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A Departure From Customary Practice – Options to Reduce the Use of Materials in Tramway Track Structures

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The track system traditionally used in tramway track design is 59Ri2. Due to technical progress, the rigidity of modern flexible track structures has become sufficiently rigid and durable, and as a result, track systems with much lower inertia, such as Ts52, have also appeared. The use of the 59Ri2 rail system continues to dominate in embedded rail structures, which is not only statically oversized, but also significantly increases the amount of pouring material used, considering that both rail systems are suitable to carry road rail loads and their service life is considered similar (same wear allowed). This is not only an economic issue, but also a manufacturing and logistical one. Due to the scarcity of resources, a greater length of track can be built at unit cost by minimising the use of materials, and the amount of pouring material available on the market has been periodically limited in recent years. In this article, we use the side results of our previous finite element models to show the impact of track system dimensions on the amount of pouring material, and also detail the extent of material savings with PVC pipes and concrete material saving blocks.

Keywords:
tramway track,
optimization,
embedded rail system
(ERS),
pouring material,
material saving items

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R32,
R41

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1 Introduction

In 2014, Zoltán Major made the following observations on the cost-optimal design of embedded rail structures in an article (Major and Kulcsár, 2014).

The practical design of embedded rail structures is currently based on costly laboratory tests, with one variant tested at a time. Their optimisation is not addressed at all in Hungarian practice, and only rarely in international practice, although correctly chosen parameters can lead to significant cost savings and more accurate compliance with environmental load requirements. Other research groups (Markine et al., 2000) have presented the optimisation of embedded rail structures for several parameters. In this paper, the optimisation process also considers variations that are "redundant" for practical design, since the range of available materials and rails is considered given, and therefore variations are only possible for specific cases in engineering practice. For example, there is no point in describing the variation in rail thickness during optimisation as a function, since these are values specific to a particular rail system and even if an optimum is found, no new rail type will be developed taking into account the values obtained. Thus, the properties to be optimised are summarised below:

- elasticity properties,
- the amount of casting material,
- maintenance needs,
- acoustic properties.

In this article we will focus in detail on the issue of the quantity of the pouring material, as it is the most costly component of the track structure and its availability to contractors has been limited at times. The price of a typical material used in Hungary from 2023 (SIKA, 2023) is 14,529 HUF/kg. This corresponds to a price of 36.3 Euro/kg at an exchange rate of 400 HUF/Euro. The density of the material is 0.9 kg/liter, so the price per volume is 40.4 Euros/liter.

2 Theoretical Background

The general knowledge (Darr and Fiebig, 2006) and design (Freudenstein et al., 2018) of ballastless track structures are discussed in detail in the literature. However, the literature available typically deals with the issue of track structures with embedded rails in less detail. The study of these structures from an ecological economics point of view can also be considered as a new field of research, which was also addressed by Major et al. (2023a). For these structures, the use of a well-chosen type of pouring material, precisely designed pouring dimensions and, if necessary, elastic tapes can have a positive influence on the development of stresses in the rail, the vertical and lateral deformation of the rail under vehicle load, as well as safety against vertical thermal expansion and gap opening due to rail breakage. Due to the homogeneous support, the stresses and deformations of the rail are more favourable than in other tracks, allowing the use of rail systems with lower mass than conventional designs. The amount of pouring material is not independent of the spring constant to be used, so optimisation is only possible by considering these two factors together. The quantity is influenced by the chosen rail system, the geometry of the rail channel and the pouring, the use of material savings items. Based on the known geometry, it is possible to determine the specific material consumption, which is the amount of pouring material per metre of rail. The general layout of the structure is illustrated in Figure 1.

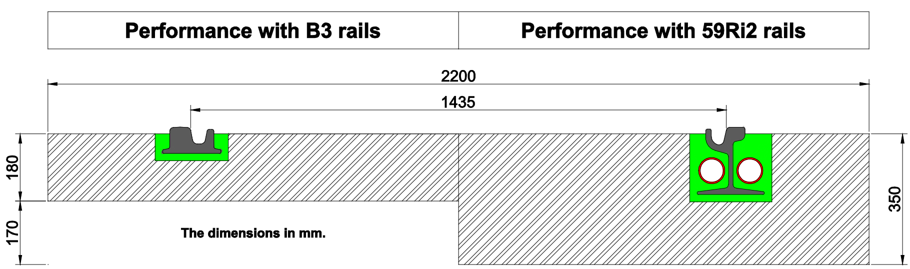

Figure 1: The performance of embedded rai structure (two structures)
Source: author's own illustration

3 Methodology

Numerical modelling allows the analysis of a large number of variations, replacing much of the time-consuming and costly laboratory testing. The results of finite element analysis can be used to select the optimal variation. In addition to the results of the structural analysis, additional tests can be performed for each variation based on side results such as the amount of pouring material. Our models also allow us to deal with the practical problem of placing a PVC pipe or a material saving concrete block in the pouring material or using a different rail system in the superstructure. In our investigations, we have used several different models to explore the differences in behaviour of each variant. These models were as follows:

- reference model: channel with full pouring (Figure 2),
- model with concrete material saving blocks (Figure 3),
- model with PVC pipes of different diameters (Figure 4).
- block rail/smaller rail model (Figure 5).

In this article, we will not examine structures with concrete material saving blocks due to space constraints and less used application in Hungary.

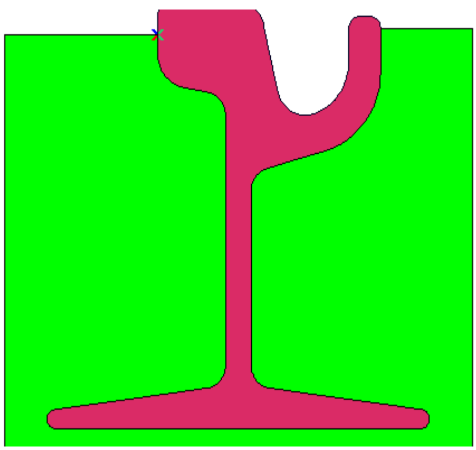

Figure 2: Finite element model of the reference structure
Source: Axis VM program

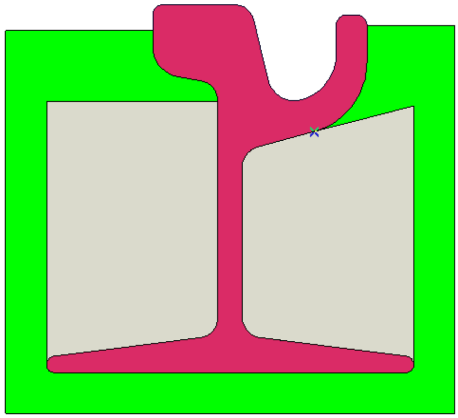

Figure 3: Finite element model of a structure with concrete material saving blocks
Source: Axis VM program

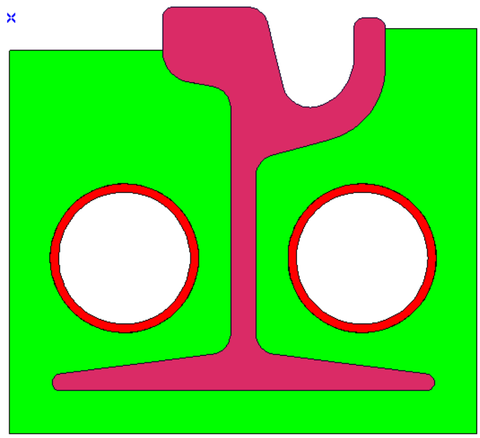

Figure 4: Finite element model of the structure with PVC pipes
Source: Axis VM program

Figure 5: Finite element model of the block rail structure
Source: Axis VM program

4 Results

The amount of pouring material is one of the most important descriptors of the chosen superstructure design, as it can have a major influence on the cost of installation. The quantity depends to a large extent on the desired flexibility, the rail system chosen and any material saving items used. In order to get an accurate picture of the variation of the pouring material as a function of the underpouring thickness, we have plotted the material consumption of our finite element models and fitted a linear function to the values. This is illustrated in Figure 6.

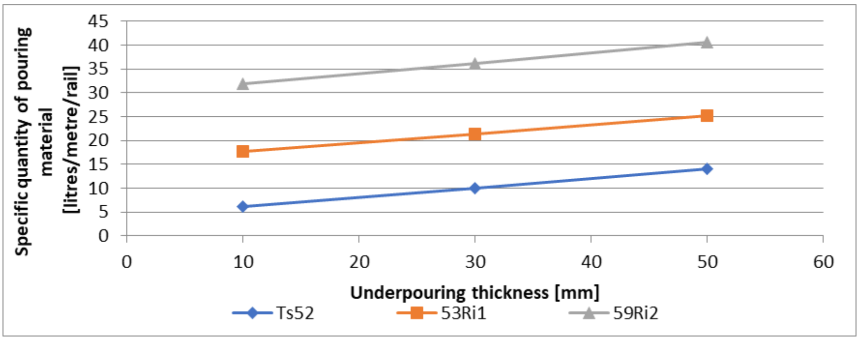

Figure 6: Specific pouring volume of investigated rail systems
Source: author's own illustration

Based on the amount of material and the specific price, we determined the material cost of the rails, which is illustrated in Figure 7.

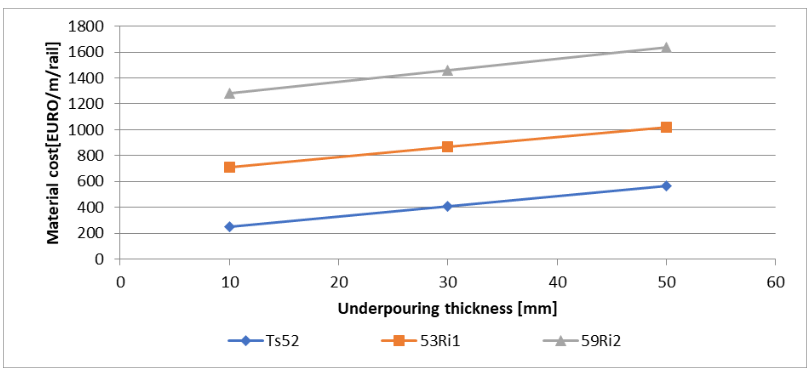

Figure 7: Material cost of investigated rail systems
Source: author's own illustration

Figure 7 clearly shows that the rail system used significantly affects material costs. Significant cost savings can be achieved by using the Ts52 rail. In the case of the 59Ri2 rail, it is possible to install material saving items to reduce costs. In Hungary, the use of concrete material saving blocks is currently still discouraged, while the use of PVC pipes is restricted only in certain cases. One such restrictive design case is road crossings, where cross traffic also uses the road structure. The contractors are trying to lift this restriction and concrete over PVC pipes. In this article, we will therefore only deal with the impact of PVC pipes on the volume of the pouring material. For different track systems, different diameters of pipes can be installed in the sling chambers, the diameters in use being 32, 40, 50 and 70 mm. In the case of block rails, PVC pipes cannot be used.

The amount of pouring material that can be saved with PVC pipes is summarised in Table 2. In this table, we have also summarized the price of the pipes (Termofix, 2024) at an exchange rate of 400 HUF/EURO, as well as the value of the savings that can be achieved with them.

Table 2: Amount of pouring material saved per pipe diameter

Diameter [mm]	Specific exclusion [litres/metre/pipe]	Specific exclusion [EURO/metre/pipe]	Price [EURO/m/pipe]	Saving [EURO/m/pipe]
32	0.8042	32.5	1.6	30.9
40	1.2566	50.8	1.9	48.9
50	1.9635	79.3	2.3	77.0
70	3.8485	155.5	3.5	152.0

As can be seen in Table 2, in the case of using 2 drab 70 mm diameter pipes, savings of up to 300 EURO/meter can be achieved, which makes the costs of using the 59Ri2 rail fiber more favorable. Nevertheless, these costs are still much higher than when using the Ts52 rail. Based on the obtained values, the costs can be significantly reduced with the careful use of materials, and thus it is possible to make more significant investments even in periods of lack of funds.

5 Discussion

As we have the possibility to complement the existing data by considering costs and CO_2 emission values, we plan to further research the development of a more complex method for the multi-criteria analysis of spilled duct structures, taking into account life cycle engineering considerations (Gáspár et al., 2011). This analysis requires special data analysis solutions, which have been addressed in detail by Kocsis (2014).

6 Conclusions

In this article, we have presented in detail the possibilities of reducing the amount of pouring material in embedded rail structures and their effectiveness in optimising the materials used in the structure. Reduced material use results in a lower environmental impact, the positive effects of which can be further enhanced in urban environments. To this end, efforts should be made to develop green corridors, the general aspects of which are described in detail by Kappis et al. (2014) and guidance on the level of CO_2 emission reductions that can be taken into account is provided by Major et al. (2023b). Based on this, the CO_2 emissions saved during the building process can be added to the CO_2 sequestered by vegetation on an annual basis, which needs to be summed up to the end of life (analysis period) in order to make the individual removals comparable.

References

Darr E., & Fiebig W. (2006) Slab track, Eurailpress. Hamburg

Freudenstein S., Geisler K., Mölter T., Mißler M., & Stolz C. (2018). ballastless track. Ernst & Sohn Verlag. Berlin

Gáspár L., Horvát F., & Lublóy L. (2011). UNIVERSITAS-Győr Nonprofit Ltd.

Kappis C., Schreiter H., & Reichenbacher K. (2014). track greening MANUAL. eurailpress. Hamburg

Kocsis, T. (2014) Is the Netherlands sustainable as a global-scale inner-city? Intenscoping Spatial Sustainability. Ecological Economics, 101, 103-114. https://doi.org/10.1016/j.ecolecon.2014.03.002

Major, Z., Horváth, R., Szennay, Á., & Szigeti, C. (2023a). EXAMINATION AND OPTIMIZATION OF THE ECOLOGICAL FOOTPRINT OF EMBEDDED RAIL STRUCTURES In Conference Proceedings of the 7th FEB International Scientific Conference: Strengthening Resilience by Sustainable Economy and Business - Towards the SDGs (pp. 19-27). http://doi.org/10.18690/um.epf.3.2023.5

Major Z., & Kulcsár N. (2014) Flexible ballasted cast-in channel railway superstructure (2.): Numerical modelling of flexible channel channel outpourings. TRAIN VILAGA 56:(1) pp. 22-26.

Major, Z., Szigeti, C., & Czédli, H. M. (2023b). CHEMICAL ENGINEERING TRANSACTIONS, 107, 289-294. http://doi.org/10.3303/CET23107049

Markine V. L., de Man A. P, Jovanovic S., & Esveld C. (2000). Optimal design of embedded rail structure of high-speed lines. http://www.esveld.com/Download/TUD/RE2000.pdf. downloaded: 2016.04.10.

URL: https://hun.sika.com/dms/getdocument.get/cf9c96ac-e826-4fe1-9b57-156e02e6eeb5/%C3%81rlista_2023_II_HUF.pdf, downloaded: 2024.04.04.

URL: https://www.termofix.hu/termekek/szennyvizelvezetes_szifonok/pvc_cso_idom/pvc_lefolyocso, downloaded: 2024.04.04.