Intelligent Ballast Management Will Cut Costs

Track authorities and vertically-integrated railways can achieve major savings in track maintenance costs by adopting intelligent ballast management with the aid of the latest technology in ballast distribution and profiling.

Helmut Misar
Technical Information Department,
Plasser & Theurer, Austria

This Amtrak machine has a material conveyor and hopper unit to increase capacity.

EVERY kilometre of a conventional double-track line has between 3000 and 5000m^3 of ballast, depending on the type of permanent way and the track spacing. The economical handling and management of these huge quantities of material pose a great challenge for track maintenance contractors.

The ballast is required to distribute the load from the sleepers as uniformly as possible over the foundation, to give the sleepers and track sufficient resistance against lateral and longitudinal movement, and to keep the track dry by providing the best possible passage for the circulation of air and water run-off.

During maintenance, the target geometry of the track or the switch should be restored without substantial exchange of track materials. This is performed using levelling, lining and tamping machines. The ballast cross-section is formed by ballast profiling machines.

A knowledge of the quantities of ballast in the track is the start of efficient ballast management. Machines can be equipped with a laser measuring system and an integrated computer evaluation to measure the ballast profile.

A laser scanner acts here as a non-contact measuring system, scanning the track in two dimensions. When the laser pulse hits the ballast profile, it is reflected and registered in the laser receiver. The contour of the ballast profile is calculated from the sequence of pulses received and the evaluation performed in the unit.

The measured profile can be superimposed on the target profile on the computer screen. This enables the ballast plough operator to select the ideal positioning of the plough shares or insert ballast from a hopper. The computer also displays the ballast surplus or deficiency as a bar chart, for example.

Using such equipment to monitor the ballast profile enables extremely cost-efficient ballast management. A ballast profiling machine with sweeper unit and ballast hopper is required to pick up and deposit the ballast at the appropriate spots (Figure 1).

The AFM 2000 automatic track finishing machine is the first to provide all these functions. It has been working on Austrian Federal Railways (ÖBB) since 1998 as part of an MDZ 2000 Mechanised Maintenance Train.

When the profile measuring device is mounted on a track recording car, such as an EM-SAT 120, it is possible to plan ballast management in advance by selecting the appropriate ballast ploughs (with or without a ballast hopper) and by calculating on a PC the exact volume differences which can be displayed and processed.

During ballast work, the ballast is rearranged, so it might be worth assessing ballast quality, especially on the shoulders, at the same time. The production of so-called radargrammes enables the ballast situation to be recorded very accurately.

Using special antennae, extremely short electromagnetic pulses (300 to 1000MHz) are injected into the track ballast. These pulses are reflected on the edges of ballast layers or individual objects and then conditioned by special software. When the data has been processed, the exact layer-by-layer image of the track is displayed continuously on the monitor to show damage spots, fouling, and order of layers.

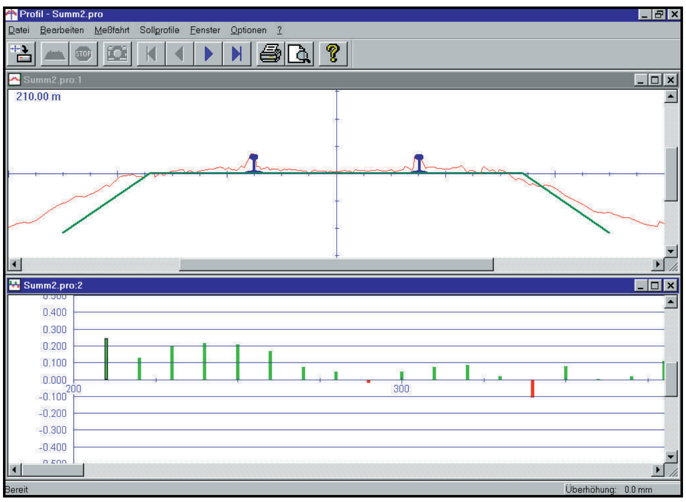


Figure 1: Display of ballast profile and related ballast quantities.

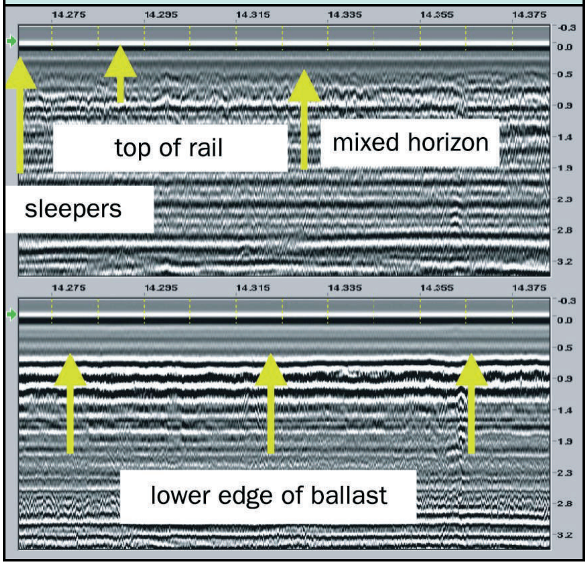
With the Geo-Radar system developed by Wiebe, which is now known as GeoRail, an additional profile is produced on the track side as well as the normal profiles in track axis and on the field side. The sensors can penetrate to a depth of up to 4m. Another special antenna serves as a "ballast magnifying glass". With a penetration depth of 1.4m it offers an even higher vertical resolution.

The four profiles per track are produced concurrently at a speed of 30km/h. The output per shift is up to 200km. Four recordings correspond to 800km of recorded profiles. The layout structure is documented without interruption.

The physical horizontal resolution, which is very important to assess fault spots, covers seven to 10 separate scans per linear metre. Each scan is produced from around 1000 transmitted pulses. This makes it possible to display the layout sharply on a scale of 1:500 (standard 1:2500). This is imperative to evaluate the ballast quality and document fault spots.

Measurements on the field side and track side indicate a general tendency: sometimes the track axis appears to be fouled, whereas the field side shows a clean and clearly reflecting continuous lower edge of the ballast. Therefore the track axis is more heavily fouled due to operating circumstances. The shoulder is generally cleaner or the shoulder may have been cleaned. The same applies for the track side.

FIGURE 2: RADARGRAMME



Thus the ballast available there is a good starting material for inserting the ballast from the shoulder or from the middle section into the tamping area of the track.

The radargramme example (Figure 2) shows a uniform fouling in the track axis (top) and a cleaned shoulder (below).

The following statement appears in a German Rail (DB) text book: "To produce the ballast cross-section *heavy demands* are also made on modern ballast profiling machines." As cost becomes increasingly important, ballast profiling machines have to fulfil the following criteria:

- rapid availability
- high working speed, adapted to three-sleeper tamping machines or other high-capacity machines
- high sweeper capacity with excellent performance
- ballast storage facilities
- continuous working action and exact re-profiling of the ballast cross-section in one pass, and
- compliance with the applicable standards (CEN).

DB's permanent way guidelines state: "For work on the ballast bed, the ballast embankment should be produced with the natural angle of repose (1:1.25). The design of the ballast cross-section should be based on a cross-fall of the ballast embankment of 1:1.5." Depending upon the line speed, the sleepers must be ballasted around the ends by 0.4 to 0.5m (plus a maximum of 0.1m).

Due to the tolerance of the slope of the ballast embankment in the specified ballast cross-section, it is possible to plough the ballast upwards into the tamping area and distribute it in the ballast crown area. The shoulder angle for the cross-fall is between about 31 and 38^o (measured from the horizontal).

Over time, the shoulder angle following maintenance will flatten due to environmental influences and traffic, so ploughing can counteract uneconomical widening of the ballast bed. Due to the differences in the shoulder angle, ballast can be reclaimed for re-use in other areas. Therefore, the ballast within the standard ballast cross-section can be managed extremely cost-effectively.

Ballast profiling in the central section of a double-track line requires a slewing limitation of the side plough. With the help of a computer-based measuring device, the shoulder plough can be operated in this area without problems. Once the track spacing is defined, the electronically-controlled measuring unit only allows a working width which does not foul the standard clearance gauge of the adjacent track and enables unhindered travel on the adjacent track. Recovered ballast from the central section can also be utilised. When the slewing limitation was introduced in 1986-87, it was estimated by DB that around 990,000 tonnes of ballast could be reclaimed annually from the central section.

The shoulder ploughs of Plasser & Theurer's profiling machines fully comply with the operational requirements. In the low position, they are extended to the sides and not folded down. This also ensures that the plough slewing movements do not affect the adjacent profile. The ploughs have a large adjustment range from 0 to 45^o, and an additional adjustment range over the horizontal of around 10^o for operations in stations. To enable relatively small setting angles that favour the ballast flow in the ascending area, the side ploughs have a long plough share. Some models are fitted with optional equipment to clear the side area using movable end plates or a rotating brush.

Symmetrical plough shares with feeder plates on both plough sides enable work in either direction. Telescopic designs also allow operation even on a superelevation of up to 150mm on the outer side of the curve.

Sharp-edged ballast is brought into the tamping area by ploughing and drawing up the ballast from the shoulder to the ballast crown. This circulates material in the ballast bed so that practically new ballast is available for the next tamping operation, thereby maximising intervals between tamping.

Ploughing the shoulder and clearing the side path helps to combat vegetation growth. However, as this consists mainly of treating the upper layers of ballast, accumulations of humus in the ballast bed or any deep roots will not be reached.

Front or middle ploughs, which are used to treat the upper ballast bed, are designed in V-shape and carry out simple jobs, whereas centre ploughs in a cross plough design can work in both directions and perform complex tasks.

Usually a middle plough is used on high-capacity ballast profiling machines to take up the ballast from the shoulder ploughs and distribute it along the trackbed. This makes it possible to move ballast across the entire trackbed, from one shoulder to the other, or from the shoulder to the centre area or vice versa. In one combined operation, ballast can be ploughed away or ballast added wherever required.

Ideally, the tamping area is filled. By appropriate height adjustment, a maximum of one grain size over the upper edge of sleeper should remain. Additional baffle plates, adjustable longitudinally, improve the ballasting of the tamping zone and protect the track conductor lying in the middle from damage caused by undesirable ballast flow. A channel covering protects the rail and the fastenings, but still allows the ballast to flow. Control of the plates enables rapid adjustment of the ballast flow.

Partial application in switches and crossings is possible due to the plough halves being split down the middle longitudinally.

After tamping and ploughing it is important, especially on lines with a maximum speed of above 140km/h, to sweep the sleeper surfaces and ballast cribs thoroughly using the sweeper unit to prevent ballast being swirled up when trains pass at high speed.

The profiling machine can be equipped either with a sweeper unit with transverse conveyor belt or, if there is a ballast hopper, with a sweeper conveyor unit which moves the material via a steep conveyor belt to the ballast hopper. From there it can be placed in areas which lack ballast. On machines without a ballast hopper the surplus material is deposited on one of the flanks by the reversible transverse conveyor belt.

Plasser's AFM 2000 automatic track finishing machine in operation on Austrian Federal Railways' network.

The rotating sweeper brush is powered hydrostatically with optimum turning capacity at high torque and with step-less speed adjustment. A rapid change system allows speedy conversion of the brush shaft, enabling rapid reaction to the prevailing sleeper shapes or the need for lower sweeping in sleeper cribs between the rails.

On lines with a maximum speed above 140km/h, the sleeper cribs between the rails should be swept out 3 to 6cm lower than the upper edge of the sleeper. The machine can be equipped with a dust-arresting sprinkler to dampen dust during sweeping. A second sweeper unit is recommended to achieve high working speeds. The first sweeper brush performs the rough work and the second one the fine work.

Plasser & Theurer ballast distributing and profiling machines can be equipped with ballast hoppers ranging in capacity from 5 to 13m^3. With a density of 1.65tonne/m^3, this is equivalent to 8.25 to 21.5 tonnes. At current ballast prices, such quantities of ballast are worth around Euros 90 to 220.

Ballast recovery is actually a side effect of the ploughing and profiling work. However, ballast distribution and profiling machines that do not have a ballast hopper can only displace the ballast in the immediate vicinity and produce the desired profile, whereas a hopper enables quantities of ballast to be moved where it is needed. This also avoids separate runs with ballast trains.

Amtrak took ballast management a step further with the introduction of the Ballast Distribution System (BDS). The holding capacity of the unit can be enlarged as required by adding material conveyor and hopper units.

This system consists of two machines operating independently. The front machine section has a ballast metering unit, a plough to work on the ballast crown, and shoulder ploughs. An integrated ballast hopper has storage capacity of 25m^3. The second machine carries the sweeper unit and the conveyor belt which transports the ballast to the hopper and the hopper units in between.

The BDS was introduced in May 1991. As a result, Amtrak was able to reduce its purchase of new ballast by 71% during the remainder of that year, a saving of around US$ 360,000, which is equivalent to about 34,000 tonnes of ballast. Other benefits were that Amtrak did not require work trains, gangs to unload the ballast, or other machines to profile the ballast bed. Amtrak estimates the system paid for itself within two years.

Today, high-capacity ballast distribution and profiling machines operate in continuous working action and combine all individual functions in one work sequence. Depending on the individual requirements for output and storage capacity, machines are now available with a total mass of 15 to 85 tonnes and with two to six axles.

The ballast distribution and profiling machine is an important part of a mechanised maintenance train (MDZ), led by a levelling, lining and tamping machine, and designed to keep pace with the increasingly higher outputs of the tamping machines.

Universal or switch tamping machines with a sweeper-conveyor unit and ballast hopper have proven their worth by having ballast available in the switch area.

A combination of the dynamic track stabiliser with front ploughs and sweeper unit at the rear have been designed for track maintenance in Japan, as has a similar combination for the maintenance of high-speed lines in France.

Using intelligent ballast management systems has the potential for large reductions in the amount of new ballast that needs to be purchased annually and thereby avoid the associated transport and unloading costs. The irregular distribution of ballast along the track also represents a source of potential savings. There is too much ballast on many sections of track compared with the standard profile which could be re-distributed. Track renewal, with a change of sleeper type and ballast profile, can also cause a surplus of ballast, either due to the larger sleeper cross-section or a change of the standard profile. **IRJ**

A universal ballast distribution and profiling machine operated by DB Bahnbau.

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