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CURRENT METHODS OF HANDLING AGGREGATE FROM RAILWAY SUPERSTRUCTURE AND ITS DEFINITION AS WASTE OR SECONDARY RAW MATERIAL

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ABSTRACT

This article describes the latest methods of handling aggregate from railway beds. The updated waste management methods are based on the new Act No. 541/2020 Coll. and its implementation in operation. Attention is paid to the hierarchy of the methods of handling ballast from railway superstructure, new normative documents and regulations in the implementation of maintenance and reconstruction of railway lines. The article also deals with the possibilities of using old materials for new purposes.

Keywords: Ballast; Possibilities of material use; Railway track renewal; Railways; Recycling; Waste management hierarchy.

1 INTRODUCTION

When the Parliament of the Czech Republic approved the new Waste Act No. 541/2020 Coll. [1] (hereinafter referred to as the Act) with effect from 1 January 2021, a number of companies and institutions were forced to update their regulations regarding waste and packaging material management. This obligation also affects Správa železnic, s.o. (hereinafter referred to as Správa železnic or SŽ) that manages a relatively dense network of railway lines. The network currently stretches to app. 9 400 km, the lines consist of 15 300 km of tracks, including nearly 22 000 switches. The vast majority of this railway network has already undergone conventional reconstruction of the superstructure and substructure, but there is still a relatively large part to be reconstructed, not to mention that many sections reconstructed in the early 1990s are already undergoing reconstruction again.

Using a very rough calculation, we can estimate that 30 million m^3 of aggregate, representing approximately 54 million tonnes, is stored in the railway bed of the railway lines managed by Správa železnic and other railway lines operated by Správa železnic (hereinafter referred to as the railway lines of the Czech Republic) [2,3].

Operational waste, according to Decree No. 8/2021 [4], often in the hazardous category, represents another significant issue.

2 WASTE MANAGEMENT HIERARCHY AND THE METHODS OF IMPLEMENTATION INTO PRACTICE

The material used for the construction of the railway superstructure in most of the reconstructed sections consists of broken recycled stone fr. 0/32 mm reclaimed from old railway bed and also from newly purchased materials.

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This fulfils as far as possible the requirement of Act No. 541/2020 that sets out the waste management hierarchy [1,5]:

1. waste prevention,
2. preparation for re-use,
3. recycling of waste,
4. other use of waste (e.g., energy use – in the conditions of SŽ, for example, the use of wood chips for heating, etc.),
5. waste disposal.

With the constantly and hugely increasing operational loads, higher axle loads, the introduction of machine adjustment of the geometric position of the track pairs, and the increase in the use of concrete sleepers, crushed natural dense aggregate fraction 32/63 mm or 31.5/63 mm has become the basic material for the railway beds [6].

Especially in recent years, the law has imposed a strong emphasis on recycling. Since the 1990s, new aggregate has also been successfully replaced by recycling the recovered original railway bed, which, after quality verification for recycled aggregate, re-enters the railway line construction and reconstruction process. Unfortunately, Directive S3 prohibits the use of recycled aggregate in railway superstructures at speeds exceeding 200 km per hour [7].

The machine cleaning process involves screening the 32/63 mm railway ballast to extend its lifetime and thus fulfil the first point of the waste management hierarchy [2].

According to Act No. 541/2020 Coll. [1], waste management is characterised as waste concentration, waste collection, waste storage, waste treatment, waste utilization, waste disposal, waste trading and waste transportation. Waste treatment must be carried out only in the manner prescribed by the law and other legislation issued for the protection of the environment and human health for the given type and category of waste, and waste must be treated only in a facility designated for the treatment of the specific type and category of waste and must be handled in such a way to prevent its theft or leakage or its deterioration.

In practice, however, this relatively simple requirement is very difficult to implement and is possible only with enormous effort and considerable financial resources. People were used to treating waste in the same way for many years, and some find it very difficult to adapt to the new requirements and obligations.

It is also necessary to distinguish:

1. Secondary raw material of the character of “recovered material” according to SŽDC Directive No. 42 – Management of recovered material [8].
    a. These are mainly railway superstructure materials and other designated materials taken over to stock. Examples include rails and rail fastening systems, concrete and wooden sleepers, precast concrete, all-rubber crossing structures, or insulators and conductors.
    b. Material of a different nature, i.e., material not taken to stock. Examples include ballast, gravel sand, broken stone, and soils of various compositions.
2. Waste or construction and demolition waste fulfilling the character of waste according to the legislation of the Czech Republic, generated as a result of construction and demolition activities [9].

The fine material fraction of 0/32 mm produced during this work is mostly composed of ballast and dust fragments and does not cause problems on the reconstructed lines. In the case of lines that have not been reconstructed yet, this material may be contaminated with particles of oil and biological waste and is usually contaminated especially with PAHs, C10-C40 hydrocarbons, and heavy metals.

The length of the four main transit corridors in the Czech Republic is more than 1 300 km of mostly double-track lines, i.e. about 2 500 km of line and continuous station tracks. Only the railway bed of these tracks contains an estimated 5–6 million m^3 of aggregate [2,3].

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It means that if we wanted to replace all the aggregate in the railway bed with newly quarried aggregate as part of the maintenance of the railway lines and the related infrastructure, this would mean an enormous use of the best quality irreplaceable natural resources of aggregate and the associated devastation of the landscape and the environment.

3 PRESENT SITUATION

Nowadays, new technologies for analysing samples have made it much easier to detect and locate contamination. This is also the main prerequisite for successful decision-making whether ballast from the railway bed is waste or reused material according to the waste treatment hierarchy.

Re-used material (hereinafter referred to as 'RM') – all reused material reported in a different way than waste or recycled waste – is mainly material referred to as recovered material within the meaning of SŽDC Directive 42 Management of recovered material as amended [8], and also reused material used directly within the construction in question (mainly ballast and soil).

RM include in particular:

- ballast from the railway superstructure – i.e., the ballast reused in the given construction;
- tracks and rail fastening system (recovered material) – tracks and rail fastening systems handed over to the contracting authority as 'recovered material'; it includes both recovered material reused within the given construction and recovered material that the contracting authority uses in other ways;
- concrete sleepers (recovered material) – sleepers handed over to the contracting authority as recovered material; they include both recovered material reused in the given construction and recovered material that the contracting authority uses in other ways;
- wooden sleepers (recovered material) – sleepers handed over to the contracting authority as recovered material; they include both recovered material reused in the given construction and recovered material that the contracting authority uses in other ways;
- wood – wood and wood mass handed over to the contracting authority as recovered material; wood and wood mass designated as recovered material is not counted as recycling as it is mostly subsequently used for energy purposes (firewood);
- other recovered material – other material handed over to the contractor as recovered material not listed above (recovered wires, insulators, etc.) for reporting purposes, excluding safety and communication equipment.

For the sake of clarity, I would like to point out that other materials not intended for reuse are also part of the recovered material, mainly metals and wood. These are reported as waste.

Recycling is the process of material/waste treatment where the material or waste is reused. It is the cyclical reuse of waste. Recycling of construction and demolition waste includes the transfer of waste to recycling bases, recycling centres, intermediate dumping site, and sorting lines for further use, use for landfill engineering or landfill reclamation, use for landscape recultivation, material use within the given construction – back into the superstructure and structural layers, and also, e.g., for backfilling, facing layers, and embankments as aggregate for concrete of lower strength classes, for construction of building site roads, for local adjustments of the unevenness of the embankment body, extension of the railway path, and other landscaping.

SŽ SM096 Directive [5] defines several basic terms:

1. Recovered material – recovered material removed from the construction of the railway infrastructure during the implementation of investment projects and repair and maintenance work. It is either usable recovered material taken over by the SŽ for further use in other projects or material whose secondary use is not possible but which has a residual value (e.g., metals, wooden mass, etc.). The most commonly recovered materials include rails and rail fastening systems, concrete sleepers and wooden sleepers, precast concrete, or insulators and conductors. The recovered material is not counted as waste. It is governed by the SŽDC Directive No. 42 Management of Recovered Material as amended [8]. Ballast from the railway bed used in the given construction is not considered recovered material under this

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definition, see OPM definition. The Statement of Secondary Materials and Waste does not include communication and safety equipment recovered material.

2. Material/waste suitable for recycling – for the purpose of this article, it means, in particular, construction and demolition waste suitable for recycling, as listed in the Methodological Guidance of the Waste Department of the Ministry of the Environment on the Management and Disposal of Construction and Demolition Waste dated August 2018 (Annex 1 – List of CDW suitable for recycling, conditionally excluded and excluded from recycling) [10] and, at the same time, the EU Construction and Demolition Waste Management Protocol dated September 2016 (Chap. 4.3 Recycling that includes a list of typical construction materials intended for recycling) [11]. The waste materials listed in the aforementioned Methodological Guidance and the EU Protocol are counted towards the 70% recycling and reuse rate for CDW that must be achieved in accordance with applicable European and national legislation, in particular, according to the requirements of the State Fund for Transport Infrastructure.

3. Material/waste suitable for recycling conditionally – these are mainly waste materials potentially containing hazardous substances (components). Their admission to the facility (recycling site/centre) is possible only if their treatment in the facility includes separation and removal of the hazardous substances (components) from these waste materials, mainly caused by the use of diesel traction locomotives and operating fluid leakages, the fallout of transported materials, especially coal, or windblown pollution from the surrounding environment [9].

The investors from Správa železnic, through their planners, are trying to promote recycling as much as possible because, according to the law, the second most important thing after waste prevention is the use of waste for its original purpose. In the early days, stationary sorting equipment was used, but the disadvantage of this method was the need to transport the processed material into and out of the facility, which is why mobile recycling machines are mostly used at this time. Their great advantage is that they can be moved operatively and immediately according to the actual needs of construction, repair or reconstruction project.

In simple terms, recycling crushes the sorted material that can be sorted further. Such a process produces a new certified material fully capable of replacing the material from a quarry, saving money not only for the purchase of the new material but also for its transportation.

Although initially it was not easy to enforce recycling, the ever-increasing costs, especially for transport and loading of materials, together with the overall legislative framework aligned with the European Union regulations, have created enormous pressure for waste prevention. The protection of natural resources, along with the human environment, has become a matter of course. Virtually all material from the railway superstructure is recycled, except for the hazardous parts located mainly under the switches and in the rail parking areas of diesel traction locomotives [12].

When EN 13450 standard “Aggregates for Railway Ballast” [13] was adopted by the European Committee for Standardisation in 2002, it was considered a huge milestone as it set or benchmarked standards for railway bed aggregate. It was subsequently adopted into the Czech Technical Standards system where, together with other European standards adopted, it replaced the original standards ČSN 72 1511 [14] and ČSN 72 1512 [15].

The common European product standard for aggregates for railway beds already foresees the use of aggregate recycled from the recovered material from existing railway beds. The adoption of the European standards did not bring fundamental changes in the aggregate parameters, but in the way they are verified. The acceptance of the uniform European testing system meant that testing laboratories had to be equipped with new aggregate testing equipment. The aggregate properties determined according to the test procedures in force at that time were fully satisfactory. However, a large number of comparative tests had to be carried out to select the appropriate standard categories required by the new test methods. Most Czech testing laboratories and aggregate producers were involved in this process and provided the necessary test samples for this comparison. Following the publication of the European standard, new General Technical Specifications (GTS) “Aggregates for railway track beds” were developed. These GTS specify which optional properties and value categories listed in EN 13450 must be tested and declared when offering new and recycled aggregates for tracks and switches of railway tracks in the Czech Republic [13].

For railway bed and its arrangement, Regulation S3 Railway Superstructure [7] states:

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- For railway beds of tracks with speed v > 200 km/h, the aggregate of class B0 according to GTS "Aggregates for railway track bed" shall be used. The use of recycled aggregate is not allowed in these tracks.
- The thickness of the railway bed t (see Figures 2 to 6) from the loading surface of the sleeper to the plane of the substructure measured at the points below the rail strip for tracks and switches with a speed v > 200 km/h is usually 350 mm, but not less than 300 mm. The thickness of the railway bed shall not be increased due to the use of asphalt concrete in the plane of the substructure body. [7]

The profile of the railway bed is shown:

a) on a single-track line with the track without elevation gain in Fig. 1,

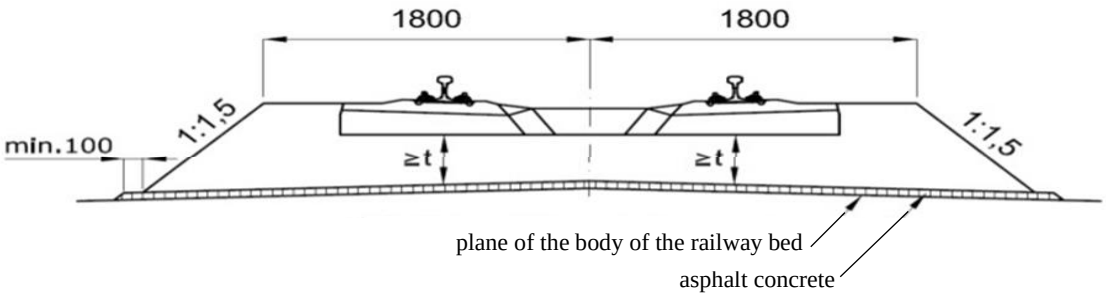

Figure 1. *Single-track line with track with speed > 200 km/h without elevation gain [7]*

b) on a single-track line with the track with elevation gain in Fig. 2,

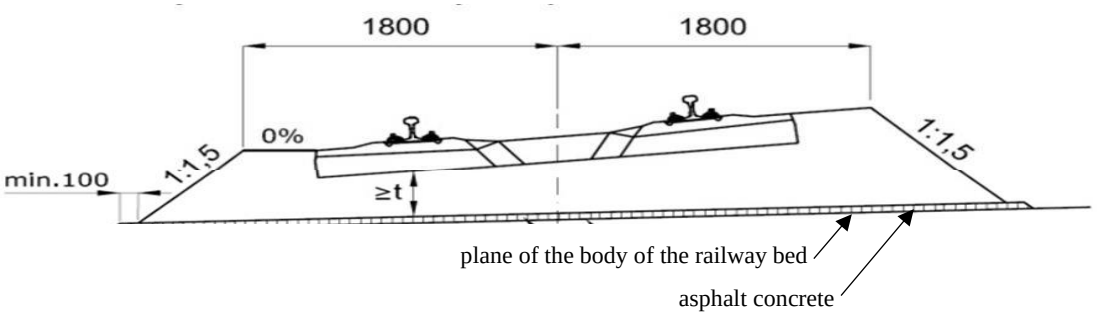

Figure 2. *Single-track line with track with speed > 200 km/h with elevation gain [7]*

c) on double-track line with the track without elevation gain in Fig. 3,

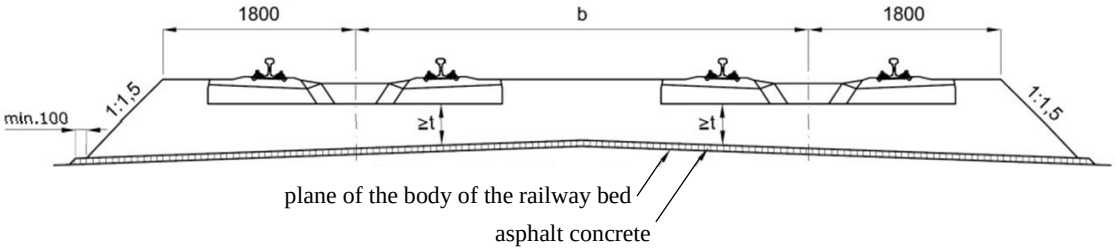

Figure 3. *Double-track line with track with speed v > 200 km/h without elevation gain [7]*

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d) on double-track line with the track with elevation gain in Fig. 4.

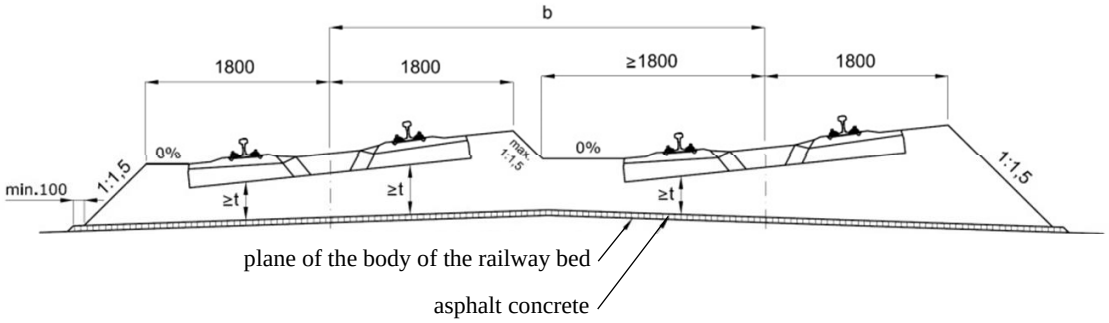

Figure 4. *Double-track line with track with speed v > 200 km/h with elevation gain D ≤ 100 mm when the surface slope of the asphalt concrete layer is up to 3% [7]*

Railway bed camber is not carried out in sections with track intended for speed v > 200 km/h. The railway bed behind the sleeper ends on the outside of the curve shall be adjusted at the level of the upper edge of the sleeper end in the continuation of the junction of the upper edges of the sleeper end. On the inner side of the curve, the railway bed shall be adjusted at the level of the upper edge of the sleeper end to make it horizontal. It is also considered permissible and safe to adjust the railway bed behind the sleeper ends in the continuation of the junction of the upper edges of the sleeper ends on both sides of the track. In the space between adjacent sleepers on the same track, the upper surface of the railway bed shall be adjusted at the level of the junction of the upper edge of the sleeper end and the edges of the upper surface of the central part of the sleeper. A minimum width of 0.10 m must always be maintained between the bottom edge of the railway bed and the top edge of the asphalt concrete layer [7].

Figure 5. *Reconstruction of the railway superstructure (old conditions on the left, new conditions on the right); photo by the author*

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We are now reaching a stage where the oldest upgraded or optimised sections of the transit corridors have been in operation for over 25 years. In order to maintain the quality standard and to extend their effective lifetime, it will be necessary to undertake continuous renewal works as part of their maintenance. The reconstruction process can be seen in Fig. 5. In the area of recycling, improving the survey work in the designing and preparation stage of construction projects is particularly needed for better use of the recovered material. The methodological guidance of the Správa železnic, s.o. concerning the issue of railway bed sampling in the preparation and execution of constructions defines the scope and frequency of the survey of railway bed aggregate, which should be carried out before the recycling proposal in the construction documentation. It is irrelevant whether the recycling is carried out using a recycling line at the recycling base or using special track machines in the track axis. It is also not so important whether the aggregate is recycled to the fraction of 0/32 mm or 32/63 mm [12–15].

4 RAILWAY BED SAMPLING

According to the methodological instruction of Správa železnic on the issue of railway bed sampling within the scope of the preparation and execution of constructions [16], it is necessary to ensure:

a) Information regarding the possible presence of hazardous substances in the reconstructed railway body on the basis of archival documents, the existence of old environmental burdens, accidental spills, the presence of ash pits and original tanks for substances with hazardous properties will be provided as early as the Project Intent stage. Furthermore, the serviceability of the line or the signal box, including shunting tracks, will be taken into account. This will be secured by the Railway Line Manager in cooperation with the Department of Environment of the Organisational Unit to ZTP.
b) The Project Contractor shall ensure that the railway bed contamination survey is conducted in accordance with the engineering-geology investigation of the sleeper bed. This means that the sleeper bed investigation probes will be used for the railway bed contamination investigation.
c) The Project Contractor shall submit a Sampling Plan to the Client's Environmental Specialist, which shall provide a clear proposal of the sampling locations for the project, based on the input data from the ZTP, an inspection of the section in question, and personal experience. The Plan will include a clear overview with a map of the probes. The overview will clearly show which probes are proposed as part of the engineering-geological survey and will be used for the investigation of the contamination of the railway body and the railway bed. In addition, the Plan will include an inventory of all probes according to tracks and track mileage, indicating mixed and primary samples.
d) The preparation of the Sampling Plan should be carried out by the Project Contractor in cooperation with the Specialist (Waste Sampling Manager) to guarantee the quality of the waste sampling carried out.
e) The submitted Sampling Plan will be approved on the basis of an inspection with the Project Contractor (Sampling Plan compiler), where it may be further modified. The approved Sampling Plan will include a proposal of the expected sampling date.
f) The Client's Environmental Specialist will be invited to the sampling (together with the engineering-geological survey). The compiler of the Sampling Plan shall be present during the sampling.
g) During the sampling, the Sampling Plan may be updated and refined according to the actual circumstances (judgment sampling method).
h) The scope of the sampling must meet the legal requirements and methodological recommendations.
i) If it is necessary to sample the individual profiles (ballast, structural layer, if it exists, and soil of the earth plain) separately, it will be done so that the whole profile is not mixed and the results are not biased. In other cases, sampling will be based on the specifications of the project documents.
j) Profile overview: depths are indicative only as they depend on the age of the railway line.

The sampling process will be divided into the following 3 profiles:

1. Railway superstructure – railway bed – fraction 32/63 mm, separate sample from the depth of 0–0.4 (0.5) m in Fig. 6.

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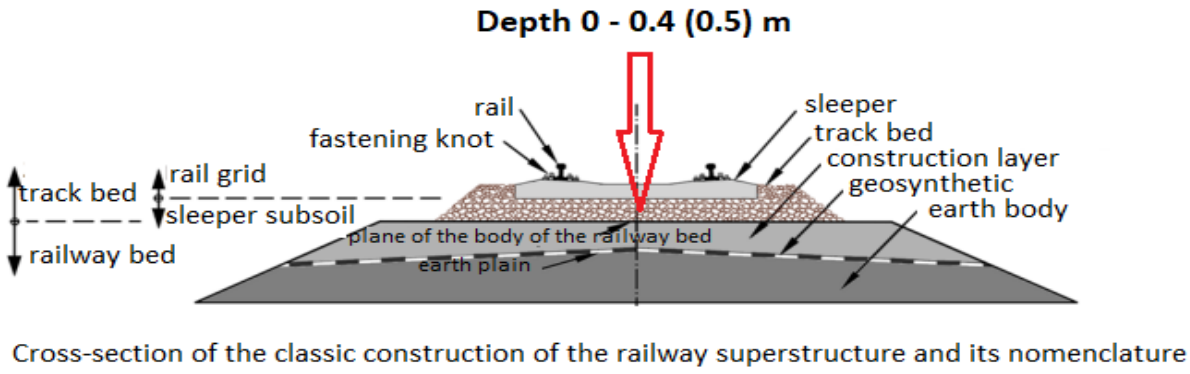

Figure 6. *Sampling location from the railway bed – fraction 32/63 mm, sample from the depth of 0–0.4 (0.5) m [16]*

2. Substructure – construction layer – fraction 0–32 mm, separate sample from the depth of 0.4–0.7 m in Fig. 7.

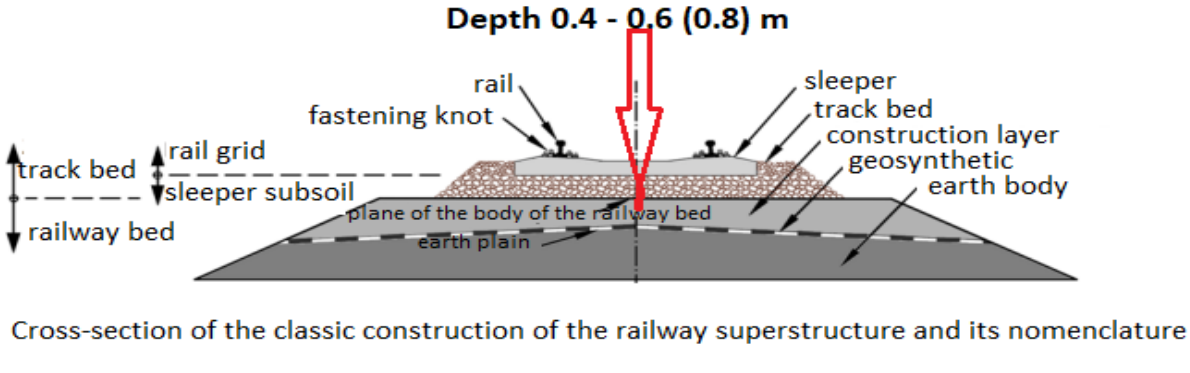

Figure 7. *Sampling location from the railway bed – fraction 0–32 mm, sample from the depth of 0.4–0.7 m [16]*

3. Substructure – earth body – separate sample from the depth of 0.7–1.2 m in Fig. 8.

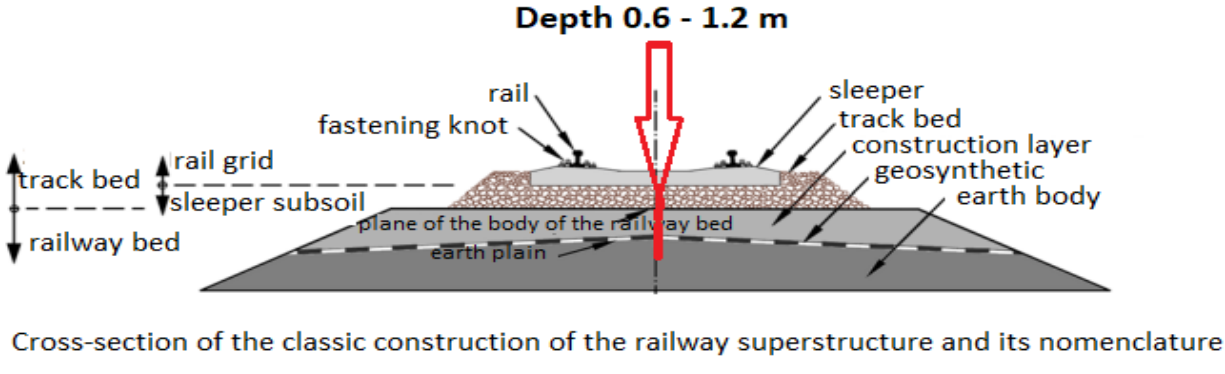

Figure 8. *Sampling location from the earth body, sample fromthe depth of 0.7–1.2 m [16]*

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a) Based on the sampling, a detailed survey will be prepared, which will include the information defined in the Sampling Plan, as well as photo documentation of the sampling.
b) If, as part of the execution of the construction, part of the soil or existing slopes will have to be excavated, these parts shall also be sampled according to the above requirements.
c) The waste management will take into account exactly how and in what quantity the waste or material will be handled according to the construction sites/operational files. A separate summary table will be prepared to show the anticipated amount of recycled construction and demolition waste, its use and the amount of waste intended for landfilling or backfilling in accordance with the current legislation [16].

A summary table will be provided at the end for all operational files and construction sites. It will show an overview and the estimated amount of generated waste. A separate table of construction and demolition waste will be produced, showing the estimated amount to be recycled and the estimated amount to be landfilled [16].

In the event that the subsieve fr. 0/32 mm resulting from the initial sorting of the material shows higher limit concentrations of pollutants. This material must be handled in accordance with the legislation in force, either as material which, although it failed to meet the criteria for storing the material on the ground surface, can be used in landfills for other waste, or the values are already so high that it is a hazardous material. The latter is currently treated mostly by biodegradation methods or landfilling in hazardous waste landfills. However, as this is still a significant part of the material balance, there is an effort to use it as well by means of modern cementation methods used to obtain a substitute input material.

We are also trying to use this hazardous material in our research. We are currently preparing grain size curves and samples for chemical analysis. Sampling of aggregate was conducted at Ostrava main station as described in Chapter 4. The sample was then sieved using standardized sieves, and we prepared samples in fractions 0/63 mm, 32/63 mm, 0/16 mm and 16/32 mm that will now be subjected to chemical analysis according to Decree No. 273/2021 Coll., Figures 5.1 and 5.2 [17].

5 CONCLUSION

The above-presented facts show the infinite potential for the use of waste materials and the possibility of using them to replace natural inputs. The aim is to protect nature and people, to reduce the burden of transport and mining, as well as to save public budgets from having to landfill hazardous waste. It is a complex change in the approach and the concept of waste management, where the subsequent use of waste must be addressed before the beginning of the actual process of generating the materials that later become waste. And, if they are generated, it is necessary to think of them as raw materials, not waste to be stored or disposed of somewhere. Only this change of approach is a sustainable solution for the future, and it is in line with the ideas of the circular economy. This should be reflected in the relevant legislation, which should define and support this change of approach. It is often done only theoretically, and unreasonable demands are often imposed on people who want to use waste as a substitute for natural resources.

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ABBREVIATIONS AND SYMBOLS

The list below contains the abbreviations and symbols used in this document. The list does not include legislative abbreviations, abbreviations and symbols commonly known, established by legislation, referred to in the figures, examples or tables.

ČD	*České dráhy, a.s.*
WTP	*Wastewater treatment plant*
EC	*European Community*
EU	*European Union*
GD	*SŽ General Directorate of Správa železnic, state organisation*
FB	*Fire Brigade of SŽ*
INP	*Identification number of the plant*
INE	*Identification number of the equipment*
ISOD	*Information System for Operational Documentation*
MTS	*Material technical supply*
MoE	*Ministry of the Environment*
WM	*Waste management*
OU SŽ	*Organisational units of SŽ*
O15 E	*Operational Department, Environmental Department of the SŽ General Directorate*
OC	*Organisational components (general directorate and organisational units)*
PCBs	*Polychlorinated biphenyls, polychlorinated terphenyls, monomethyltetrachlorodi–phenylmethane, monomethyl dichlorodiphenylmethane, monomethyl dibromodi–phenylmethane*
HA	*Head of Administration*
DOU	*Director of the organisational unit*
BD	*Building Division*
SW	*Software – computer software*
SŽ	*Správa železnic, state organisation*
HED	*Head of Environmental Department*
HED OU	*Head of the environmental department of the organisational unit of SŽ*
SC	*Site clearance*
RTC	*Railway Transportation Communication*

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