Handling of railway superstructure material at the end of the life cycle

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Abstract. This article deals with the recycling of railway bed aggregates. It briefly describes the methods of handling of the obtained material. It evaluates new possibilities of processing gravel from railway superstructure. It describes the development of the maintenance and reconstruction of railway lines. Furthermore, this article deals with the possibilities of using old materials for new purposes. It presents the results of analyses of railway aggregate extracts and their comparison with the limit values for deposition on the terrain surface.

1. Introduction

The network of railway lines managed by the Railway Administration, a state organization in the Czech Republic, is currently approximately 9,400 kilometres long. These lines form 15,300 kilometres of tracks, including almost 22,000 switches. The vast majority of this railway network has conventional construction of railway superstructure, i.e. a rail grate placed in a gravel railway bed [3]. Using a very rough calculation, we can estimate that the railway beds of the railways managed by the Railway Administration, state organization (hereinafter referred to as the Railway Administration) and other railways operated by the Railway Administration, s.o. (hereinafter referred to as the railways of the Czech Republic) consist of 30 million m$^3$ of aggregates, which represents about 54 million tons. However, this calculation is really only indicative. Aggregate volume per running meter depends on a number of parameters:

1. whether the railway bed is open or boxed-in;
2. on the number of tracks;
3. on the actual thickness of the railway bed;
4. on the type of sleepers and their distribution;
5. on the track elevation difference value in the curve;
6. on the use the widening and elevation of the railway bed in the smaller radii of the directional curves of long welded rails
7. on the method of renovation of the railway track.

With regard to the variability of the above-mentioned parameters, the volume of aggregates of the railway bed can range from app. 1.7 - 4.5 m$^3$ per running meter. In practice, an approximate coefficient of 2.5 m$^3$ per running meter is usually used for the calculations [1].

2. Past

The material used for the construction of railway superstructure has changed over the years depending on the speed of transport, the weight of the transported loads and technological sophistication, and the
latest scientific knowledge and local conditions. However, the economy has always played a major role, which is why the material that was most widely available was used, which was excavated gravel fraction 0/70 mm, sand fraction 0/15 mm, locomotive ash or blast furnace slag fraction 40/80 mm. In some rare cases, construction and mixed waste was used as well. Screened broken stone fraction 15/25 mm was used for sleeper sub-base, especially in the area of rail joints. Even in the 1980s, the custom of using "switch" gravel fraction 16/32 mm still persisted.

With increasing operating loads, higher axle weights, the introduction of mechanical adjustment of the geometric position of the track and the increasing share of the use of concrete sleepers, crushed natural dense aggregates fraction 32/63 mm and 31.5/63 mm became the basic material for railway beds [4].

32/63 mm railway gravel is sieved during machine cleaning. The fine material of the 0/32 mm fraction, which is produced during these works, is mostly composed of fragments of gravel, dust, oil substances and biological waste and it was mostly dumped directly on the slope of the cleaned line [2]. By repeating this process, contamination accumulated, especially the accumulation of PAHs, C10-C40 hydrocarbons and heavy metals. In the case of a complete reconstruction, the material obtained in this way was used at most as backfill material, or as material for access roads and was irretrievably lost.

When the government of the Czech Republic decided in 1994 to renew the transit railway corridors included in the pan-European network, discussions on the topic of replacing new materials by recycling the old ones began.

As the length of all four main transit corridors in the Czech Republic exceeds 1,300 kilometres of mostly double-track lines, i.e. about 2,500 kilometres of main line and continuous station tracks, an estimated volume of 5-6 million m³ of aggregates are stored in the railway bed of these tracks alone.

If we wanted to replace all the aggregates of the railway bed with new ones as part of the modernization of the railway network, it would mean an enormous use of the highest quality irreplaceable natural resources of aggregates and the devastation of the landscape associated with that. This is why in 1994–1995 specialists from the then Czech Railways Transport Division, in cooperation with other interested experts from construction companies and the field of geotechnics, focused on determining, verifying and announcing the conditions and rules for the recycling of railway bed aggregates. Ing. Mojmír Nejezchleb, CSc. from VÚŽ, Ing. Miroslav Šolc from the Technical Central Office of Infrastructure, Ing. Miroslav Hörbe older from the Stone and Aggregate Testing Laboratory in Hořice, Ing. Milan Kovář from the company SG-Geotechnika Praha, Ing. Aleš Suchánek from ŽSD, Mr. Pavel Čupr from the Technical Central Office of Infrastructure, RNDr. František Žižka from the Prague Construction Administration and many others participated in this work. The task was also solved in cooperation with the Railways of the Slovak Republic, represented by Ing. Miroslav Havrila [1].

3. Present

At present, thanks to new technologies based on the analysis of samples, it is much easier to detect and locate pollution. The most contaminated material was created by the use of track engine locomotives and from drips of operating fluids, the fall of transported materials, especially coal, or by the pollution blown-in from the environment. In addition, the grains are smoothed and crushed due to the load and dynamic effects of the operation. However, this does not mean that this material is completely degraded after the long period of use [2].

In cooperation with designers, investors try to promote recycling as much as possible, because according to the Waste Act, the use for the original purpose is right behind the prevention of the production of waste. In the beginning, stationary sorting facilities were promoted, but their disadvantage is the necessity to bring in and transport the processed material away, so nowadays, mobile recycling machines are most commonly used. Their great advantage is that they are capable of operational relocation according to the current needs.

Simply put, the sorted material is crushed during the recycling, and it can then be further sorted. This process produces a new certified material that can fully replace the material from the quarry and to save not only the money on the purchase of new material, but also on its transport.

Although the enforcement of recycling was not easy at the beginning, the ever-increasing costs, especially for transport and loading of materials, together with the overall legislative framework
aligned according to the European Union regulations, created enormous pressure on waste prevention. The protection of natural resources together with the human environment has also become a matter of course. In fact, all material from the railway superstructure is recycled, with the exception of hazardous parts located mainly under switches and in the places of engine bays [5].

In 2002, EN 13450 standard "Aggregates for Railway Beds" was adopted by the European Committee for Standardization [7]. This standard was subsequently taken over into the system of Czech technical standards, where it replaced the original standards ČSN 72 1511 [8] and ČSN 72 1512 [6], together with other adopted European standards. The common European product standard for railway bed aggregates already foresees the use of aggregates recycled from the existing railway bed. The adoption of the European standards did not bring fundamental changes in the parameters of aggregates, but in the way of their verification. The acceptance of a single European testing system meant the need to equip the test laboratories with new aggregate testing equipment. The properties of the aggregate determined according to the test procedures valid until that time were fully satisfactory. However, a large number of comparative tests had to be performed in order to select the appropriate standard categories determined by the new test methods. Most of the Czech testing laboratories and aggregate producers took part in this process, providing the necessary test samples for this comparison. Following the publication of the European standard, new General Technical Conditions (GTC) "Aggregates for Railway Beds" have been issued. These GTCs determine which optional properties and value categories specified in ČSN EN 13450 must be tested and declared when offering new and recycled aggregates for railways and switches of railway lines of the Czech Republic [7].

The statistics kept by the Technical Centre of Infrastructure show that by the end of 2017, more than 5 million tonnes of aggregates had been recycled from the railway bed, which in approximate terms represents 3.5 million m³. Just to give you an idea, it is such an amount of aggregates that would be sufficient to build the railway bed of two double-track lines running along the route of the first corridor from Břeclav to Děčín [1]. This means that recycling the aggregate from railway bed saved more than three quarters of a billion crowns for depositing the material in a landfill.

![Figure 1. Mc Closkey sorting machine in action, photo Halík M.](image-url)

We are currently getting to the stage where the oldest modernized or optimized sections of the transit corridors have been in operation for over 25 years. In order to maintain the quality standard and to prolong the effective service life, it will be necessary to proceed with continuous renewal works as part of their maintenance. There is no doubt that they will also include the cleaning of the railway bed, the importance of which for the stability of the track has been unjustifiably forgotten in recent years.
Although the cleaning of the railway bed is not recycling, it makes it possible to restore a suitable curve of the aggregate grain size and thus prolong its service life. This contributes not only to the extension of the effective life of the track, but it also reduces the consumption of new aggregates. In the area of recycling, in order to make better use of the benefits, it is necessary to improve the survey work in the design stage and preparation of buildings. The valid GTC "Aggregate for Railway Beds" defines the scope and frequency of the survey of railway bed aggregates, which should be carried out before the recycling design in the construction documentation. It does not matter whether the recycling is carried out using a recycling line at a recycling base or by special track machines in the track axis. It is also not so important whether we recycle the aggregates to a 0/32 mm or 32/63 mm fraction [6].

In the past, there was a requirement to correctly identify the sites that need to be excluded from recycling due to their environmental pollution. Today, however, the effort is to use the material extracted during the renewal of railway lines as much as possible. It is necessary to take into account the degree of pollution and degradation of aggregates as well as the climatic conditions during the execution. As the possibility of more thorough separation of the extracted materials increases with the constantly improving abilities of machinery equipment, a test facility sorting railway aggregates from soils originally intended for landfill is already in operation today. For the time being, the facility is showing very decent results and it is possible that it will become a significant alternative source of railway gravel in the future. Figure 1 shows the Mc Closkey sorting machine processing these soils.

![Figure 1.](image)

**Figure 2.** Overview of aggregate recycling in 1999 - 2017 [1].

However, a significant problem during sorting and recycling is the formation of a contaminated part of the material, where most of the pollution is concentrated. This applies both to the parts polluted at the input and to those parts that originally complied with the limits according to the Decree. In general, the process of renewal of railway bed aggregates can be divided into three stages:

1. Pre-sorting of the input material - the input material is purified and divided into the basic fractions - undersize, intermediate and oversize, the grain size of which can be influenced by the correct choice of sieves. Undersize material (usually up to 32 mm) can also be used on site as a material for landscaping after sampling. Intermediate material (usually 32/100 mm) is the main source of material suitable for further processing. Oversize material (usually over 100 mm) can be used in the lower layers of service roads. This material can be degraded by unwanted impurities in the form of branches or large pieces.

2. Recycling - crushing intermediate fractions is among the main tasks of recycling and, in addition to the main economic value, it also creates a material that can fully fulfil the functions of the input aggregates from a quarry and thus save the non-renewable natural resources. By means of various types of crushers (jaw, cone, etc.), it reduces the input fraction and restores all the required properties of railway bed aggregates.
3. Sorting - the material obtained in the 2nd stage can be used directly as a fraction from 0 to 100 mm. Alternatively, it can be sorted into different fractions according to the investor's requirements. The sorted material generally has a higher market value and some standards directly require the use of the exact range of the output material. On railway constructions ordered by the Railway Administration, s. o., the 0/32 mm fraction is most often used for the railway bed and 32/63 mm for the railway superstructure. Oversize material is no longer considered at this stage, as the output from the crusher is already set to the desired upper value.

4. Extractability

Table 1 illustrates the results of extractability tests and their comparison with the limit values of permissible concentrations of pollutants in dry mass of waste according to Table No. 10.1 of Annex No. 10 to Decree No. 294/2005 Coll., on the conditions for depositing waste in landfills and their use on the terrain surface and amendment of Decree No. 383/2001 Coll. on the details of waste management. A sample of aggregate K101 was taken from the section of the Pilsen-Cheb line, sample K102 was taken from the line Pilsen - Domažlice line and sample K103 was from the Vlečka Škoda line.

The results of the extractability analyzes show that pollution can occur in various forms. The most common are petroleum substances, PAHs and heavy metals. Even if the material complies with the extractability classes for landfilling, we must use Table No. 10.1 and 10.2 of Annex No. 10 of the Decree in the case of the use of such treated waste, because we will use the product on the terrain surface.

| Representative sample: | K101 | K102 | K103 | Limit valuea (in mg/kg of dry mass) |
|------------------------|------|------|------|-----------------------------------|
| **Metals**             |      |      |      |                                   |
| As                     | 52.300 | 75.600 | 29.800 | 10.000 |
| Cd                     | 10.900 | 22.900 | 1.340  | 1.000  |
| Cr total               | 169.000 | 232.000 | 78.500 | 200.000 |
| Hg                     | 0.363  | 0.502 | 0.264  | 0.800  |
| Pb                     | 453.000 | 851.000 | 105.000 | 100.000 |
| V                      | 120.000 | 124.000 | 61.400 | 180.000 |
| **Monocyclic aromatic hydrocarbons (non-halogenated)** |      |      |      |                                   |
| Sum of BTEX            | <0.050 | <0.050 | 0.512  | 0.400  |
| **Polycyclic aromatic hydrocarbons** |      |      |      |                                   |
| Sum of PAU             | 10.500 | 7.840 | 28.500 | 6.000  |
| **Chlorinated aliphatic hydrocarbons** |      |      |      |                                   |
| EOX                    | <1.000 | <1.000 | <1.000 | 1.000  |
| **Other hydrocarbons (mixed, non-halogenated)** |      |      |      |                                   |
| Hydrocarbons C_{10-C_{40}} | <20.000 | 35.100 | 347.000 | 300.000 |
| **Other aromatic hydrocarbons (halogenated)** |      |      |      |                                   |
| PCB                    | 0.076  | 0.132 | 0.436  | 0.200  |

*a these are the limit values for storing on the terrain surface (according to table 10.1 annex no.10 of decree no. 294/2005 Sb.

From the table presented above, it is evident that the average value of As concentrations in comparison with the limit value exceeded this value five times, PAH almost three times. Hydrocarbons C_{10-C_{40}}, the most frequently anticipated contamination exceeded the limit value only in the sample K103 and on average complied with the limit values.
In the event that the undersize fraction 0/32 mm formed during the input sorting of the material shows increased limit concentrations of pollutants, it is necessary to handle this material according to the valid legislation. Either as the material that did not meet the criteria for landfilling, but can be used in landfills of other types of waste, or the values are already so high that it is considered as hazardous material. This kind of material is currently most often processed by biodegradation methods or landfilling at hazardous waste landfills. However, since it is still a substantial part of mass balances, there is an effort to use this material as well. Modern cementation methods are used to obtain replacement input material.

5. Conclusion
The facts presented above show that the material from the railway superstructure at the end of the life cycle has a huge potential for use as a substitute for natural resources of aggregates, if the right method of remediation of contaminated aggregate is chosen for subsequent use in construction practice. The biggest advantages of reusing waste materials (in our case, aggregates from the railway superstructure) include:

- reduction of landfilling costs;
- protection of natural resources;
- reduction of emissions from transport;
- protection of the environment.

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