Further Development of Mechanised Ballast Cleaning

The quality of the ballast track depends on the design of the rail track and on the state of the ballast bed. Only a clean ballast bed guarantees a durable, good track geometry.

The requirements on mechanised ballast cleaning can be seen from function of the ballast bed. A description of the equipment of the standard machines RM 80 U and RM 76 U made by Plasser & Theurer, which can also clean ballast in switches, is given. After outlining how the work is performed, machines for high demands, i.e. RM 800, RM 900 and RM 95, are presented with details of their cost-efficiency.

1 The Ballast Bed

1.1 Requirements on the ballast bed and the subgrade

A clean, elastic and homogeneous ballast bed is an essential pre-requisite for the wheel-on-rail system to function smoothly. The ballast bed has a considerable influence on the service life and the quality of the track geometry and consequently the cost-efficiency of the overall track maintenance.

A well-functioning ballast bed has to fulfil the following tasks:

- ▷ uniform transmission of the ballast pressure onto the subgrade,
- ▷ high resistance to longitudinal and lateral displacements of the sleepers,
- ▷ easy restoration of the track geometry after its alteration (tamping and lining work),
- ▷ assurance of the track elasticity to reduce the dynamic forces,
- ▷ good water drain-off and ventilation to assure a long service life of the sleepers and to preserve the bearing strength of the subgrade.

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The subgrade formation must also possess the following qualities:

- ▷ adequate strength to absorb and distribute the dynamic forces.
- ▷ frost stability and to prevent fine particles from penetrating the ballast.
- ▷ the subgrade must be level and have a crossfall of 4 - 5% (1:25 to 1:20) so that water falling on the ballast is drained off.

1.2 Fouling of the ballast bed – causes and effect

The desired properties of the ballast bed defined by the ballast structure will be lost if the quantity of fine particles in the ballast bed is much greater than the permissible proportion. On new ballast the permissible proportion of fine grain is normally 3 to 5 % of the total weight of the ballast specimen. (Normally ballast stones with a diameter smaller than 25 mm are regarded as fine particles.)

The causes of fouling are on the one hand the dynamic forces (causing attrition of the ballast stones) and on the other hand pollution from the air, spillage during transport (coal dust, ore, etc.) and fines rising up from the subgrade.

Fouling is caused artificially by inserting fine-grained ballast under the sleepers to correct the longitudinal level of the track. Such methods were applied around 50 years ago under the name „shovel packing“ or „Soufflage“ in Central Europe. The crushed stone used had a grain size of 10 - 22 mm. Besides the associated artificial fouling of the ballast, the main drawback of this method was that it caused a considerable reduction of the track’s resistance to lateral displacement and was smaller than after tamping without stabilisation. (In the case of tamping without stabilisation the resistance to lateral displacement is reduced by approx. 50% compared to the ballast bed compacted by traffic load.) On DB and on ÖBB therefore this method was

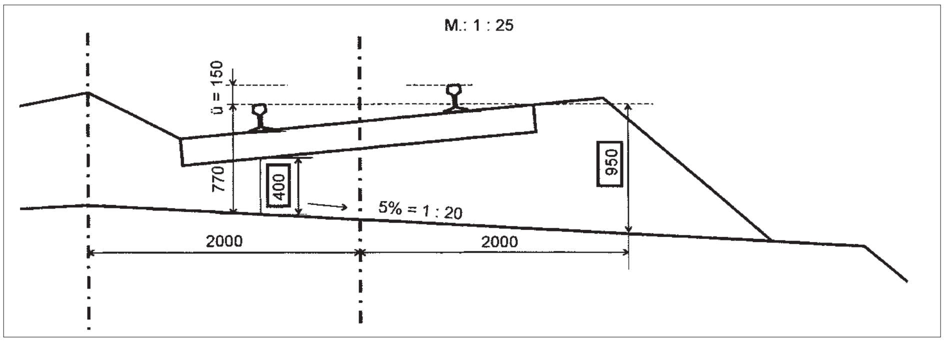


Figure 1: Excavation depth in the track for double track line, ballast profile for cleaning machine (UIC 60 rail, concrete sleepers)

not used on continuously welded track and in tracks for a speed of 100 km/h. Since the introduction of tamping machines the method has lost its importance and has not been used since on DB and on ÖBB.

For almost 20 years attempts have been made to mechanise the method (stone blower). The drawbacks are the same as for the manual method as also in this case crushed stone is used with a grain size of around 20 mm. The resistance to lateral displacement is lowered, causing a fast deterioration of the track alignment. There is also a danger of track buckling at high temperatures.

In fouled ballast the inner friction is greatly reduced. The above mentioned conditions for the ballast bed no longer exist. There are uneven settlements of the track.

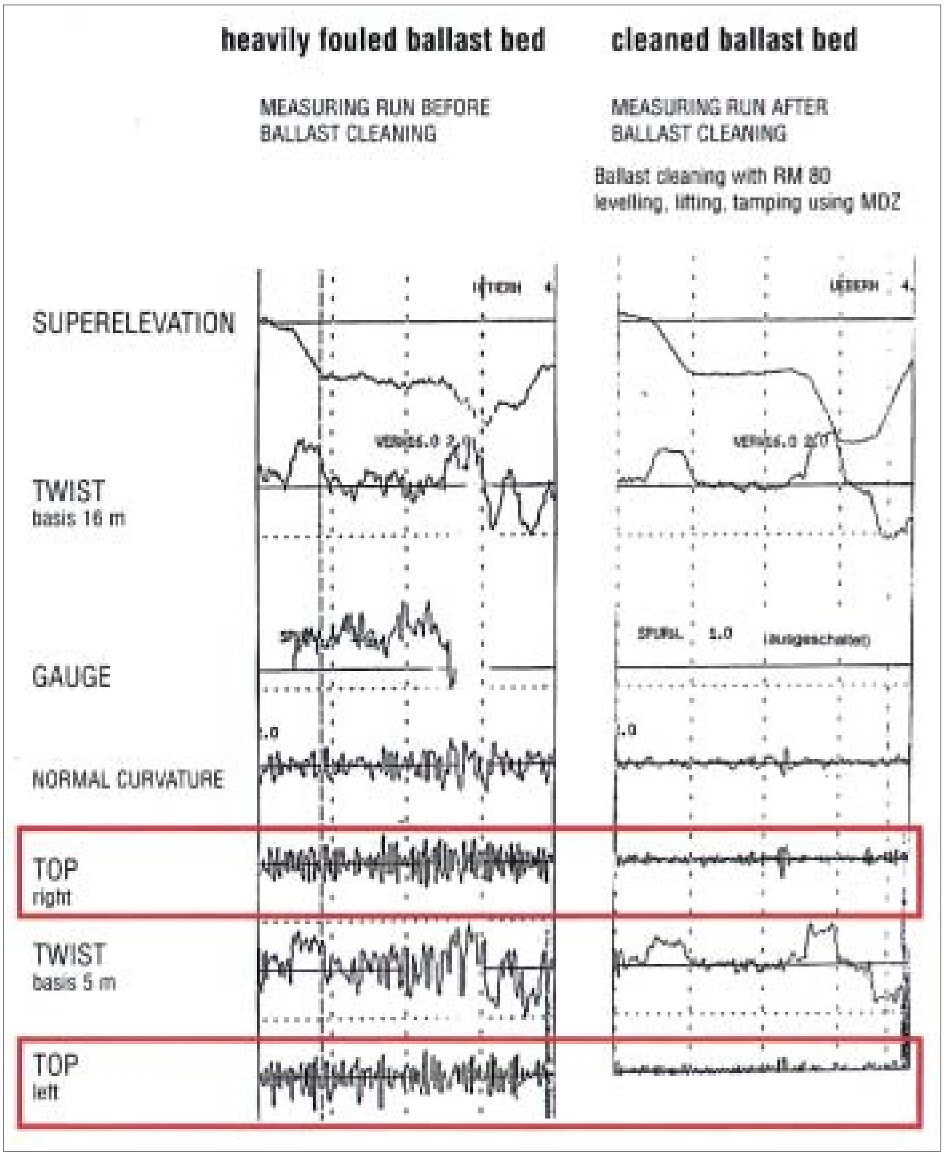


Figure 2: Recording car measuring strip

Restoration of the track geometry by „tamping“ is only effective for a short time. The track geometry deteriorates rapidly, the subgrade is subjected to even greater stresses. It goes so far until clay and mud rises to the surface of the ballast bed. Dips occur in the track which may even lead to derailments.

1.3 Need for ballast cleaning

Assuming that ballast cleaning should not be left until the track is so fouled that tamping no longer achieves any improvement of the track geometry, the correct time for ballast cleaning is reached, according to a recommendation by the ERRI (European Rail Research Institute, Question D 182), when the fouling is approx. 30% of the total weight. (screened through a 22.4 mm square-meshed screen)

A pointer to the necessity of ballast cleaning is supplied by the track measuring strip made during a measuring run of a track recording car. Short-wave longitudinal level faults occur in the track due to fouling of the ballast bed. Above all, the parameters „surface irregularity left“ and „surface irregularity right“ and the twist measurement on the 5 m base provide information on the condition of the ballast bed as these measurements are longitudinal level measurements over a short base. (Figure 2) Furthermore, if the recording car is equipped with the ADA II analysis system, the need for ballast cleaning can be determined on the basis of the so-called „RM figure“. For a freely chosen section of track – normally for 500 m – the analysis program calculates a quality figure from the change in the track irregularity.

Normally ballast cleaning is performed during an isolated exchange of the sleepers or during complete renewal of the track. Practical operations over the last decades have shown that, following a once-performed mechanical ballast cleaning and with regular maintenance of the tracks using the mechanised maintenance train (MDZ), good functionality of the ballast bed will be assured for the entire service life. However, the essential features are a strong bearing subsoil and the use of high-quality ballast stone (e.g. basaltic or diabase). If these last requirements are not assured, then an intermediate ballast cleaning will have to be performed to avoid a speed restriction. On poor subsoil a lasting solution can only be achieved by thorough rehabilitation of the track subgrade.

2 Features required on machines for ballast cleaning

To meet the above mentioned requirements with regard to the nature of the ballast bed and the subgrade, machines for ballast cleaning must provide the following features:

Excavating device

- ▷ The ballast excavating device must be designed so that it is capable of producing a level subgrade formation in longitudinal and transverse direction with a crossfall of approx. 4 – 5 % (1:25

Figure 3: RM 80 U ballast cleaning machine

to 1:20). According to the specialists, the combination of excavating chain and rigid cutter bar achieves the best results.

▷ An electronic monitoring system for the height regulation of the cutter bar is required to produce a perfectly level longitudinal direction of the subgrade formation.

▷ The ballast should be excavated over the entire width of the ballast bed. Therefore it must be possible to extend the cutter bar if required.

▷ The possible excavating depth should be approx. 1.0 m, measured from the top of the rail that is not superelevated. This enables the necessary crossfall to be produced even on superelevated tracks with opposite crossfall (Figure 1).

▷ The excavating equipment must be able to work even on hard and encrusted ballast.

Lifting and slewing device

▷ A lifting and slewing device should be available close to the excavating chain to reduce the excavating depth and to perform displacement of the track.

Vibration screening unit

▷ The vibration screen should separate all material that does not correspond to the specified stone size. The stone size should be laid down by the railway administration. Total excavation must be possible in the event of very heavy fouling.

Ballasting

▷ To achieve good track geometry when re-filling the track with ballast, the cleaned ballast must be distributed as uniformly as possible under the sleepers and around the sleeper ends.

Transport of spoil

▷ The transport of spoil should not lead to any renewed fouling of the ballast. The spoil should therefore be taken away towards the front end of the machine, in the direction of work, using a slewing depositing belt.

▷ The subsequent track correction work should not be hindered by spoil loading.

3 Ballast cleaning machines - equipment

Since 1963 Plasser & Theurer has supplied around 400 trackbound ballast cleaning machines to 58 countries around the world. The currently operating ballast cleaning machines made by Plasser & Theurer fully comply with the requirements listed above. In the following, the equipment of the standard machines, i.e. RM 76 U and RM 80 U – both powered fully hydraulically – will be described (Figure 3).

3.1 Excavating unit

The excavating unit is designed so that the entire subgrade is completed in one working pass. Depending upon the design, excavating widths up to almost 8 metres are possible. The excavating width can be varied by inserting intermediate sections, each 500 mm, in the chain cutter bar. Quick-release fastenings enable fast execution of this work.

The chains consist essentially of scraper shovels with two to five fingers, connecting links and bolts. The fingers loosen the encrusted material from the ballast bed, the scraper shovels convey the material in

Figure 4: Excavating chain – scraper shovels with 4 fingers

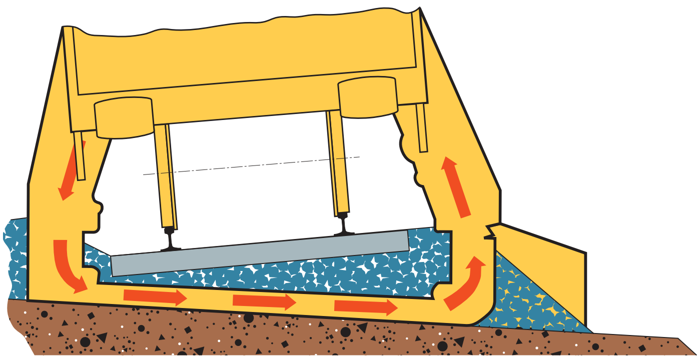


Figure 5: Positioning of cutter bar on Plasser & Theurer machines – to produce an accurate subgrade

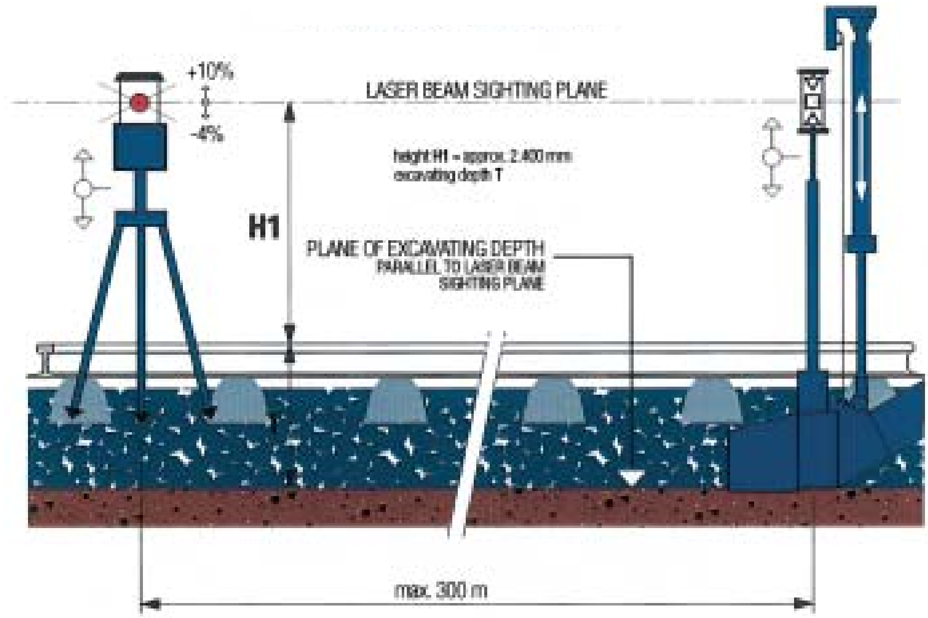


Figure 6: Excavation depth and longitudinal alignment controlled by laser measuring device

the chain guides directly to the screening unit. This process already achieves a certain degree of separation of the spoil from the ballast (Figure 4).

The chain is guided underneath the track in a cutter bar. This enables an exact and straight cut over the entire excavating width. The required crossfall of the subgrade can be produced accurately in this way (Figure 5).

To be able to avoid obstacles or to position the excavating unit in the middle of the track during work in curves, the chain guide can be displaced laterally without changing the formation crossfall or the cleaning depth.

The lifting and slewing device near to the ballast excavation enables the track to be lifted and displaced laterally.

The possible excavating depth is up to 900 mm on the RM 76 U and up to 1150 mm on the RM 80 U.

3.2 Measuring and control system for excavation depth and chain crossfall

Using an electronic measuring system, the crossfall of the chain cutter bar can be selected steplessly. Superelevation is taken into account automatically using the electronic pendulum. The main frame of the machine serves as a reference base for the excavation depth. Guidance of the excavating chain is either performed automatically or controlled manually from the work cabin.

3.3 Laser measuring device to control the excavation depth

This device automatically controls the excavation depth of the excavating chain to produce a straight subgrade in relation to the longitudinal alignment of the track. It consists basically of a rotation laser transmitter in front of the machine, a laser adjusting reference receiver unit on the machine frame, a laser receiver unit on the cutter bar and control devices. (Figure 6)

The laser control serves to extend the measuring base up to 300 m. This guarantees a uniform height of the ballast bed and also the correct crossfall of the subgrade.

3.4 The screening unit

The better the quality of the screened material, the less frequently it will have to be cleaned and tamped later. The screening quality is therefore decisive for the cost-efficiency of a ballast cleaning machine. Optimisation of the screening unit of a ballast cleaning machine with regard to quality and output is achieved through the factors: screen size, screen

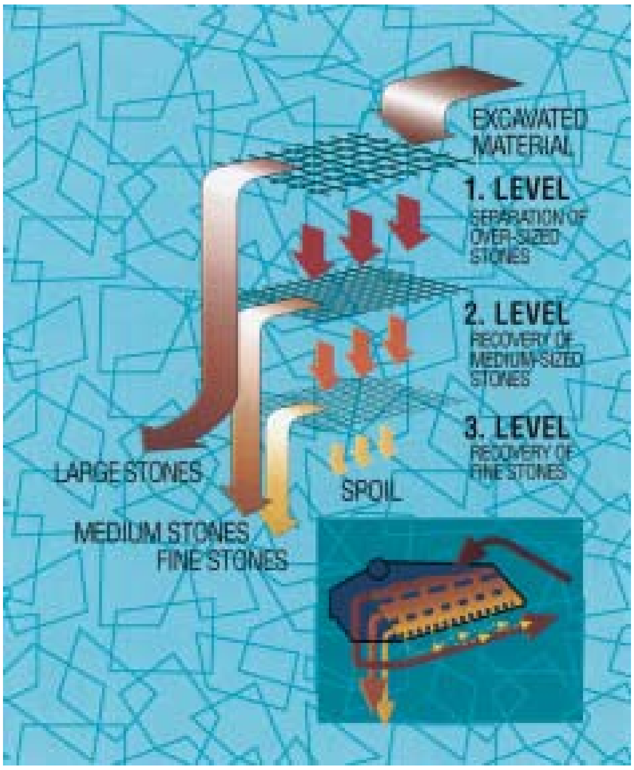


Figure 7: Three-level vibration screening unit

Figure 8: Distributing conveyor belt for re-inserting the cleaned ballast

mesh, screen vibration as well as direction of vibration and angle of the screens.

The RM 80 and RM 76 ballast cleaning machines are equipped with a 3-layer vibration screening unit with three screen levels (Fig. 7).

1st level: Separation of over-sized stones
2nd level: Recovery of medium-sized stones
3rd level: Recovery of small stones, separation of fine particles

When working on superelevation in track curves, the screening unit can be held in horizontal position by use of hydraulic cylinders. Direct loading of the excavated ballast without screening is also possible.

3.5 Ballasting

The cleaned ballast coming from the screening unit can be transported via hydraulically adjustable baffles either to slewing distribution conveyor belts or unloaded directly into the track.

The following options for ballast distribution are possible:

▷ The entire ballast is placed in the track using slewing distribution conveyor belts directly behind the excavating chain. It can be distributed there uniformly over the entire subgrade or deposited in the required zones depending upon the setting of the slewing range. The trajectory parabola of the distribution conveyor belts ensures uniform filling underneath the sleepers (Figure 8). A height-adjustable profiling device behind the trajectory device produces a perfect sleeper bed.
▷ The entire ballast falls into the track directly in the area in front of the rear bogie.
▷ Regulation of the ballast bed height, therefore any distribution either behind the excavating chain or directly in front of the bogie or a combination of both.

Due to this technology of ballast insertion, it is possible to regulate the exact height of the track.

A plough grader is positioned behind the ballast distributing unit which sweeps off the ballast left on the sleepers and even the rails during ballast cleaning and at the same time grades the ballast crown.

3.6 Transport of spoil

Spoil is taken away on a conveyor belt positioned at the front end. This conveyor belt can be slewed to enable unloading to the side. Depending upon the machine model, the conveyor belt can be either folded away or retracted. Thus no match wagon is required for transfer travel.

The spoil can either be deposited at the side of the track, loaded onto wagons standing on the adjacent track, or loaded onto a spoil handling system in front of the machine – e.g. MFS material conveyor and hopper units.

Figure 9: Lengthening the chain cutter bar to extend the excavation width (for cleaning switches)

Figure 10: MFS material conveyor and hopper unit for transporting spoil

3.7 Electronic recording unit

An electronic recording printer provides ideal quality monitoring of the work performed. The printer can record up to six parameters, such as excavation depth, subgrade crossfall and track settlement.

4 Ballast cleaning in switches and crossings

All statements made so far concerning the ballast bed also apply generally to switches and crossings. If ballast cleaning is to be performed without removing the switch, high-quality cleaning can only be achieved by using ideally designed machines. The RM 76 U or RM 80 U ballast cleaning machines are especially suitable for mechanised cleaning of switches and crossings.

The chain cutter bar can be extended to a width of 7.70 metres by inserting intermediate sections each 500 mm wide. The excavating width is extended until that point is reached where the distance between the sleeper ends is large enough for each track to be worked individually (Figure 9).

5 Execution of Work

5.1 Ballast cleaning in conjunction with track renewal

As already mentioned, ballast cleaning is normally performed in conjunction with an isolated exchange of the sleepers or complete renewal of the track. In the case of complete renewal of the track, mechanised ballast cleaning should be carried out in any case even if the degree of fouling lies under the value recommended by the ERRI, as a high initial quality of the track can only be guaranteed by a fully functioning ballast bed. The high initial quality is essential for cost-efficient maintenance and long service life of the permanent way.

Generally, ballast cleaning should be performed before the track renewal so that the new track components are not subjected to any undue stresses. Lasting deformation of the track, especially at the rail ends, can be caused by ballast trains riding over the track.

Normally only track possessions lasting a few hours are available for ballast cleaning. These should not be shorter than 8 hours if possible, so that for example when operating an RM 80 U, including supply of new ballast and a tamping pass, an output of around 900 metres per shift is achieved. For the tamping itself, an MDZ comprising levelling, lining and tamping

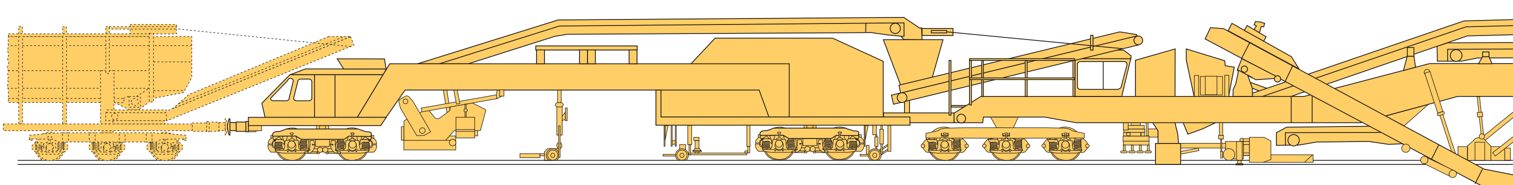


Figure 11: RM 900 high-capacity ballast cleaning machine with new ballast supply using MFS

Figure 12: RM 95 RT ballast cleaning machine according to standards developed for British Rail

machine, ballast profiling machine and dynamic track stabilizer should be used.

5.2 Loading and unloading the spoil

During ballast cleaning using trackbound cleaning machines around 0.6 to 1.0 m3 of spoil per metre of track are generated depending upon the excavation depth and the degree of fouling. Deposit of the spoil onto embankments using the conveyor belt of the cleaning machine is only possible to a limited extent. Such depositing should not be carried out at all on cuttings. In all cases where the spoil cannot be deposited to the side, it has to be loaded onto suitable railway wagons. Over the last two decades the most efficient method has proven to be the loading onto MFS material conveyor and hopper units.

A material conveyor and hopper unit (MFS), system Plasser - Knape, consists of a special car with the hopper and conveyor equipment mounted onto the vehicle frame. The floor of the hopper is designed as a conveyor belt. This allows continuous and complete loading of the MFS. A slewing conveyor belt is positioned at the front end of the unit for unloading or passing on the material (Figure 10).

Several models are in operation with differing storage capacity. Primarily the models MFS 40 and MFS 100 with a storage capacity of 40 and 68 m3 respectively are in use.

As regards cost-efficiency, a rough cost estimate shows that with an annual output of approx. 100,000 m3 of spoil, loading and unloading using MFS 40 units will incur additional costs of around 40% compared to the use of MFS 100 units.

6 Ballast cleaning machines for the highest requirements

Due to the application of track relaying machines with high output, it became necessary to develop ballast cleaning machines with a higher output. In 1988 Plasser & Theurer built the first RM 800 ballast cleaning machine with a peak output of 800 m3/h. This fully hydraulically powered machine consists of excavating car, screening car and drive car.

The major difference compared to the standard machines RM 76 U and RM 80 U is the addition of two eccentric screens with a screening area of 35 m3 each in a 3-tier design on the screening car. In the transport wagon of the cleaned ballast, between screening unit and filling unit, a large-sized ballast hopper is provided to supply missing quantities of ballast occurring at the start and end of work or when the machine is at standstill.

The machine can be equipped with a device to compact the cleaned ballast (sleeper-end tamping units) which saves a tamping pass. A variation of the RM 800 is the RM 801 in slightly lighter design.

Further developments are the RM 900 and 802 ballast cleaning machines with new ballast supply. On these machines new ballast can be taken on conveyor belts to the excavating car via the trailer at the rear from towed MFS-units (Figure 11).

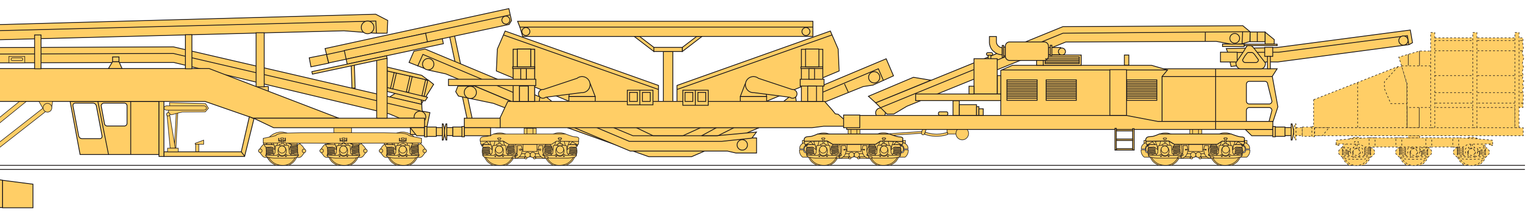
The high-capacity ballast cleaning machines of the RM 800 and RM 900 series enable the application of new measuring and regulating systems. Measuring equipment and an industrial PC allow the automatic control of excavation depth, subgrade crossfall and height of the cleaned track.

Besides these heavy-duty machines, a ballast cleaning machine with the designation RM 95 RT has recently been developed. Primarily, this machine can be operated on lines with a restricted clearance gauge and tight loading gauge. It complies for example with the special requirements of the British railway norm (Railway Group Standard GM/RT 2400). Screening is performed using a particularly large vibration screen with three screen levels. Two such ballast cleaning machines have already been supplied to England (Figure 12).

7 Cost-efficiency

High-quality cleaning of the ballast bed – as achieved for example using the Plasser & Theurer ballast cleaning machines – brings the following benefits:

- High operating safety, because on the cleaned ballast bed a perfect track geometry can be achieved using levelling, lining and tamping machines.
- Avoidance of speed restrictions. On fouled ballast there can be irregular settlements of the track. Restoration of the track geometry by „tamping“ is only effective for a short period. After track maintenance the track geometry deteriorates very quickly and in some cases the track has to be tamped 2 – 3



times a year. Speed restrictions have to be imposed to keep damage as low as possible in the event of derailments.

- Extension of the intervals between maintenance. In the cleaned ballast bed the good track geometry is retained longer than in the fouled ballast bed. Even on tracks carrying heavy traffic, the intervals between maintenance in the cleaned ballast bed can be 3 - 5 years.
- Extension of the service life of the track. A fouled ballast bed no longer possesses the required elasticity. With concrete sleepers there is a danger that these may be cracked by impacts from non-round wheels (flat spots). Wooden sleepers become rotten due to poor drainage.
- High recovery of ballast, thus savings in the purchase and in the transport of new ballast.

8 Summary

Fouling of the ballast bed leads to irregular settlements of the track. Restoration of the track geometry by „tamping“ is only effective for a short period of time. Ballast cleaning must be performed at the latest when the degree of fouling has reached 30% in weight. A pointer to the necessity of ballast cleaning is supplied by the track recording chart made during a measuring run of a track recording car or the ADA II analysis system.

To achieve high-quality cleaning of the ballast, the ballast cleaning machines have to fulfil a variety of requirements. The Plasser & Theurer ballast cleaning machines comply fully with all expectations. The equipment of the standard machines RM 76 U and RM 80 U can be regarded as perfect in respect of excavating unit, measuring and control system, screening unit, ballasting and spoil evacuation.

Basically, mechanical ballast cleaning should be undertaken either for isolated sleeper exchange or complete renewal of the permanent way.

Utilisation of the material conveyor and hopper units, especially the MFS 100, is extremely cost-efficient for loading and unloading the spoil.

Ballast cleaning machines for the highest demands have been developed since 1988. These are the machines of the RM 800 and RM 900 series. Besides peak performance, the RM 802 and RM 900 ballast cleaning machines also enable the placement of new ballast.

The RM 95 RT high-capacity ballast cleaning machine with integrated new ballast supply was developed for lines with restricted loading gauge. Two machines have already been supplied to England.

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Plasser & Theurer

The RM 900-QR high-capacity track-bed cleaning machine

The high-capacity track-bed cleaning unit, RM 900-QR, built for a rail gauge of 1067 mm, has been in service with the Queensland Rail Company in Australia since August 2001. Recently, it managed to complete work on 3200 metres of track in a single shift. The RM 900-QR is the first narrow-gauge high-capacity track-bed cleaning machine with integrated ballast recycling and equipment for adding fresh ballast (see Figure).

The machine's plough ensures that the ballast is distributed over the whole cross-section of the track. A separate compacting unit ensures that the applied ballast is automatically compacted to a predefined degree. Another separate compacting device deals with the ballast around the protruding ends of sleepers. The state of the track immediately after the cleaning machine has finished its work is good enough to permit train speeds of 70 km/h without the need for any additional tamping.

A further plus when it comes to making full use of short track-closure periods is the RM 900-QR's own onboard crane and fast-acting hydraulic clamps, which make it much easier to assemble the excavating chain, thereby appreciably reducing the necessary set-up times.

Fresh ballast is fed onto the machine from MFS units coupled to it. Immediately behind the excavating unit, the distribution chutes feed either the thoroughly cleaned ballast or fresh ballast into the tamping zones. A separate automatic compactor acts on the ballast to produce the required compaction density.

High-capacity track-bed cleaning machines of types "RM 800" and "RM 900" have been in successful use in Germany and the USA for many years. A few weeks ago, two further countries introduced the new ballast-cleaning technology: Italy (with the RM 860) and the Russian Federation (with the RM 2002). (3010)

Figure: Plasser & Theurer's RM 900-QR working in Australia