Track substructure renewal on Polish State Railways

Over the years, the condition of the track substructure on Polish State Railways (PKP) gradually deteriorated to the stage that a large part of their network was badly in need of substructure repair. Since November 1999, the Plasser & Theurer AHM 800-R formation rehabilitation machine has been working on PKP, achieving a high output and accuracy of work.

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In Poland, 80% of the railway network was built before the First World War for the then prevailing conditions of the permanent way and the track substructure, lower running speeds, lower axle loads, and types of rolling stock and traffic safety systems very much different to those of today.

It used to be common practice to renew the entire permanent way at the end of its service life, and to adapt and modernise it to meet the prevailing technical standards, as far as the financial means available would allow. This work also included the introduction of concrete sleepers, which required a ballast bed featuring a higher formation layer, or an increase in the strength and the weight of the rails. Also, continuously welded rails (CWR) and new types of rail fastenings were introduced. However, as the technical means for simultaneously improving weak spots in the track substructure were not available, the new and heavier track often led to problems.

Especially today, as axle loads of 22.5 t/axle and running speeds of 160-200 km/h are widely in use, it is necessary that the track substructure is strengthened, in order to achieve a stable and firm track formation, as *insufficient stability directly leads to deformations and faults in the track geometry.*

Track substructure condition on PKP

The railway network of PKP is about 23,000 km long and, thus, there is a similar length of track substructure. The track substructure not only consists of earthworks in the form of embankments, benches, cut slopes or cuttings, which on PKP make up about 27,000 hectares of embankments and about 44,000 km of substructure crown benches, but also includes the substructure drainage installations that take care of the drainage of surface and ground water, which amount to a length of approx. 29,000 km. The technical condition of the track substructure on PKP varies greatly, as it depends on many influencing factors. For instance:

- throughout the network of PKP, the geological structure varies (unfavourable geological conditions could be the cause of subsidence);
- deterioration of the geo-technical conditions resulting from mining of raw materials and minerals (e.g. mining damage), which alters the water conditions and the stability in the soil;
- influence of climatic conditions, such as:
  - atmospheric precipitation, which alters the moisture of the soil;
  - change in temperature, which causes freezing and thawing of the soil;
  - blowing-away of grains from loose soil by the wind;
- ageing processes of the structures;
- type of track maintenance applied.

Deterioration of track substructure condition

Apart from age, war damage also has had a considerable influence on the track substructure condition on PKP. As restoration of the railway lines had to be performed quickly, track rebuilding or repairs were, in general, performed without any geo-technical preparations.

Also, in the period after the war, improvement of operating conditions on the railway lines was achieved by repair or modernisation work that was restricted to the permanent way only. This produced short-term successes and led to a gradual deterioration of the increasingly burdened substructure.

Track substructure repair work was merely limited to malfunction and accident elimination work, or to jobs which did not prolong the closure of the track under repair. These provisional jobs produced an ever poorer track substructure condition. Very often, existing protective layers were destroyed during ballast bed cleaning. Ballast cleaning was carried out without shoulder cleaning, and also without profiling of the embankment. This led to the occurrence of water spots under the ballast bed - 'mud spots' were commonplace. Also, insufficient work was carried out with respect to the drainage installations, which also negatively influenced the track substructure condition.

It was not until the 1970s that the significance of the substructure was recognised and that substructure repair work was undertaken to a larger extent on PKP, although there was still no complete understanding of the complex execution of the work. It should be noted that, at the time, the need for performing substructure improvement work did not become fully clear until the track substructure condition no longer permitted any normal traffic or the safety of the traffic was endangered. Without the occurrence of these obvious factors, it is practically impossible without exact investigations to determine the necessity of improvement work.

Investigations conducted on the network of PKP, in accordance with geological criteria, yielded that poor substructure conditions existed on about 30% of the network operated (i.e. approx. 7,000 km).

Attempts to remedy the situation

For the period 1991-1995, it was decided that drainage installations had to be installed or renewed, and the substructure strengthened and modernised, over a length of approx. 10,000 km (i.e. about 47% of the network operated), in the course of maintenance operations.

However, because the mechanical means to do so were not available, these plans had to readjusted and limited to 4,400 km (i.e. approx. 40% of the work required). Thus, substructure improvement work of around 880 km annually was required.

Financial means, however, became limited, and the extent of work at many worksites was not only restricted but, in some cases, the work was stopped altogether.

Fig. 1: AHM 800-R formation rehabilitation machine

Thus, by the year 1994, the annual need for renewal of the track substructure had increased to 1,135 km which, for instance, for the year 1994 would have required the performance of the following tasks:
— the renewal of 82 km of substructure;
— the insertion of a formation protective layer over a length of approx. 154 km;
— the installation of geo-fabric over a length of 51 km;
— the repair of substructure drainage installations over a length of about 850 km.

By the end of the five-year period (1991-1995):
— substructure repair work over a length of about 1,300 km had been carried out, i.e. approx. 30% of the work planned initially and approx. 12% of the work required;
— the financial means earmarked for this purpose covered approx. 26%.

This neglect of improvement work resulted in a further deterioration of the track substructure condition which, quite certainly, had a considerable impact on the operating performance of the railway lines and also on the service life of the permanent way. In order to minimise the negative effects of these circumstances, the following steps were undertaken:
— the investigation/appraisal system of the technical condition of the substructure to assist decision-making with respect to renewal measures required was improved;
— execution of the work was concentrated on the main lines (priority lines) with the proviso that it had to be carried out completely.

In addition, special machines were acquired to assist in the substructure improvement work, such as ditch excavators and machines to produce drainage channels.

Further, a study was made of the methods applied by the railways of other countries to improve the track substructure.

Analysing methods used in other countries

Inspections made and operating experience gained during the past years on many railways, where various methods have been applied to strengthen weak points in the substructure, have yielded that the most effective method is to insert a protective layer between subsoil formation and the ballast bed.

During the second half of the 1990s, specialists from PKP analysed a number of different substructure improvement methods in use in other countries, i.e.:
— excavation of the substructure by using a RM 800 high-capacity ballast cleaning machine and machines to insert the formation protective layer, such as the SVV-100;
— improvement of the substructure with gradual exchange of the permanent way by using a special machine Puscal IV;
— formation rehabilitation by using the PM-150 machine;
— formation rehabilitation by using the PM-200 machine;
— formation rehabilitation with recycling of the used ballast, the latter to be used as part of the new formation protective layer, by using the machine AHM 800-R;

and compared them with the traditional method used until then on PKP, i.e.:
— dismantling of the old track skeleton;
— excavating of the weak substructure;
— profiling and consolidation of the substructure;
— insertion of geo-textiles;
— installation of a protective layer;
— consolidation of the protective layer;
— placement of the lower ballast layer;
— laying of the track skeleton;
— placement of the upper ballast layer.

The analyses yielded that the method deployed by the AHM 800-R would meet the requirements of PKP with respect to substructure improvement work. Thus, a machine of this type was procured (Fig. 1).

Use of the AHM 800-R formation rehabilitation machine for substructure improvement work on PKP

In November 1999, the AHM 800-R went into trial operation on the Poznan - Kunowice line of PKP. Its application created new opportunities to solve problems with respect to strengthening the bearing capacity of the substructure and eliminating weak spots in the substructure, with an output and accuracy previously not known in Poland. The main advantages of the new technology are:

- the work is performed without dismantling of the track skeleton (Fig. 2), as opposed to the traditional method used on PKP for substructure work or the insertion of a formation protective layer which, making use of construction machines, required the complete removal of the track;
- the formation protective layer to be inserted is prepared in the machine;
- savings in transport are made, as the used ballast does not have to be taken away and less new material is needed;
- lorry transport runs are not needed and, therefore, no access/exit roads for lorry transports need to be built;
- the adjacent track can be travelled at operating speed, and does not have to be displaced laterally. Also, no transport is needed on the adjacent track;
- during operation, the machine does not exceed the clearance gauge;
- the machine enables the formation protective layer to be installed simultaneously to the removal of spoil in the upper substructure layer (Fig. 3);
- frost heaves, water spots, as well as ballast contaminated by coal dust can be eliminated;
- the material forming the protective layer is continuously optimally moistened and consolidated;
- fabric, geogrid, insulating slabs and other materials in various compositions can be inserted simultaneously;
- no depots or storage places, nor processing plants for the material, are required at the worksite;
- a high output is achieved - up to 80 m/h;
- because of the higher output achieved, track closures are reduced - by more than 50%;
- it can unrestrictedly be deployed at various worksite locations (embankments, cuttings, stations, on mountainous lines, etc.);
- the work can be performed together with track renewal;
- the protective layer can be inserted over the entire width of the track formation - up to 6 m;
- the substructure soil on track benches and embankments can be consolidated.

The main task of the machine is to insert a stabilised, consolidated formation protective layer under the ballast bed, in order to achieve a much higher bearing capacity of the substructure, as compared to the previous state. Various kinds of material can be included in the formation protective layer, depending upon the result desired. In the outcome, the deformation or settlement of this protective layer will be far smaller.

Machine appraisal

Thorough investigations and inspections during operations at different worksites featuring various track substructure conditions have been conducted, in order to assess the work performed by the new AHM 800-R track formation rehabilitation machine.

Fig. 2: Raising the track and insertion of the new formation protective layer without dismantling of the track skeleton, using the AHM 800-R

Fig. 3: Excavation of material and simultaneous installation of a compacted formation protective layer

It was important to observe the effectiveness, the accuracy and the durability of the work performed, in order to avoid possible errors and to optimise the process of stabilising and strengthening the substructure.

The investigations and tests performed at various worksites, and with respect to various protective layers, have enabled a technological logistic programme to be drawn up for the efficient application of the new method used. Further experience will be gathered to help optimise the method of work.

Conclusions

The new Plasser & Theurer AHM 800-R track formation rehabilitation machine, designed to meet the specific needs of PKP, has performed very satisfactorily for the past two and a half years, creating new opportunities with respect to strengthening and stabilising the track substructure and, thus, contributing greatly to the improvement of the overall condition of the railway track on PKP.