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Ballast trough on ground as an alternative to slab track

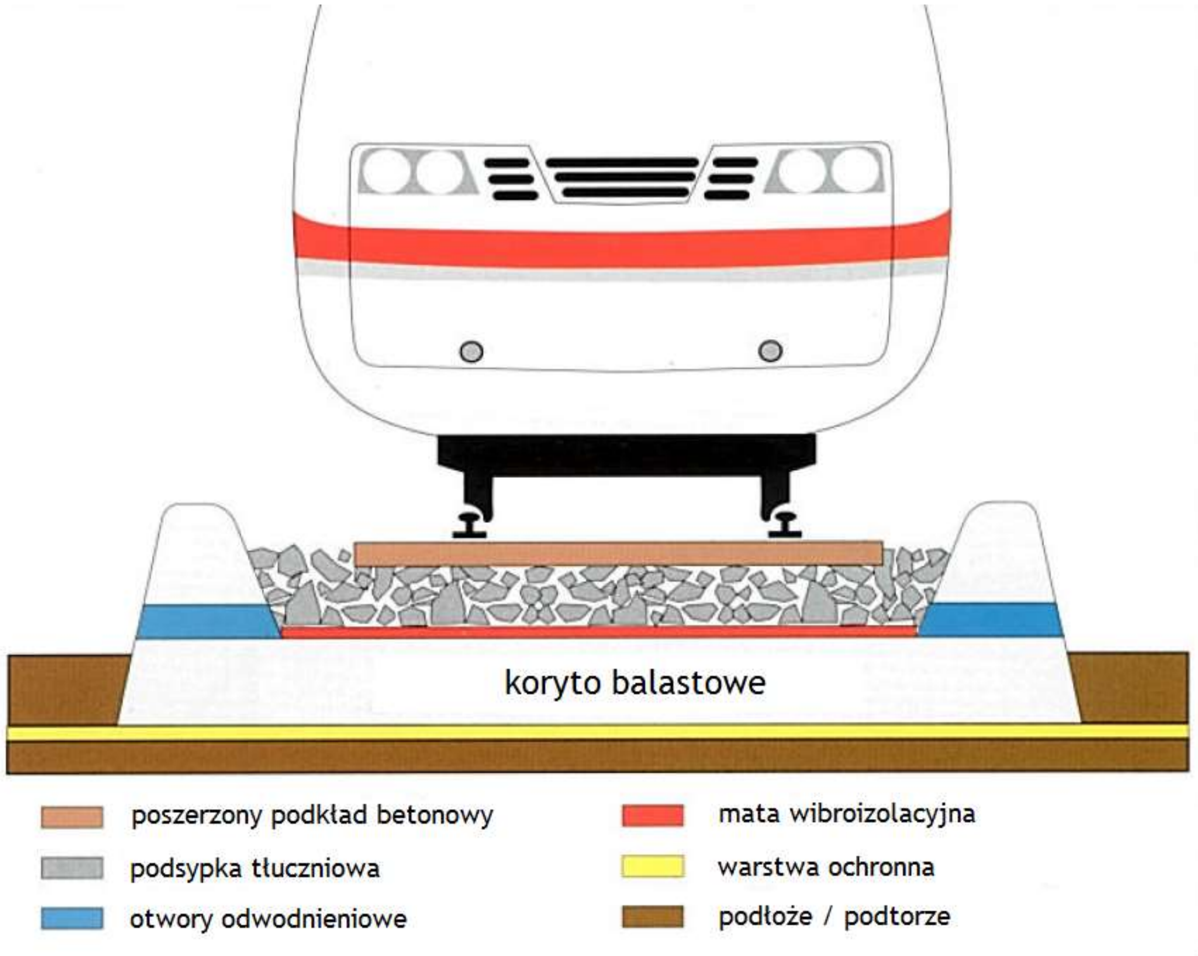
Abstract: Due to an increase in expectation concerning human environment and increase in comfort of habitat and workplace, a rising role of means and measures protecting from excessive noise and vibrations can be noted. To meet the requirements of sustainable development, countermeasures should result in long-lasting social and economic benefits. The paper deals with the subject of noise and vibration protection of people and structures along a railway line. A system consisting of concrete trough on ground, containing ballasted track was proposed and erected. This structure was compared with classic and slab track.
Keywords: Ballast trough; Ballasted track; Slab track

Introduction

Numerous boards crossings, including Polish, facing the modernization of the railway line passing through built-up areas with the problem of proper selection of protection against vibration and noise. Along with the easier access to knowledge and information, local communities and other neighbours of railway lines and stations generally indicate exceeding of acceptable levels of noise and vibration, which affect their buildings, seeking to limit their intensity below the permitted threshold. One of the proven ways to reduce the level of impact of railroads on the environment is the use of properly selected slab track. The only selection of the type of road surface is a complex issue - for example, ANKOT according to the method described in [8], to achieve the optimal design in a given location, expects the analysis of 16 technical issues. In addition, each type of track has numerous variations, options or additional parts, which significantly increases the number of combinations. The classic antagonism of this type is to compare advantages and disadvantages of slab track and ballast-free structures. There are considered for example geometric issues of the track position, the sustainability of its individual components, costs or the level of impact on the environment. It turns out that in some respects a classic slab track still dominates over the intensively developing ballast-free structures. In order to eliminate or reduce its obvious shortcomings all kinds of additional elements are used, such as geosynthetics, breakstone mats or chemical stabilization crushed stone [1,4,10].

Track in ballast trough – assumptions

The owner of the patents granted in the late 90s on the described solution is the company Grötz. The main element of the system is a ballast trough. It differs from solutions for bridge objects in that it is made of plain low-shrinkage concrete modified with silicates, having a thickness of about 65 cm, and produced in a controlled cracking process [5]. The trough is partially buried in the ground, thus a high level of resistance to horizontal movement is ensured. The large support surface of the bottom plate provides a low pressure on the ground, which makes the system suitable for use on grounds with low or varying load. In the measurements, it was shown that the stresses are reduced to 50% below 50 cm of the backfill bottom in comparison to the classical slab track [6]. The side elements of trough may be formed as a monolith with the bottom, but in the example, conglomerates have been applied, which were combined with the plate by means of steel connecting pins spaced at regular intervals. It is also reserved a solutions, in which the longitudinal concrete beams with trapezoidal cross section are placed in a pile of ballast near the outer edges of its base. Their role is to reduce creeping of the prism ballast, but with no intention to completely eliminate this negative phenomenon. An exemplary cross-section of the slab track ballast in trough is shown in Figure 1.

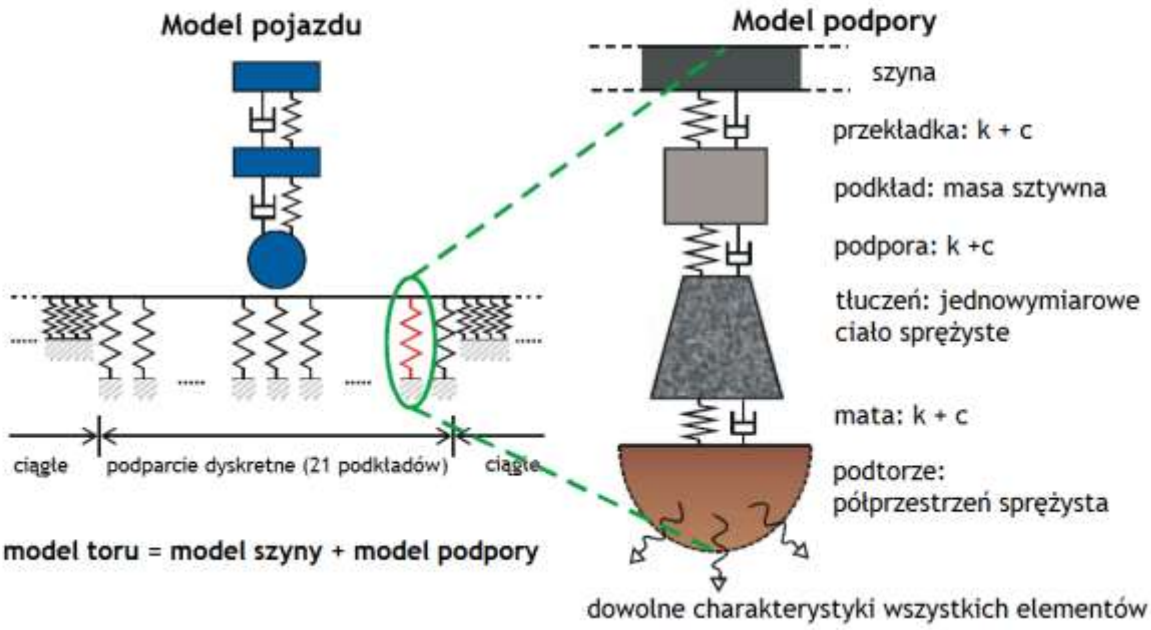


1. An exemplary cross-section of the slab track in the ballast through, according to [1]

The use of a rigid support for the ballast is to limit the possibility of its movement, which should be understood first of all as the loss of the original shape of the prism (called outcreeping), and eliminating the possibility of a so-called ballast bags. In addition, it has been shown that the share of ballast in the development of permanent deformation of the classic rail surface exceeds sometimes even 70% [9]. The only displacement limitation of the ballast, for example by increase in stiffness of substrate, however, would lead to larger stresses in the layer and this could result in accelerated wear, e.g. by grinding the edges of grains or crushing. It is therefore advisable to introduce additional vibration isolating elements such as highly susceptible fastenings, elastic support sleepers or breakstone mats that will take over from the ballast layer an essential part of surface structure work in its elastic state. According to the assumptions, the surface should be almost maintenance-free.

Computational model and validation

Operation of the system was simulated using a specialized software iSi present in various variants, dedicated to various surface structures. The program, whose development has already been started around 1995, is based on the so-called inertial model. As a load it was adopted a widely used model consisting of three masses combined by dampened and elastic ties. Temporary track sections were modelled as a continuous support. In the middle section, the model includes 21 discrete supports, in the form shown and described in Figure 2.



2. Model of surface and vehicle used in the program iSi, according to [6]

The program was limited to vertical forces and displacements. Other models [2,3] based on similar assumptions allow to obtain the value of displacement, velocity and acceleration at a given point along the route, both for a track and a vehicle. The load is presented as a model of a train with multiple degrees of freedom, which approximates to the actual state, but the used procedure requires a relatively considerable amount of computational work. To confirm the results of computer simulation, measurements of surface behaviour under movable load were performed on the track section built in 2004. A measurement train consisted of two locomotives and two carriages and moved at speeds of 80, 100 and 125 km/h. The resulted measurements are summarized in Table 1. The comparison was carried out in pairs, with regard to each relative difference in damping between individual solutions of pavement, and expressed in numbers (in dB) and percentage.

An analysis of the data compiled in Tab. 1 shows that the solution in the form of ballast trough on the ground with the addition of vibration isolating mats, met with considerable reserve requirements resulting from the agreement between railway management and the local government. The reserve is understood as the difference between the numbers from the first row of the table and the next ones in the same column.

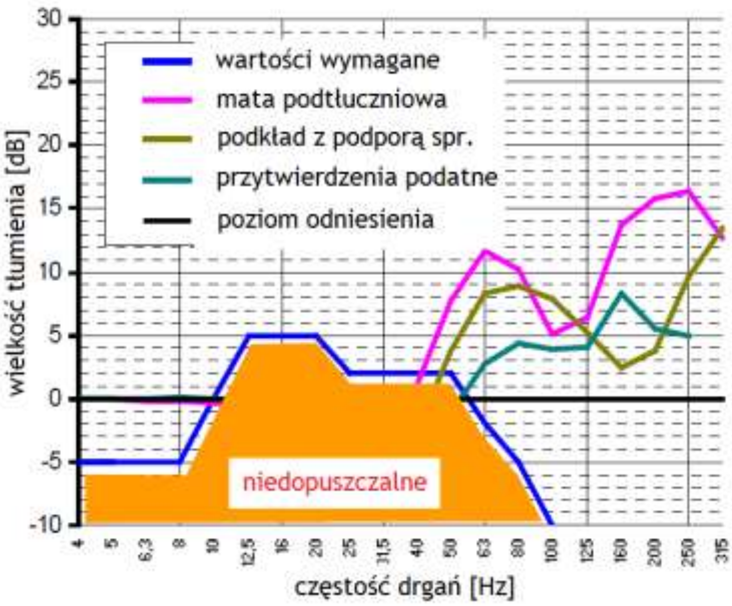
Tab. 1. Comparing relative levels of vibration for the system Grötz, according to [5]

Reference	On average 4-100Hz	Wooden roof 12,5-20Hz	Concrete roof 25-40Hz	Floating subgrade 50-80Hz
Requirements of the community Sinzheim	+4,5dB -40%	+5dB -44%	+2dB -21%	-2,5dB +33%
System Grötz: new ballasted track	+7,3dB -57%	+10dB -68%	+7dB -55%	+6dB -50%
System Grötz: previous track (exploited track on wooden sleepers)	+7,7dB -59%	+14dB -80%	+7dB -55%	+1,5dB -16%
New ballasted track: previous track	0dB	+4dB	0dB	-2dB

	0%	-37%	0%	+26%

Examples of realization

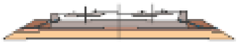
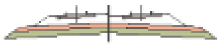
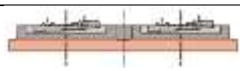
German railways DB ordered a trial section in the technology Grötz on the reconstructed and modernized line Karlsruhe - Basel, at the station Baden - Baden (Oos). The trial section with the length of about 300 m was built in 1997 [7]. On the basis of experience gained then, a decision was made in the DB that the adjacent section in Sinzheim will be also implemented in this system. Preliminary measurements showed that under the influence of the investment there are about 200 houses, exposed to high levels of vibration and noise. The issue of protection against noise was regulated by a separate agreement with the local inhabitants, already ratified in 1994. In order to reduce the emission of vibrations, precisely defined requirements about the construction of a track were determined. In buildings with wooden roofs, the damping level should be not less than 5 dB in the frequency range 12.5 - 20 Hz, and for concrete slabs 2 dB in the range of 25 - 40Hz. For floating floors, it is allowed an increase in the vibration with 2.5 dB in the range of 50 - 80Hz. A preliminary simulation led to the conclusion that none of the three standard solutions, i.e. breakstone mat, sleepers with elastic supports and particularly vulnerable fastenings, will be effective enough to independently fulfil the conditions imposed. The simulation results are plotted in Figure 3. As a result of these calculations, a trough of Grötz system with vibroisolating mat was installed on two sections with the length of 1000 m and 910 m, from the nursing home to Kartunger Str. and from the stop axis in Sinzheim to the viaduct road 500 [6]. The breakstone mat of type USM 4015 used in this section has a thickness of 14 mm, the static stiffness of 0.15 N/mm^3 and the dynamic stiffness at 40 Hz of $0.47 N/mm^3$ under the load of 0.1 N/mm^2.



3. Simulation of effectiveness of selected solutions that reduce vibration in the track, according to [5]

In 2002, an analysis was performed to compare the features and costs of selected structural solutions for the track dedicated to high-speed trains [5]. It was taken into account different elements of the subgrade and paving, necessary to build 1 m single track. The classic slab track was adopted as the reference level, which may be surprising today, because of significant dominance of slab systems, but in that time, such considerations were definitely entitled, regarding the operational experience of French, Spanish or Italian railways. A key part of the comparison is shown in Table 2.

Tab. 2. Comparing costs of surface and substructure in the systems: ballast trough on ground (Grötz), ballasted track, slab track (Rheda i Getrac), according to [5]

Single track	 System Grötz	 Slab track	 System Rheda	 System Getrac
Substructure	Protective frost-resistant, levelling layer E = 45-60MPa	Protective frost-resistant layer E = 120MPa	Protective frost-resistant layer E = 120MPa subsidence < 15mm	Protective frost-resistant layer E = 120MPa subsidence < 15mm
Cost of substructure	90 €/m	200 €/m	360 €/m	360 €/m
Surface	Non-reinforced concrete trough trough D>55cm, or breakstone mat, ballast, substructure, fastening, rail	PSS ballast, substructure, fastening, rail	Lean concrete, reinforced plate B35, or grate track with different types of sleepers fastening, rail	Lean concrete, drainage with wells, 3x bitumen layer (>35cm), connector, substructure, fastening, rail
Cost of surface	870 €/m	500 €/m	860 €/m	840 €/m
Noise reduction	Unnecessary	Unnecessary	150 €/m	150 €/m
Total	960 €/m	700 €/m	1370 €/m	1350 €/m
Difference to the classical solution	+ 260€/m	-	+ 670 €/m	+ 650 €/m

The analysis of the data in the Table shows that the preparation of the subgrade in the ballast trough system on the ground is half cheaper than the slab track and four times cheaper than in the slab tracks. The cost of the surface itself is similar in all three cases under consideration and constitutes about 170% of the ballast track. Globally, it is shown that the system of ballast trough on the ground is more expensive by about 260 €/m than a traditional solution, but added another 400 €/m should be to the slab tracks.

Another important aspect in favour of performing the surface in the form of ballast trough on the ground is that it is very easy to eliminate inaccuracies in this construction, thanks to a certain tolerance in shaping track position in the plan and profile within the trough. The impact of unplanned operational point subsidence, which do not result from the emergency state of the subgrade, can be ignored by simple raise with launching track.

Summary and conclusions

The slab track in the ballast trough on the ground is an interesting intermediate link between the classical slab track and ballast structures. It is intended to connect the advantages of both systems. Particularly promising are: the possibility of using on grounds with too little capacity for other structures, the ease of making adjustments of track position and lack of abrupt changes in the stiffness of the substrate on bridge objects. However, it is not a solution completely free of defects, for example, in the classic version, there are still unfavourable phenomena lifting gravel at high speed of rail traffic. In general, considering profits and losses, it is crucial to appeal to the twenty years operating experience of German railways. Author's professional experience shows that one of the two scenarios of ongoing construction projects and tenders is possible: either the contractor is allowed to select parameters of vibration protection, or exact characteristics of the product of a particular company are taken into account. However, there is no basic requirement about the aim which should be achieved. It is understood as a reduction of noise and vibration to a specific assumed level, as it is described in the article. This makes the selection of products completely random in multiple locations, which results in their limited effectiveness. The example shows that already two decades ago, it was possible to carry out relatively complex calculations, whose results in a sufficiently good way are able to approximate real damping-elastic characteristics of the improved rail surface.

In countries where the level of execution of construction works is not sufficient, the primary criterion for selection of the structure type is the price of building disregarding operating costs, it is safer to use solutions that offer a possibility to easily make adjustments and amendments during the operation. One of them is described in the article the slab track in the concrete trough.

It seems appropriate to carry out further work on the development of hybrid rail surface. The most appropriate direction of the development should be improvement of physical properties of gravel ballast, because this element constitutes the weakest link of surface and is characterized by particularly high volatility and hardly measurable characteristics. As a result of these studies, it may appear that the optimal solution is the surface connecting ballast and ballast-free features in selected situations.

Source materials

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