Formation rehabilitation on Austrian Federal Railways — five years of operating experience with the AHM 800-R

The improvement of the track substructure, particularly that of the formation, of existing railway lines is an important task for Austrian Federal Railways (ÖBB); as a result of the rise in speeds and traffic loads, these often outdated installations have reached the end of their technical lifetime and, thus, need to be renewed. This article looks at the experience gained during five years of operation with the Plasser & Theurer AHM 800-R formation rehabilitation machine.

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Methods previously used on Austrian Federal Railways (ÖBB) to improve the track substructure have included:

— since the end of 1960, the insertion of a protective layer composed of gravel/sand using a ballast cleaning machine;

— since 1986, the insertion of a protective layer composed of gravel/sand and fabric using a ballast cleaning machine and tamping machine ("sand tamping").

At the start of the 1990s, however, demand was growing at ÖBB for a powerful track-based machine that would be capable of efficiently installing a protective layer on the formation at a high output. This resulted in the drafting of specifications for a proposed heavy-duty machine, which included the following basic requirements:

— the length of the machine had to be as short as possible;

— both in short and longer sections of track, the machine had to have an average installation output of 40 m per hour, thereby producing a protective layer with a thickness of 45 cm;

— the machine had to have an on-board facility to add water during the installation process of the protective layer (the highest requirements of consolidation can only be achieved by the adding of water);

— the machine had to be capable of recycling excavated ballast;

— after installation of the protective layer, travel over the track on the protective layer at 10 km/h had to be possible.

Subsequently, a machine was developed featuring a throughput capacity of 800 m^3/h and a recycling plant for used ballast. It was designated as the AHM 800-R formation rehabilitation machine, a detailed description of which can be found in [1], [2] (Figs. 1 and 2).

The AHM 800-R features the following output parameters:

— total excavation is achieved in one or two passes (a second pass is required when the excavation depth is more than 1200 mm, from top of rail);

— spoil is loaded either on MFS units or deposited beside the track, up to a maximum of 6 m from the track axis;

— ballast recycling is performed in a single pass;

— installation and consolidation of the protective layer is carried out at an average output of 40 m per hour;

— longitudinal level and alignment is guided by reference wire;

— an excavation width of 4.30 to 6.00 m is achieved, steplessly adjustable;

— the track grid can be slewed up to 500 mm, and lifted up to 250 mm;

— the installation width of the protective layer ranges from 4.30 to 7.00 m (with additional output);

— integrated crushing of the excavated (used) ballast is carried out according to the granulation required;

— the new material for the protective layer is mixed with the crushed recycled ballast on-board the machine;

— water for the protective layer material can be added both inside and outside the mixing plant;

— its consolidating devices achieve a Proctor value of the protective layer of D_{Pr} 98% to 102%;

— geotextiles, geomeshing or hard-foam slabs can be installed in a single pass; the machine can carry two rolls simultaneously;

— it has a transfer speed, in train formation, of more than 100 km/h;

— the track on the formation can be travelled at V = 10 km/h;

— it has the ability to operate with substructure bearing values ranging from $E_{v2} \geq 5$ MN/m^2.

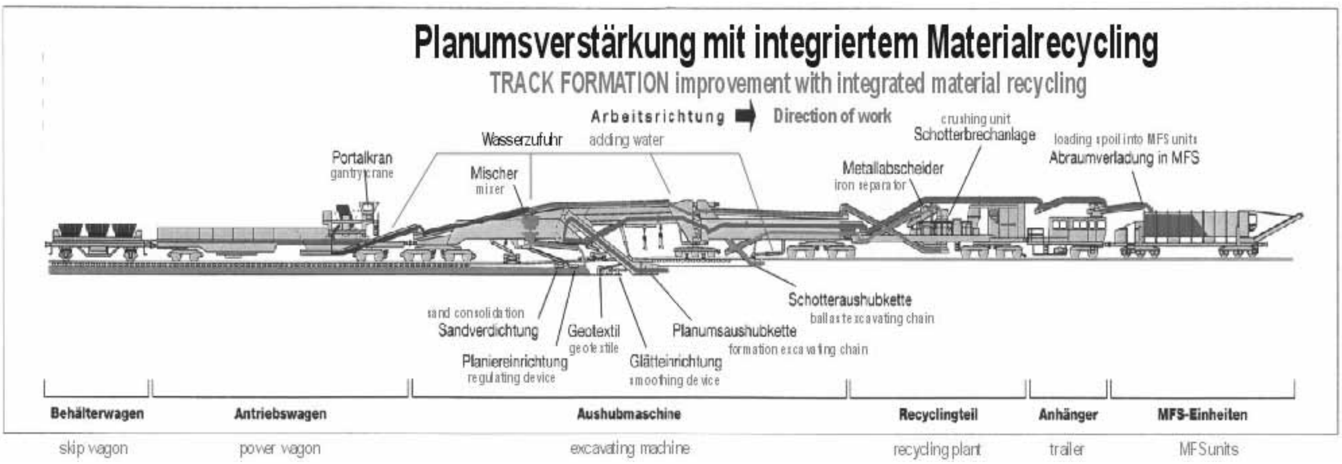

Fig. 1: Diagram depicting the AHM 800-R formation rehabilitation machine

Fig. 2: The AHM 800-R formation rehabilitation machine during operation on the line Vöcklabruck - Attnang Puchheim, Track 1

Fig. 3: Installation of geomeshing

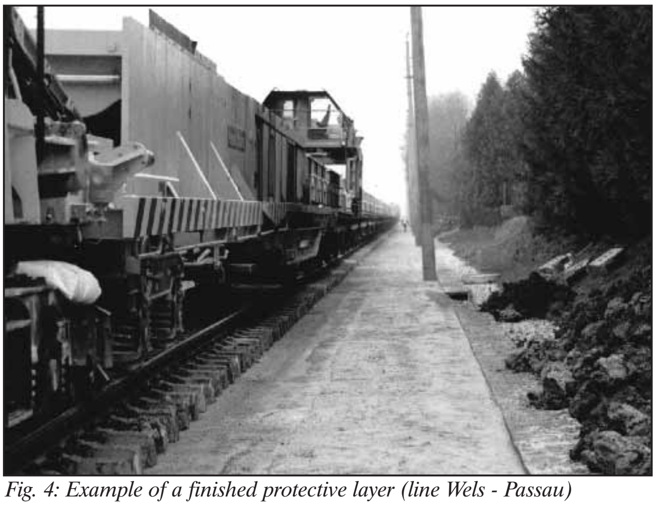

Fig. 4: Example of a finished protective layer (line Wels - Passau)

The most significant improvements over previously known methods are the application of the ballast recycling concept and the on-board facility which allows water to be added during the installation of the protective layer, thus offering improved consolidation thereof.

The AHM 800-R formation rehabilitation machine has been in operation on ÖBB since 1994.

Boundary conditions

It should be noted that, though the AHM 800-R performs an essential part of the formation rehabilitation work, other components are also of major importance: e.g. the requirements with respect to work preparation, such as the geotechnical expertise and requirements with respect to the geotextiles being used, and not least the requirements with respect to the protective layer material (the AHM 800-R can handle most sizes of protective layer required on ÖBB).

The following principles apply at ÖBB:

- when the AHM 800-R is used, the protective layer is always installed with geotextiles [3], [4] (normally fabric, if necessary geomeshing, bonded materials and also hard-foam slabs) (Figs. 3 and 4). With regard to the fabric, it should be noted that, besides the physical requirements, particularly high demands are placed on its hydraulic properties (transmissibility, permeability) because, apart from other tasks, the fabric is used especially for drainage purposes [5];
- special protective layer material is used;
- the dimensioning of the geotextiles and the applied thickness of the protective layer is effected according to geotechnical expertise;
- the installation of protective layers using the AHM 800-R is performed according to geotechnical expertise based on georadar measurements (Fig. 5) [6], [7], track measuring charts with additional probes obtained by the UUM soil probing machine, test pits (Fig. 6), ram probes, local empirical values, etc.

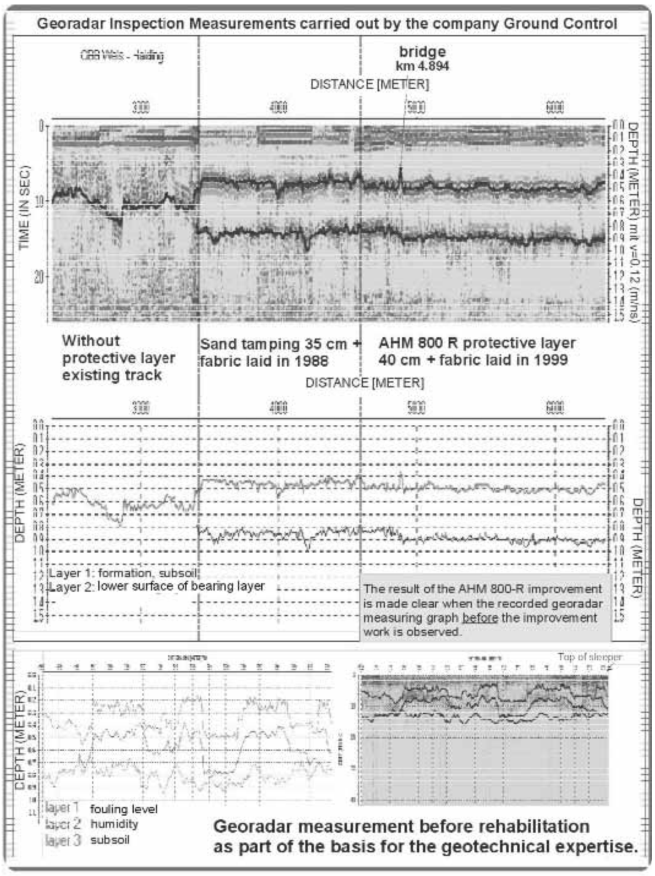

Fig. 5: Georadar measurements: line Wels - Haiding, Track 2 [6]

Fig. 6: Pictures showing test pits (line Wels - Haiding, Track 2)

Protective layer material specifications
The following specifications apply with respect to the protective layer material (Fig. 7):

- graduated grain mixture 0/32, composed of coarse sand and at least two grades of gravel. The graded gravel should be washed, but an equivalent dust separation is permitted. The coarse sand must be washed so that the portion of muddy substances is as low as possible;
- at least 90% broken grain, surface broken on all sides (for rounded grain, portion of broken surfaces at least 70%);
- grain size distribution: according to the granulation line (see Fig. 7), portion < 0.02 mm should be no more than 3%;
- the protective layer material for the entire ÖBB network is supplied solely by six companies, approved in terms of technical suitability and capacity. At these companies, the protective layer material is moistened (optimum water content) and loaded into containers.

Granulation line for protective layer material 0/32 for AHM 800-R

screen mm	Throughput Vol% from	to
0.02	0	3
0.063	3	8
0.125	4	11
0.25	5	14
0.5	6	17
1.0	11	28
2.0	19	36
4.0	28	50
8.0	40	60
16.0	61	79
22.4	83	92
31.5	100	100

The portion <2.0 mm should be close to the upper threshold line whilst observing the criterion according to Casagrande of max. 3% <0.02 mm.

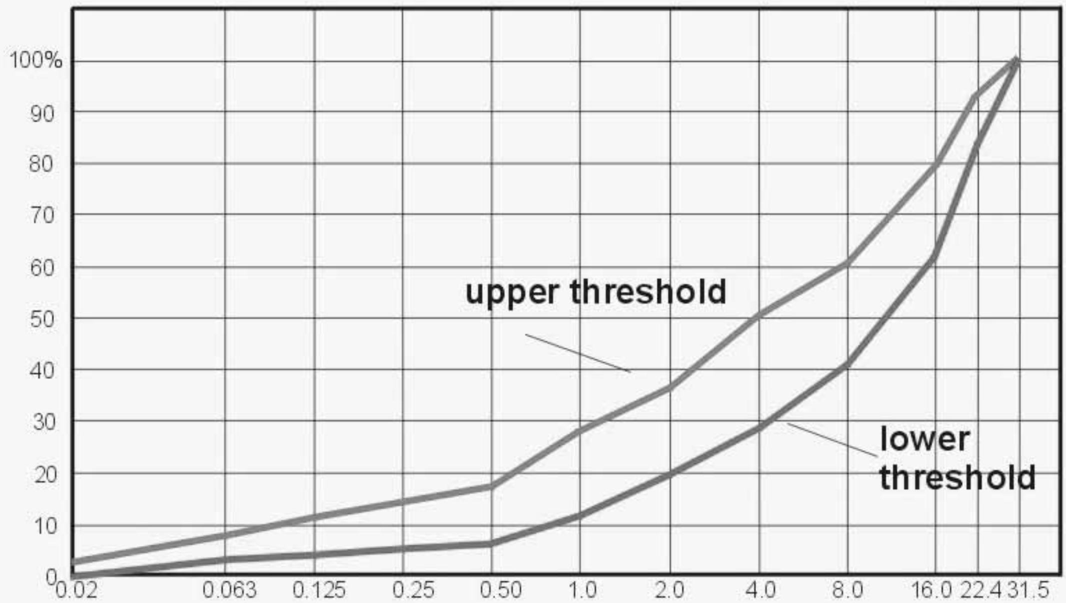

Fig. 7: Granulation of the protective layer material

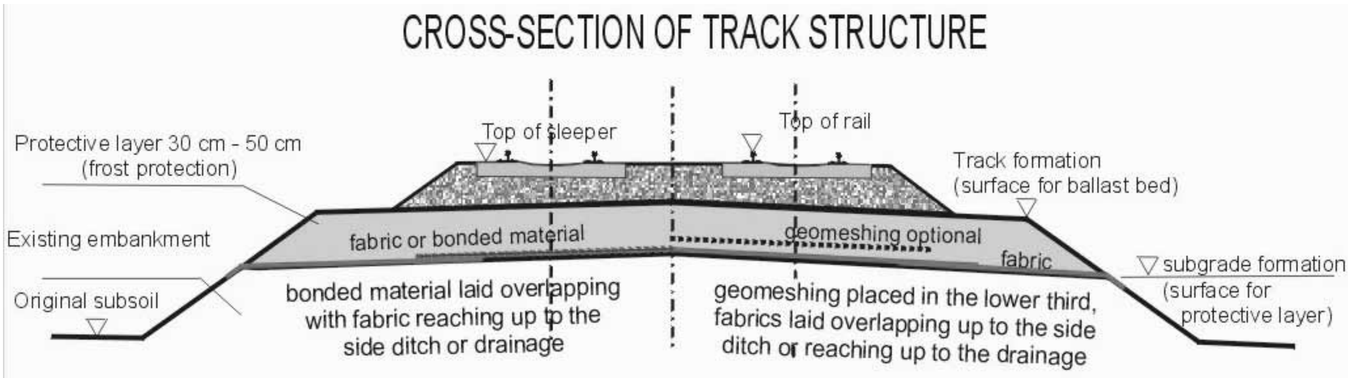

Fig. 8: Installation of protective layers with geotextiles, using the AHM 800-R

Protective layer consolidation requirements
Required consolidation values; unbound protective layers, existing track structure (Fig. 8):
— minimum requirements for the degree of consolidation D_{Pr} and/or resiliency modulus E_{v1} or E_{v2} in the area of the track formation:
— *at Vmax > 160 km/h:* D_{Pr} 97%, $E_{v1} \geq 35$ MN/m^2, $E_{v2} \geq 80$ MN/m^2, $E_{v2} : E_{v1} \leq 2.5$;
— *at Vmax ≤ 160 km/h:* D_{Pr} 95%, $E_{v1} \geq 20$ MN/m^2, $E_{v2} \geq 50$ MN/m^2, $E_{v2} : E_{v1} \leq 2.6$.

Substructure consolidation requirements
Required consolidation values substructure, existing track structure (Fig. 8):
— minimum requirements for the degree of consolidation D_{Pr} and/or resiliency modulus E_{v1} or E_{v2}. in the subsoil, substructure and underfilling, in the area of the subgrade formation:
— *at Vmax > 160 km/h:* D_{Pr} 95%, $E_{v1} \geq 18$ MN/m^2, $E_{v2} \geq 45$ MN/m^2, $E_{v2} : E_{v1} \leq 2.6$;
— *at Vmax ≤ 160 km/h:* D_{Pr} 93%, $E_{v1} \geq 7.5$ MN/m^2, $E_{v2} \geq 20$ MN/m^2, $E_{v2} : E_{v1} \leq 2.7$.

Quality achieved using the AHM 800-R
Since its start of operations on ÖBB, in 1994, the AHM 800-R has to date achieved an output of about 225 km. The operations carried out with the AHM 800-R are checked and recorded as follows:
— the excavation depth, the thickness of the protective layer and the formation cross-fall are measured at all the relevant marking points;
— at least 1x per day, for each layer, the granulation distribution and the water content of the protective layer are checked;
— plate pressure tests are carried out, roughly every 200 m. Up to 1997, static plate pressure tests and, since 1998, dynamic plate pressure tests (light falling weight) have been carried out on the subgrade formation and on the protective layer, in order to determine the resiliency modulus;
— occasionally, tests with respect to the density are performed using the isotope probe according to Troxler.
The results serve as a basis for acceptance.

Bearing strength
The bearing strength has been checked by performing plate pressure tests on various types of improvement (see Fig. 9). In this respect, the results obtained by post-measurements taken up to 12 months after installation of the protective layer are worth noting.

INSPECTION MEASUREMENTS

Average values after insertion (static plate pressure test / dynamic plate pressure test)							After x months		
Type of improvement	measurements	Subsoil formation		Protective layer			Protective layer		months
		E_{v2} MN/m^2	E_{vd} MN/m^2	thickness cm	E_{v2} MN/m^2	E_{vd} MN/m^2	E_{v2} MN/m^2	E_{vd} MN/m^2	
A: protective layer material	26	25.7		40	79.9		106		6
A: fabric / subsoil formation	151		12.3	40		28.3			
B: protective layer material, geomeshing, fabric, subsoil formation	46		9.2	45		28.4		45.0	12
C: protective layer material, bonded material, subsoil formation	7		6.1	45		30.2		39.8	10
protective layer material, geomeshing, fabric, subsoil formation	2	7.4		30	54.6		168.4		6
	2	8		40	84.4				
protective layer material, hard foam slabs, fabric, subsoil formation	4	10.4		30	39.6		134.4		6

Fig. 9: Example of inspection measurement results, per type of improvement (dimensioning) of the subsoil formation, and protective layer, up to 12 months after installation

Density guidelines:
— isotope probe according to Troxler;
— layered structure as given above;
— ideal water content: 7.4%, as per laboratory test report;
— average of 15 measurements D_{Pr} = 100.6%;
— smallest measured value D_{Pr} = 98.2% with 4.2% water content;
— largest measured value D_{Pr} = 102.3% with 6.4% water content.

Machine developments envisaged

In order to make operations with the AHM 800-R more efficient and cost-effective, the following developments are envisaged:

— conversion of the machine to enable it to place ballast at the entry and exit ramps of a construction section, or at bridges, culverts, etc. For this, approx. 20 t of ballast per ramp would be needed, which has to be transported extra in the container wagons. This method of work has already been tried in practice;

— in order to increase the portion of recycled ballast, a wagon featuring a star ballast screen (Fig. 10) will be incorporated. It is expected that in this manner approx. one extra ton of ballast could be made re-usable. This method is scheduled to be tested in practice at the end of 2000;

— in order to increase protective layer material transport capacity, four-axled container wagons are gradually being introduced. Currently, 120 two-axled container wagons (each carrying three containers, holding 6.6 t of sand/gravel each - i.e. approx. 20 t sand/gravel per wagon) and ten four-axled container wagons (each carrying six containers, holding 6.6 t each - i.e. approx. 40 t per wagon) are in use;

— ballasting of the track in a further AHM-pass.

Fig. 10: Star screen (system Wiebe)

Economic considerations

The insertion of protective layers, using the AHM 800-R, yields notable economic advantages as compared to other methods:

— due to the integrated ballast recycling system, material costs (approx. 3 t of protective layer material) are saved and, in the future, a further 1 t is expected to be reclaimed by the utilisation of the star screen mentioned earlier;

— further, by strengthening the protective layers with geosynthetics, the protective layer can be kept thinner [4], so that less protective layer material needs to be procured and inserted [8], [9]. Consequently, there will be lower costs for transport and evacuation, rubbish dump, disposal, recultivation and energy;

— in comparison to conventional rehabilitation methods using earthmoving equipment (diggers and lorries), no removal of the track is required, and also no entries and exits nor access roads. There is also no hindrance to traffic on the adjacent track;

— the excavation trench is short and shallow, and there are no support walls at the sides. The material turnover of around 20 t per metre of track is handled on the track, thus resulting in a lower burdening of the environment;

— a high daily output of around 500 m (in double-shift operation) is achieved, thus requiring shorter track possessions than when using conventional methods. In turn, this results in lower operational hindrance costs;

— a properly installed protective layer with geosynthetics achieves a high initial quality of the track with a large quality reserve. Thus, the maintenance intervals and the service life of the track are extended.

The latter is illustrated by the following example, which presents an evaluation of the “MDZ” quality indices obtained by track recording car runs, from 1996 until 2000.

Measurement location:
Section: Timelkam station - Redl Zipf station
(on the line Linz - Salzburg), Track 2,
traffic load 50,000 t per day, Vmax = 160 km/h.
Old track: UIC54E - Lv - Be 14a - RP - 650 &
UIC54E - Lv - Be 19 - Skl - 600
New track: UIC60 - Lv - Be 19a - Skl - 600

MDZ quality indices before track renewal in 1996: up to –30

In 1996, a protective layer, featuring a thickness of 40 cm and fabric 350 grammes, was installed on the subgrade formation, reaching up to the newly made drainage, using the AHM 800-R (Figs. 11 and 12).

Fig. 11: Strengthening of the formation, using the AHM 800-R (line Timelkam - Redl Zipf)

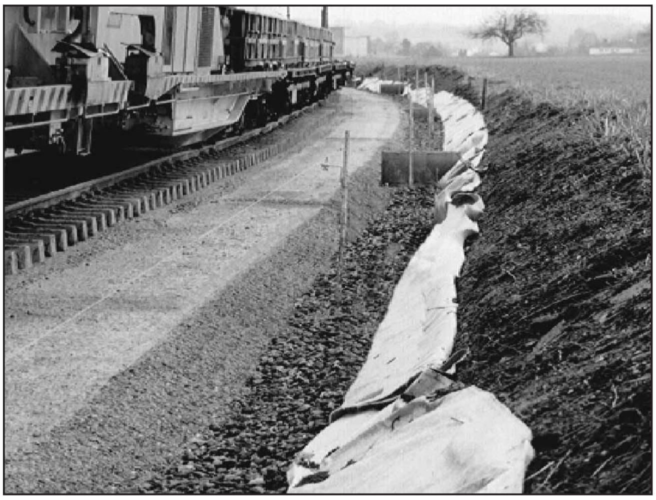

Fig. 12: Example of a finished protective layer with drainage (line Linz - Salzburg)

Measurement runs carried out between 1996 and 2000 yielded the following MDZ quality indices - average of 10 measurements:

After track renewal (Autumn 1996)	MDZ index –11
After the MDZ pass (Spring 1997)	MDZ index –10
Measurements (Spring 1998)	MDZ index –10
Measurements (Spring 1999)	MDZ index –10
Measurements (Spring 2000)	MDZ index –14

From these indices, it can be observed that the previous tamping intervals of around two years have been extended, thus resulting in lower maintenance costs [10].

Summary

The AHM 800-R has been used on ÖBB for formation rehabilitation since 1994. To date, it has achieved an output of about 225 km (Fig. 13). The results achieved can be regarded as very satisfactory. Using this track-bound method of formation rehabilitation, the following advantages can be noted:

— insertion of the new protective layer is effected without removal of the existing track;
— old ballast is recycled for use as protective layer material;
— there is no travel on the subgrade formation during work;
— consolidation or smoothing of the subgrade formation is effected using the machine;
— automatic control and moisture regulation of the new protective layer material;
— high uniform consolidating performance, thus achieving a very good quality of the protective layer;
— capability to insert geotextiles, together with the protective layer, in a single pass;
— output of the machine ranging from 40 to 80 m/h, depending on the thickness of the new protective layer;
— on double-track lines, no hindrance to traffic on the adjacent track;
— short, open excavation trench (approx. 6 m long, and approx. 1 m deep);
— various thicknesses of protective layer (up to 50 cm) can be inserted in one pass;
— a saving of up to 50% of new material is achieved by the mixing with recycled material;
— reduction of track occupation times by up to 50%;
— no installation of temporary access roads required.

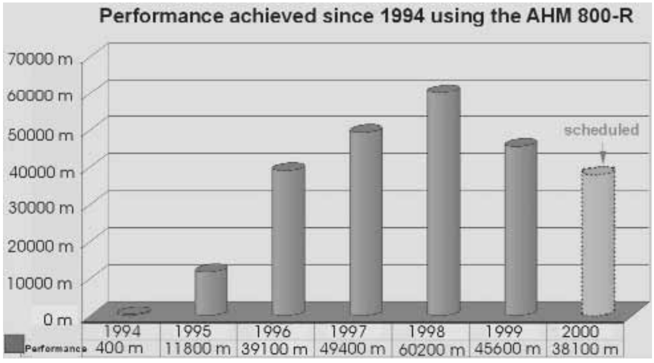

Fig. 13: Diagram showing the output achieved on ÖBB since 1994, by using the AHM 800-R

The volume of recycled ballast, achieved by means of the integrated ballast recycling unit (32% to 42% of the total excavated by both chains), could of course be increased further by external ("on site") processing plants. This would result in a lower transport requirement, thus bringing additional cost savings.

Finally, it should be said that when using the AHM 800-R together with the SUZ 500 high-speed track relaying train (track renewal), outputs previously not thought possible of up to 250 metres of finished track per day have been achieved. These figures apply for the insertion of a protective layer, including track relaying, on existing lines.

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