies in the ballast profile and to cater for ballast used as a consequence of ‘on track’ machinery operations. Several rail administrations have introduced ballast redistribution to ensure efficient operation of their networks.

In Great Britain, the ballast management process has primarily been improved over the last decade through the development of improved delivery wagons. These require far less labour, but provide faster and more accurate delivery of ballast.

However the inherent problems of ballast delivery still remain:

- Too much or inadequate stone dropped to correct the profile;
- Stone not always dropped in the correct location; and
- Ballast unloading required in possession.

Hence additional costs are incurred within the ballast profile management process.

The approaches described within this paper provide the means to more efficient and effective management of ballast profiles.

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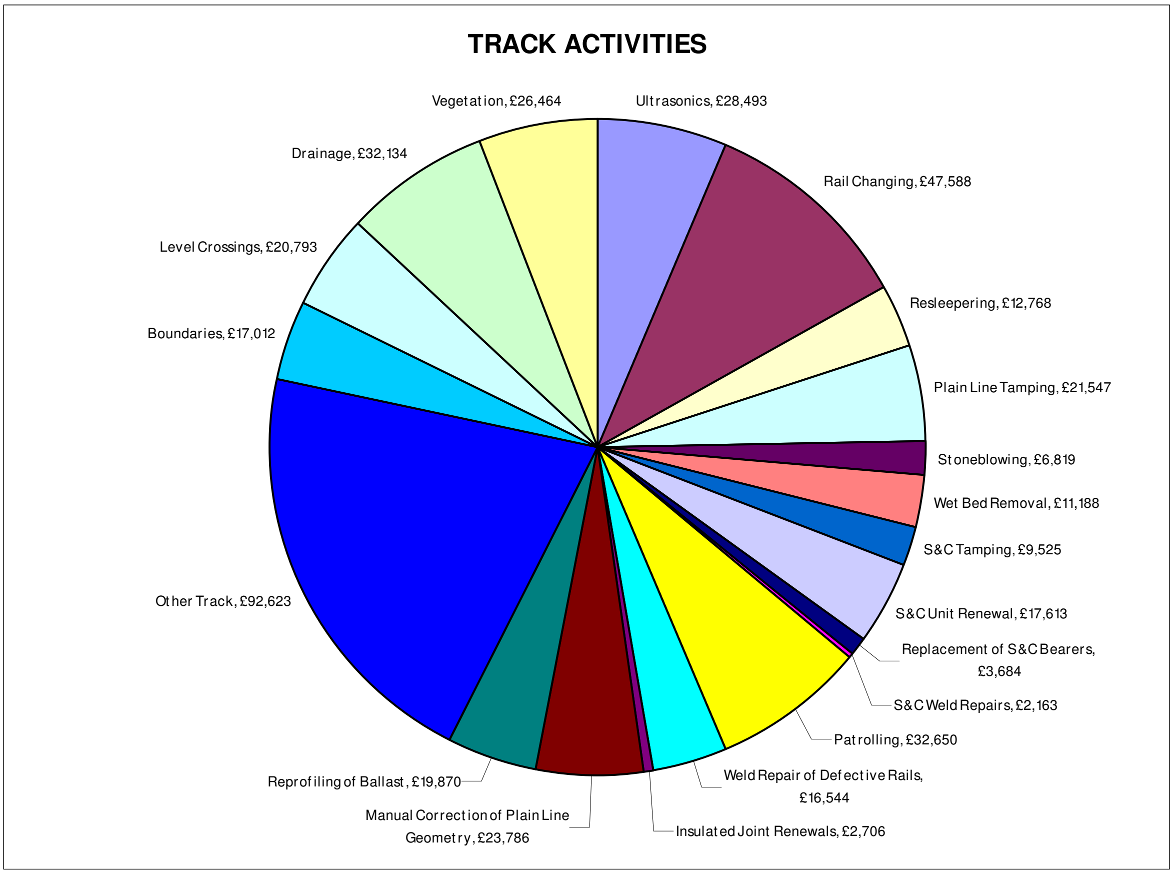
1.0 BALLAST DISTRIBUTION

1.1 Management of Ballast Profile

The effective and efficient management of ballast profiles to approved standards is an essential part of maintaining a railway system. The reasons for having the correct profile are to support the track to the correct alignment and to ensure against excessive lateral movements of the track. This requirement is delivered quite differently elsewhere.



Ballast Distribution (noted as ‘reprofiling of ballast in the pie chart above) accounts for some 4% of the maintenance costs (Source: NR Maintenance Efficiency Model, October 2007).

In Britain, the process of inspecting and assessing ballast conditions / requirements is usually based on human judgement. In other countries ballast profiles and replacement amounts are calculated using technology. This technology has been developed and used so that the rail administrations can be certain that the cost of ballast management process is minimised

Ballast delivery in Britain has been improved immeasurably over the last ten years through the introduction of improved ballast delivery wagons requiring less manpower to unload with a better distribution system. However successful attainment of of the correct ballast delivery is still very much left down to operator competency. In parts of Europe and North America improved ballast delivery, based on modern technology, has been introduced to reduce human intervention from the process

It is generally considered that much of the British network suffers from inconsistent ballast profiles, i.e. the network has both too much and too little ballast. This cannot be proved or disproved because the technology is not readily available to precisely measure and calculate the amount of stone on the ground.

Evidence from Europe, particularly from OBB in Austria, shows that their rail system did in fact have excess ballast that had been unloaded previously. This was reflected in the measured ballast profiles.

1.2 Extent of Methodology

The two case studies described in this report are specific to the localities mentioned, i.e. Austria for the use of the BDS2000 ballast redistribution system and North America for the use of the ‘Plus Train’ concept. However, both techniques are examples of an overall philosophy to minimise the cost of running track infrastructure whilst benefiting overall rail operations through the introduction of technology led ballast management systems.

1.3 Applicability

This paper only considers the activities of ballast unloading and distribution in connection with track maintenance.

Note that, whilst references are made to specific products and systems that are in use in particular countries, there may be other products available that provide a similar functionality. The report does not review all available alternatives, or consider their comparative merits. The case studies are included as being indicative of alternative approaches in asset management.

2.0 EUROPEAN AND NORTH AMERICAN APPROACH

Different approaches are used to inspect, assess, deliver and redistribute ballast in Europe and North America. However, both use the same general approach and both utilise modern technology.

2.1 Measuring Ballast Profiles

Ballast profile measuring systems reviewed in this paper use similar technology, i.e. laser profiling devices. When the laser pulse hits the ballast profile, it is reflected and the distance and measuring angle are registered.

The contour of the ballast profile is computed from the sequence of received pulses. On the computer display the measured profile is superimposed with the image of the correct ballast profile indicating where excess or lack of ballast exists.

The relevant compliant profile is chosen either by the operator or automatically linked into the computer and GPS system of the inspection trains. Precise location along the track is also recorded.

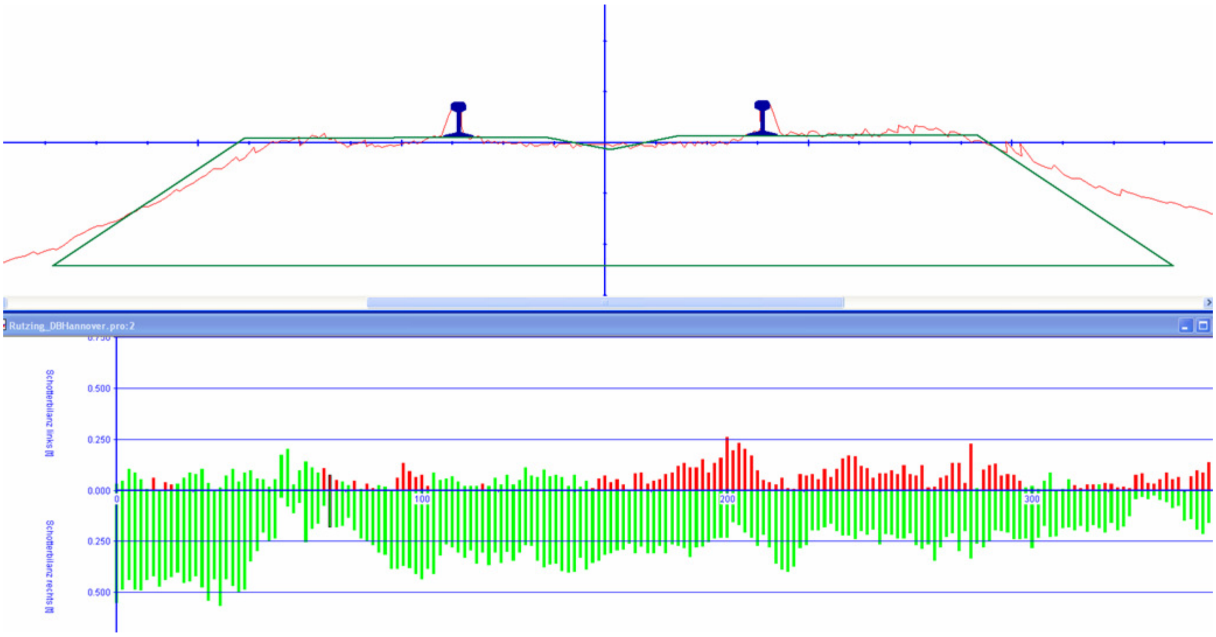
Efficient ballast management is possible using this ballast profile measuring device. Ballast can be reclaimed from areas with a surplus and placed in areas where there is a deficit. A transition to accurate ballast management provides the additional benefit in that constant measurement of ballast profiles is undertaken, enabling the safety of the line issues associated with buckling to be continually monitored.

The following pictures illustrate these systems:

- Picture 1 shows a ballast profiling system mounted to a Plasser EM-SAT track survey machine;
- Picture 2 shows a ballast profiling system mounted to a Union Pacific track inspection train that was developed by Plasser America; and
- Picture 3 shows a typical output ballast profile, indicating excess stone areas in red and areas requiring ballast in green

Picture 1: Ballast Profile Measuring System Fitted to a Plasser EM-SAT System

Picture 2: Ballast Profile Measuring System Fitted to Union Pacific Inspection Train



Picture 3: Typical Output Showing Measured Profile

Red = Surplus of ballast, Green = Deficit of ballast

2.2 Unloading Ballast

The process described in the following section is that used in North America.

A survey is undertaken using the laser profiling systems attached to either:

- Inspection trains as illustrated above in Union Pacific example; or
- A road rail vehicle fitted with laser scanning ballast profiling and GPS location systems.

In the former case the survey can be undertaken in traffic. In the latter case, a track possession is required.

Ballast requirements are then calculated using 'bespoke' software specifically developed for this purpose. This software is capable of using data from either of the above measurement systems to identify precisely where ballast is required. It also identifies where ballast cannot be unloaded, for example over level crossings or switch and crossings. The programme of ballast unloading can be enhanced by the track supervisor for locations where he knows that additional ballast will be required for planned engineering operations such as tamping.

The results from the software programme are loaded onto a computer on the engine of the locomotive hauling the ballast wagons. This is undertaken by the technician who accompanies the train. His role is to monitor the ballast unloading system on the train and to ensure that unloading is undertaken correctly.

The trains operate at line speed until they arrive at an unloading site. They then operate at a maximum of 32kph whilst unloading. Under North American operating rules, no possession is required to enable the trains to unload in traffic.

The specially modified ballast wagons unload the ballast automatically under the direction of the software data, using GPS as the guidance system. Ballast can be unloaded to either cess or six-foot sides. Regulators then reposition the ballast as required to achieve the correct profile.

Picture 4: 'Plus Train' Unloading Ballast at Circa 30kph

2.3 Redistributing Ballast

In both Europe and North America specialised ballast redistribution vehicles are used to pick up surplus ballast and then place this where a deficit of ballast exists, or where future tamping operations require additional stone to be available. Bespoke ballast distribution systems, such as that developed by Plasser and Theurer, provide a mix of ballast regulating and storage facilities for managing ballast.

These machines can handle large quantities of ballast and are equipped with a front plough, shoulder ploughs and a multi section centre plough. These provide the capability to undertake a variety of ballast transfer movements including the loading of surplus ballast to a 40tonne storage hopper. The storage hopper can be supplemented by additional storage by the addition of suitable wagons, such as MFS vehicles. These increase the capacity to store and redistribute ballast, thus enabling an extended track section to be serviced.

Picture 5: BDS Sweeper Unit Picking-up Excess Ballast for Redistribution

2.4 Management Approach

In both Europe and North America, the management approach is to improve their management of ballast profiles by deployment of modern technology and state of the art on track equipment.

2.5 Technology Involved

The technology used within the above approaches is:

- Laser scanning systems;
- Bespoke software developed for the identification of actual versus desired ballast profiles enabling calculation of additional requirements;
- GPS location systems; and
- Ballast wagons fitted with automatic unloading systems controlled by on-train software system.

All the above technologies are available and proven in either Europe or North America.

3.0 CURRENT BRITISH APPROACH

3.1 Methodology

In Britain, ballast profiles are maintained by a combination of inspection and ballast drops. These are usually planned by the local track supervisor.

Assessments of ballast required to maintain compliant profiles are carried out within normal track inspections undertaken by the track inspectors, or the supervisors themselves. No specialist measuring equipment is used. Assessments are undertaken by visual means with only the occasional use of measuring tapes. The supervisor also has to assess ballast requirements for tamping work that is planned on his section.

As a result of these inspections, a ballast requirement is developed and appropriate numbers of ballast trains are ordered some 40 weeks before they are required. These are then unloaded where necessary.

Unloading is always undertaken within track possessions. Ballast is usually delivered using trains consisting of 60 tonne Autoballaster wagons, normally in rakes of 10 or 15 wagons. These wagons are operated by two operators. It is standard practice for two members of the local track staff to accompany the train to assist in getting the correct quantity of ballast dropped where necessary.

The following shortcomings have been identified with the current process:

- The assessment of ballast requirement is based on visual identification of location and quantity that is required over each section of track. No measurement is made of exact distance or precise quantity required to re-establish the correct profile are made.
- Whilst the supervisor assesses the ballast required to allow for tamping operations he does not know what tamping lift will be required to overcome track geometry faults. Hence, he does not precisely know what additional stone he has to drop over the proposed tamping sites.
- The actual unloading of ballast has to be undertaken within track possessions and if the work is undertaken adjacent to an open line a possession is taken of the adjacent line to safeguard staff and protect trains from dropping ballast. The operators managing the wagon unloading are guided by section staff walking adjacent to the train.
- More maintenance, renewal and enhancement work is being programmed into track access periods, which restricts the opportunities for ballast unloading operations using existing methods.
- Incorrect quantities of ballast are unloaded in the wrong place. This then has to be correctly profiled using ballast regulation machines or by manual methods.

- Ballast regulator machines currently used in Britain do not have the capability to move large quantities of ballast in an economical manner. They concentrate on brushing the four-foot to maintain safe conditions for track inspection.

3.2 Management Approach

Management of the ballast profile throughout a track section is the responsibility of the section track supervisor, who has to ensure that it is in accordance with Network Rail maintenance standards. Ballast unloading to re-establish the correct profile is usually undertaken over the winter and spring months to ensure that the track is stable during the expected periods of high temperatures during the summer.

3.3 Technology Involved

The key technologies used in Britain at the moment, within ballast profile management, is that involved with the Autoballaster trains for ballast unloading and the ballast regulating machines. Inspection and assessment techniques can be considered to currently involve only low technology solutions.

4.0 BENEFITS

4.1 Asset Management

The management of the ballast profile in Britain is important for safety and operational reasons. The asset management benefits realisable from the introduction of current best practice from Europe and North America are seen as follows:

- A reduction in the overall take of ballast, as the ballast management process is improved;
- Environmental impact reduced as the use of new ballast is minimised;
- A reduction in the use of track possessions for ballast unloading operations;
- Traffic disruption due to precautionary hot weather speed restrictions reduced by better ballast profile management;
- Reduced use of ballast trains whilst surplus ballast is redistributed;
- Improved efficiency by better linkage between unloading, regulating and tamping operations; and
- More visibility to all stakeholders that value for money is being achieving.

4.2 Efficiency Savings

It is not the intent of these papers to provide a detailed, bottom-up, financial analysis. The efficiency assessments are simple analyses that provide an indication of the financial advantages if best European practice was adopted in preference to current British practice.

The following efficiency savings have been obtained from using ballast profile measuring systems in conjunction with automatically controlled ballast unloading wagons in Austria and North America:

- A significant reduction in ballast train cycle times has been achieved, allowing 68% more work to be undertaken with the available resource;
- Union Pacific identified a 14% reduction in their ballast wagon fleet, resulting in a saving of both maintenance and operational costs, with the lower numbers of ballast trains reducing fuel and train crew requirements; and
- Labour costs have been saved both directly through the removal of staff with the use of the automatic system of unloading and through the reduction in the risk of injury to labour involved in the process;

In addition, use of the ballast distribution system has provided the following improvements:

- OBB have reduced their overall requirement for new ballast by 38%;
- OBB have also saved some 60% of pre-deposition ballast required for tamping operations;

- Amtrak identified that in the first year of operation they were able to reduce their ballast take by some 71% and estimated that the system paid for itself in two years.

Further unidentified savings will have been obtained when track access and delivery costs are taken into account.

On the basis of this experience, the following savings are obtainable:

- Less maintenance stone required through ballast excess redistribution;
  A 38% saving in requirement for new maintenance ballast is estimated on a top stone take of 1.2 million tonnes, estimated at £4,300k per annum. Note that this saving will reduce.
- Improved placement of new maintenance stone using the automatic discharge concept;
  This on-going saving is assessed as 10% of 0.5 million tonnes, estimated as £500k per annum.
- Reduced manpower utilised in dropping new ballast;
  Use of the automatic discharge wagons will require less manpower resource, estimated as the equivalent saving of 8 track staff, with a value of £400k per annum.
- Reduction in possessions required for ballast unloading;
  The productivity improvements gained from using the automatic discharge concept will reduce the number of possessions required. It is estimated that approximately 700 possessions per annum will be saved, providing cost efficiencies of £1,000k each year.
- Reduction in size of existing ballast delivery wagon fleet;
  The productivity improvements will also enable the size of the wagon fleet to be reduced, providing reductions in maintenance costs. It is estimated that approximately 150 wagons could be withdrawn, providing a further £75k saving per annum.

Other potential savings, that have not been quantified include:

- Reduction in compensation payments to train operators for possessions;
- Potential benefits train operators as track access requirements are reduced (in line with the seven day railway concept);
- Improved management of the ballast profile reduces need for speed restrictions in association with hot weather precautions; and
- Less safety related incidents involved with ballast drops

4.3 Life Cycle Costs

Life cycle costs are optimised through an efficient ballast management system that ensures that a correct ballast profile is achieved and maintained. This eliminates excess delivery and the necessity to mine and create too much ballast.

5.0 SAFETY ISSUES

A key safety improvement is the removal of staff from risks areas involved with the unloading process, such as on the ground in close proximity to moving vehicles.

6.0 IMPLEMENTATION INTO GREAT BRITAIN

6.1 Estimated Implementation Duration

An outline list of key items that will need to be addressed to implement the proposal includes:

- Undertake feasibility study that will include consideration of the following:
    - Conversion of existing wagons to ballast distribution system capability;
    - Assessment of ballast profile software;
    - Development of operational specification for ballast distribution system;
    - Development of detailed business case for investment approval;
    - Development of associated ballast management process; and
    - Details of necessary trials, including success criteria.
- Procurement of ballast distribution system equipment, including safety and product approval processes;
- Conversion of existing ballast wagons to the automatic ballast discharge concept;
- Procurement, safety approval, fitting and trials of high speed laser scanning system to appropriate inspection vehicles; and
- Phased introduction of the new process across the complete network

Local engineers and supervisory staff must be involved in the trial and implementation to ensure their buy-in to the proposed changes.

The likely timescale for full implementation of the above programme is estimated as four to five years. However, benefits would start to be accrued from Year 3 as ballast profiling starts and the new trains commence redistribution and unloading of stone.

In order to minimise the implementation time and optimise the benefits, it would be preferable to work in a partnership with companies with experience of these systems.

6.2 Constraints and Dependencies

There are several constraints that are particular to the British infrastructure that will need to be overcome. These include:

- The track infrastructure has more assets attached to it than is generally found elsewhere. This includes signalling infrastructure such as balises and TPWS grids plus overhead line equipment such as bonding cables. Any new ballast management process will have to accommodate for this type of infrastructure (possibly by adopting the same solution as is used to accommodate switch rails in North America).
- In order to operate over the entire network, the use of automatically controlled ballast unloading vehicles will have to be reviewed and may require modification to accommodate the third rail infrastructure in the south east of Britain.

6.3 Investment Requirements

It has been assumed that track renewal and enhancement works have a requirement for new ballast of approximately 1.7m tonnes per annum. Thus, the annual quantity of maintenance ballast required is 1.3 million tonnes. To deliver this 85% of the maintenance ballast will require 45 dedicated wagons, formed into three plus trains. This includes an allowance for redistribution using a ballast distribution system.

Based on these assumptions, is anticipated therefore that the following investment will be required.

4 number high speed laser scanning systems	£950k
Conversion of 45 ballast wagons and 4 locomotives to automatically controlled ballast unloading format	£2250k
Procurement of two ballast redistribution systems	£7650k

Note that the ballast redistribution systems will provide benefits beyond the scope of this paper, such as to track renewals activities.

7.0 RECOMMENDATIONS FOR FURTHER WORK

It is recommended that the following additional studies are undertaken:

- OBB has successfully integrated ballast management into their tamping operations. Both operations are undertaken together. Important lessons and further efficiency gains may be gained by studying this work.

Balfour Beatty
Rail