Achieving an optimum ballast bed — key to track geometry quality — by means of state-of-the-art ballast distribution and profiling machines

The ballast bed is the foundation of a railway track and, therefore, it must be constructed and maintained with particular care. The use of state-of-the-art ballast distribution and profiling machines, in conjunction with tamping, is crucial for achieving a technologically correct ballast bed, as well as a high track geometry durability, in an efficient and cost-effective manner and, thus, optimising the life-cycle cost (LCC) of the railway track.

By: Ing. Roman Hauke, Head of Technical Department, Plasser & Theurer, Vienna, Austria.

THE BALLAST BED – FUNCTIONS AND FEATURES

Each track component has a specific function and, therefore, needs to have particular features, which also rings true for the ballast bed.

The ballast bed has to:

— allow a uniform distribution of traffic loads onto the track substructure;
— provide a high resistance to sleeper displacement (both longitudinal and lateral);
— ensure that the track formation remains dry;
— provide ventilation for the track substructure;
— provide optimum conditions for achieving a durable track geometry correction.

Therefore, the ballast bed has to be:

— adequately dimensioned (cross-section, thickness);
— elastic, but also highly compacted;
— air and water permeable.

Traffic loads subject the ballast bed to static and dynamic stresses. The ballast bed and the subsoil must absorb the pressures and tensions caused by the vertical forces [1]. Therefore, the ballast bed has to be dimensioned in such a manner that traffic loads, which act on the rails and then via the sleepers and the ballast bed onto the substructure, are distributed as uniformly as possible. Over time, however, the static and dynamic stresses affect the track geometry, due to settlement of the ballast stones. Once certain pre-defined threshold values, or so-called intervention levels, have been reached, the track geometry has to be corrected as regards longitudinal level and alignment, and also the required dimensions and air/water permeability of the ballast bed has to be restored, in order to ensure its proper functioning.

Track geometry correction can be effected by means of tamping and dynamic track stabilisation. However, for tamping to have the required effect, it is crucial that the ballast bed is optimally dimensioned – this is why tamping and restoration of the cross-section and thickness of the ballast bed is both a joint and an integrated process.

Restoration of the ballast bed cross-section

Prior to tamping, it must be ensured that sufficient ballast is in place. If this is not the case then, depending on the ballast management system used, either new ballast can be deposited or ballast be transferred from sections of track that have a surplus to those that have a shortage. Following tamping, the sleeper cribs must be filled with ballast, in order to prevent the consolidated ballast from flowing into the cribs when the track is under load and, thus, ensure sustainable tamping results. The amount of ballast present at the sleeper ends is decisive for the level of track resistance to lateral displacement. Insufficient ballasting of the sleeper ends increases the risk of track buckling. Therefore, it is of the utmost importance that ballast is added where there is a shortage and that the ballast bed is profiled in accordance with prevailing regulations.

BALLAST MANAGEMENT SYSTEMS – OPERATING PRINCIPLE AND CRITERIA FOR MACHINE SELECTION

As noted earlier, for tamping work to have the required effect as regards track geometry correction, it is crucial that the ballast bed is optimally dimensioned – this is why tamping is always performed in conjunction with ballast management. Optimum ballast management can be achieved in an efficient and cost-effective manner by using state-of-the-art ballast distribution and profiling machines, such as the Plasser & Theurer BDS 2000 E^3 and USP 4000 SWS shown in Figs. 1 and 2, respectively.

Fig. 1: The Plasser & Theurer BDS 2000 E^3 ballast distribution and profiling machine with hybrid drive technology achieves a high efficiency in ballast management in an environmentally-friendly manner

Fig. 2: The Plasser & Theurer USP 4000 SWS ballast distribution and profiling machine for plain track and turnouts — this machine, in conformity with TSI Noise 2015 [2], has a number of noise and dust reduction features, thus making it suitable for operation in areas that are sensitive to noise and dust emissions

Machine operating principle

The work units of ballast distribution and profiling machines operate as follows:

— *the front plough (Fig. 3)* levels and pre-distributes the ballast that has been deposited;

Fig. 3: Front plough

— *the adjustable shoulder ploughs (Fig. 4)* profile the ballast shoulders and draw the ballast into the sleeper-end area and towards the ballast crown.

The front end of the shoulder ploughs can be split and adjusted to allow the removal of any ballast that may be present on the track bench.

A slewing limitation ensures that the shoulder ploughs do not infringe the clearance gauge of the adjacent track, thus traffic on the adjacent track can continue without disruption;

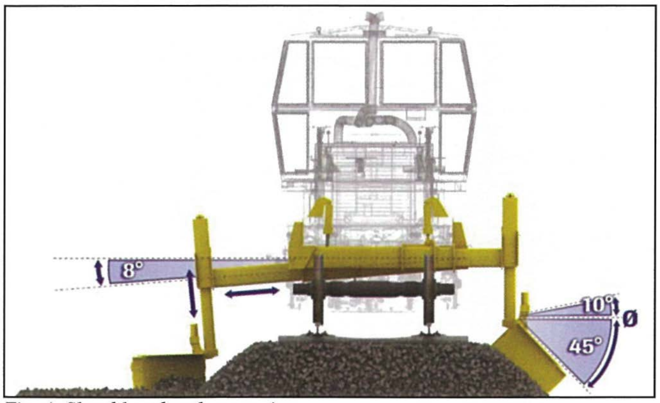

Fig. 4: Shoulder plough operation

— *the crown plough (Fig. 5)* takes the ballast from the sleeper-end area and distributes it in the crown area of the track using adjustable baffle plates. In order to protect the rail fastenings, as well as the rails, the crown plough is fitted with rail fastening protection covers (on large machines, the crown plough is usually configured as a centre plough, and on smaller machines as a front plough);

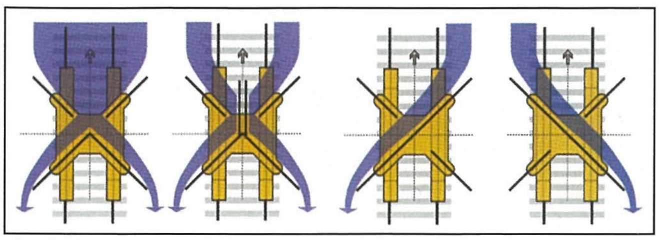

Fig. 5: Crown plough operation

— *the sweeper unit (Fig. 6)* clears any ballast stones that may have been left behind on the sleepers, which are then deposited either to the side of the track or, for greater cost-efficiency, transferred via a conveyor belt to a ballast storage hopper – this allows it to be re-used, for instance, in locations where there is a shortage of ballast. As the output of the sweeper unit determines the performance of the overall machine, ballast management systems may be fitted with more than one sweeper unit;

Fig. 6: The high-capacity sweeper unit of the BDS 2000 ballast distribution and profiling machine

— *the rail fastening brush* clears away any ballast that has remained in the rail fastening areas;
— *the fine sweeper brush (optional device)* takes care of final sleeper surface cleaning and dust removal.

Important matters of attention for when performing ballast distribution and profiling

When performing ballast distribution and profiling, it is of the utmost importance that – in compliance with staff protection regulations – ballast is removed from the track bench, the rail web and the rail fastening areas, as well as from the surface of sleepers, as otherwise accidents may occur when walking on the track bench or along the track. As noted earlier, the front end of the shoulder ploughs can be split and adjusted to allow the removal of ballast that may be present on the track bench.

Another matter that deserves specific attention is the need to avoid the risk of flying ballast, especially on high-speed lines, as this may cause damage to devices and equipment located underneath the train. It goes without saying that – to avoid ballast from flying around, it must never be pre-deposited on high-speed lines, and also all ballast stones must be removed from the surface of the sleepers. Further, deep sweeping should be applied. For instance, on the high-speed lines (≥ 200 km/h) of ÖBB, the ballast level in the sleeper cribs is lowered to 4-5 cm below top of sleeper.

Machine selection criteria

Ballast management entails the transferring of ballast from sections of track that have a surplus to those that have a shortage. With modern ballast distribution and profiling machines this can be done in a continuous operation, whilst the track is being maintained. Depending on prevailing worksite conditions, different tamping machines and ballast management systems are used as part of a mechanised maintenance train (MDZ).

The MDZ concept is successfully applied on many railways around the world – on high-capacity lines (high-speed and heavy-haul), standard and regional lines, urban and industrial lines, either featuring narrow-gauge or standard-gauge track, and each having its own specific demands that are met by different MDZ configurations. The selection of machines to be included in a MDZ configuration is determined by the design of the lead machine, which ranges from a high-capacity, continuous-action four-sleeper tamping machine in standard railway vehicle design to a two-axle single-sleeper tamping machine working in cyclic mode.

Within the main MDZ configurations, there are numerous variations possible to create the best fit for the specific task at hand.

Accordingly, there is a wide range of ballast management systems available, ranging from compact systems for complementing cyclic-action tamping machines to systems that can be used with high-capacity tamping machines or as independent ballast management systems. When selecting a ballast management system, it should first be determined:
— whether the machine will be operated solely on plain track or on both plain track and turnouts;
— what type of tamping machine will be used;
— what the working speed of the tamping machine will be – the output of the ballast management system in a "one-pass" process (distributing, profiling and sweeping in a single pass) should correspond to the working speed of the tamping machine;
— whether, for levelling the ballast in longitudinal direction of the track, any ballast will need to be picked up, stored and returned to the track, or rather whether a ballast storage hopper will be needed and, if so, what size – the storage capacity of a ballast hopper significantly determines the output of both tamping and ballast management;
— whether the machine will be operated on railway lines with multiple tracks – if so, the machine must be equipped with a slewing limitation, in order to ensure that trains can pass safely on the adjacent track;
— whether the machine will be operated in areas that are sensitive to noise and dust emissions. When developing new machines, a special focus is placed on the reduction of noise and dust emissions. The USP 4000 SWS universal ballast distribution and profiling machine (Fig. 2), for instance, in conformity with TSI Noise 2015 [2], features a number of noise and dust reduction measures. Its sweeper unit has a special rubber lining that not only reduces noise, but also wear, and its integrated 5 m^3 ballast storage hopper features a lining of plastic sheets. There is also a dust arresting atomiser in place, which ensures that there is a minimum of dust emissions;
— whether the machine will be operated on high-speed lines (in Austria ≥ 200 km/h). If so,
  — deep sweeping will be required; and
  — ballast must not be pre-deposited;
  in order to prevent ballast from flying around, which may cause damage to devices and equipment located underneath the train. Therefore, on high-speed lines, ballast must never be pre-deposited. As noted earlier, in order to avoid ballast flying, deep sweeping is applied on the ÖBB high-speed lines (≥ 200 km/h), whereby the ballast level in the sleeper cribs is lowered to 4-5 cm below top of sleeper.

THE BDS 2000 – MACHINE OF CHOICE FOR BALLAST MANAGEMENT ON ÖBB

For performing ballast management, ÖBB Infrastruktur AG has opted for the BDS 2000 ballast distribution and profiling machine. For over a decade, it has successfully proven its high efficiency as regards the pre-depositing and relocation of ballast in the course of track geometry correction work, using high-capacity three-sleeper (09-3X), as well as four-sleeper (09-4X) tamping machines.

Before tamping is conducted, a survey of the actual track geometry is performed by measuring both longitudinal level and alignment, in order to allow the correction values to guide the tamping machine to be calculated, and also the actual ballast profile is measured. The pre-measuring run is performed using an EM-SAT track survey car that is also equipped with a non-contacting ballast profile measuring system which, by means of a laser scanner, records the actual ballast profile. The recording results enable decisions to be made about the lifts to be performed and the prevailing ballast requirements. Taking into account the lifts to be carried out, it is determined in an automated process where there is a surplus of ballast that must be picked up and where there is a shortage and ballast must be added, in order to produce the standard ballast profile. If additional ballast is needed, it can be supplied by the BDS 2000 when it arrives at the worksite.

Following tamping, the BDS 2000 can pick up surplus ballast when profiling the ballast bed, store it in its integrated large hopper or in additional MFS material conveyor & hopper units, if needed, and then redistribute it in locations where there is a shortage. Thus, the need for a separate supply of ballast by means of ballast trains or trucks has become obsolete.

As the BDS 2000 operates as part of a machine group that carries out standard track maintenance work (MDZ), traffic hindrance is reduced to a minimum. At the same time, the tamping output is increased significantly. This, together with the reduction of the amount of new ballast needed, significantly contributes to a reduction of track maintenance costs.

COST EFFICIENCY IN BALLAST MANAGEMENT BY USING THE BDS 2000 – AND THE BDS 2000 E^3

Ballast is an important capital asset. High investment costs for the substantial quantities of ballast needed make cost-efficient management of this resource essential. By using the BDS 2000 ballast distribution and profiling machine, which can transfer ballast from sections of track that have a surplus to those that have a shortage, in a continuous operation, during track maintenance or as an independent ballast management system, a high cost efficiency can be achieved. When working as part of a mechanised maintenance train (MDZ), a considerable saving in time, personnel and equipment is achieved and, thus, a high cost efficiency – something that the conventional method of loading, transporting, distributing, reclaiming and returning excess ballast, using ballast wagons or trucks, cannot achieve [3]. Thus, the efficient operation of the BDS 2000 has a great time and cost saving potential, which has also been confirmed by operating experience gained on various railways around the world.

ÖBB study confirms cost efficiency

In a study conducted by ÖBB, the cost of ballast management using the BDS 2000 was compared with that incurred when using conventional ballasting methods in the course of maintenance tamping. The following factors were taken into account in the calculation:

— the reduction in the quantity of new ballast needed;
— the cost of new ballast;
— the cost of transporting ballast;
— the cost for conventional ballast unloading;
— the additional cost for transporting the BDS;
— the additional machinery cost of the BDS.

The outcome of the study is clear: when the quantity of new ballast needed is reduced by approx. 38%, the BDS 2000 is the more economical alternative. On ÖBB, this mark has clearly been surpassed. An analysis of available measuring data has yielded that, by using the BDS 2000, the quantity of new ballast needed can currently be reduced by an average of 60% [4].

However, the overall cost efficiency of the BDS 2000 is far higher than this, as in the ÖBB study factors that also have a high economic relevance were not included. For instance, due to the high working speed of the BDS 2000, it was possible to increase the working speed of the overall MDZ considerably, in turn, leading to shorter track possessions and, thus, lower costs. Moreover, the uniform distribution of ballast achieved by the BDS 2000 has a very positive effect on the subsequent durability of the track geometry. The BDS 2000 has also proven its efficiency as an independent ballast management system on ÖBB where, because of a line speed increase to ≥ 200 km/h, deep sweeping needed to be carried out on more than 100 km of existing lines, in order to prevent the occurrence of flying ballast. Using the BDS 2000, this task was performed in the shortest possible time and with the least possible hindrance to traffic during the night (Fig. 7).

It should be noted that, for many years, also on other railways the use of the BDS 2000 has resulted in a high cost efficiency in ballast management. For instance, its use on the North-East corridor (New York - Washington) in the USA, significantly reduced the amount of new ballast needed (by some 70%).

Fig. 7: The BDS 2000 performing deep sweeping on ÖBB, in order to prevent ballast flying (WN)

In fact, AMTRAK estimated that the system paid for itself within two years [5]. Also in Lithuania and Latvia, the technical and economic benefits of the BDS 2000 soon convinced the engineers. In Lithuania, for instance, some 2,500 km of track was treated by the BDS 2000 during the time period 2005-2009, whereby the system paid for itself within just a few years.

The BDS 2000 E^3

Plasser & Theurer places a great importance on developing environment-friendly solutions that keep noise and exhaust-gas emissions during track work to a minimum, which is very much exampled by the fact that there is today also a hybrid version of the BDS 2000 available – the BDS 2000 E^3 (Fig. 1), which can be alternatively driven by electric or by diesel power. The machine is always powered by one power source only, i.e. either by the electric motor or the diesel engine. Whenever current can be collected from the overhead line, the entire machine can be powered electrically both during work and transfer travel. Use of hybrid drive technology not only leads to a reduction in noise and exhaust-gas emissions, but also to economic benefits [6].

FINAL REMARKS

As the ballast bed functions as the foundation of a railway track, it has to meet optimum quality requirements, which must be attained both during track construction and maintenance. Only by using state-of-the-art ballast distribution and profiling machines, in conjunction with tamping, a technologically correct ballast bed, as well as a high track geometry durability, can be achieved in an efficient and cost-effective manner, thus optimising the life-cycle cost (LCC) of the railway track.

The BDS 2000 (both the conventional and the hybrid version (E^3)) and the USP 4000 SWS noted in this article represent the leading edge of ballast management systems. They handle the ballast – a highly important capital asset, which is needed for a proper functioning of the railway track – with due care and precision.

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