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Resilient pads with custom designed stiffness

Abstract: The paper deals with examples of using vibration insulation in project documentation. The research methodology and the results of measurements of elastic characteristics of rail fastening components in the form of rail pads and baseplate pad was presented. High precision of designing and manufacturing of elastic elements with a specific characteristic was emphasized. Shortcomings of national legislation in this area have been pointed out. In the summary, the desired directions of changes in this unfavorable situation were defined.

Keywords: Resilient pad; Railway; Railway track

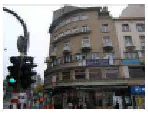
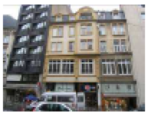
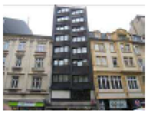
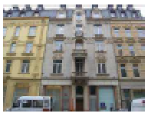
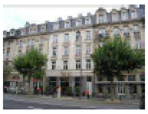
Introduction

Continuous investments in the field of urban and long-distance rail transport infrastructure force investors, designers and contractors to find compromises between the optimization of project costs and compliance with today's standards and expectations of low levels of vibrations and noise. It becomes necessary to apply new technologies and components both in the design of new rail infrastructure facilities and in the modernization of existing structures. In the latter case, spatial restrictions, related to the close vicinity of the development, the historical shape of the routes in the intensively developed terrain or the presence of underground facilities become particularly important. Therefore, it is rational to choose the technologies and materials used to minimize their purchase and maintenance costs over the entire lifetime, while maintaining high operational parameters.

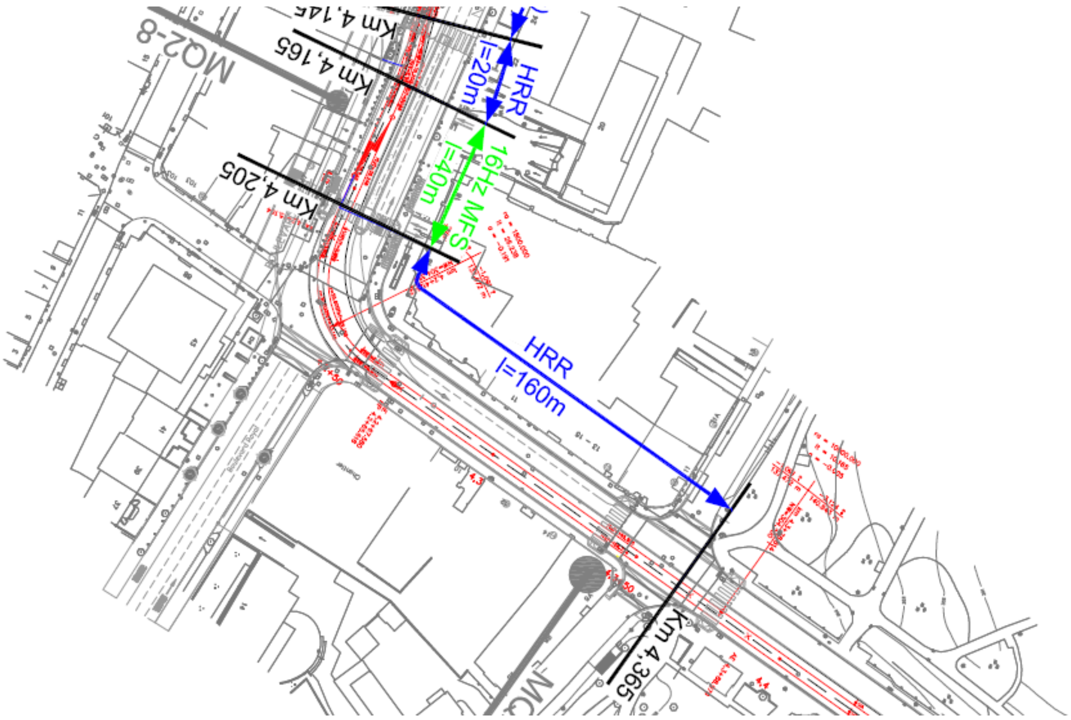
Selection of the surface type - a positive example

In 2015, construction work began on a new tramway line in Luxembourg. The key stages of the project, the progress of work and other relevant data were given in quite detailed studies to the public [10]. One of the preparatory studies was to determine the state of street buildings constituting the corridor, which the planned tram line was supposed to run, in order to select appropriate protection measures. The extensive volume [7] indicates a procedure algorithm that, according to the author, can serve as a model for all such investments. The first part describes briefly the differences and dependencies between vibrations, primary noise, and secondary noise, and then a few methods of reducing these impacts are indicated. The second part contains a description of two measurement stations: in Luxembourg, in 20 previously selected measuring points, and in Brussels, at the reference track during the tramway crossing. At this stage, places requiring special protection (e.g. a concert hall), as well as elements of the track generating increased impacts (turnouts, arcs with small radii), have already been identified. The third stage proposed the deployment of specific protection measures, both in tabular form and in situ plans. A fragment of the table with the description of the measurement points is shown in Fig. **1**, while Fig. **2** shows a section of the situational plan with the applied solutions, where HRR stands for High Resilient Rail, and 16Hz MFS - Masse Feder System (mass-spring system) with an own frequency of 16 Hz).

Projekt: Luxtram Proj.-Nr.: 10-5360	Erschütterungstechnische Untersuchung	Datum: 15.8.2011	Seite: - 25 -

Mess-querschnitt	Bild	Adresse	nächst-geleg. Boden-gutachten	Bauwerks-typ / Nutzung	Ge-schoss-anzahl	Entfer-nung zum Gleis	Unter-kellert	Holz-/ Beton-decke	Datum der Mes-sung	Zone* (vgl. Anmer-kung S. 30)	gem. DIN4150-2 Tab. 1	zu beur-teilender Zeitraum	max. zul. Schallpegel [dB(A)]		
													gemittelt Tag/Nacht		einer Vor-beifahrt
MQ2-01		1, place de la Gare	FR2-01	Bäckerei	6	13,6 m	✓	Beton	02.10.10	MI	Zeile 3	t/n	40	30	40
MQ2-02		61, av. de la Liberté	SG 2-03	Wohngebäu-de/Geschäfte	5	5,7 m	✓	Beton	02.10.10	SP	Zeile 3	t/n	40	30	40
MQ2-03		59, av. de la Liberté	SG 2-03	Apartment-Hotel	9	5,7 m	✓	Beton	02.10.10	SP	Zeile 3	t/n	40	30	40
MQ2-04		41, av. de la Liberté	SG 2-04	Wohngebäu-de /Büro (Bank)	5	5,7 m	✓	Beton	01.10.10	SP	Zeile 3	t/n	40	30	40
MQ2-05		33, av. de la Liberté	SG 2-06	Bürogebäu-de/ Geschäf-te	5	9,8 m	✓	Beton	29.09.10	SP	Zeile 3	t/n	40	30	40

1. Tabular description of the measurement points at the planned tram route in Luxembourg, for [7]

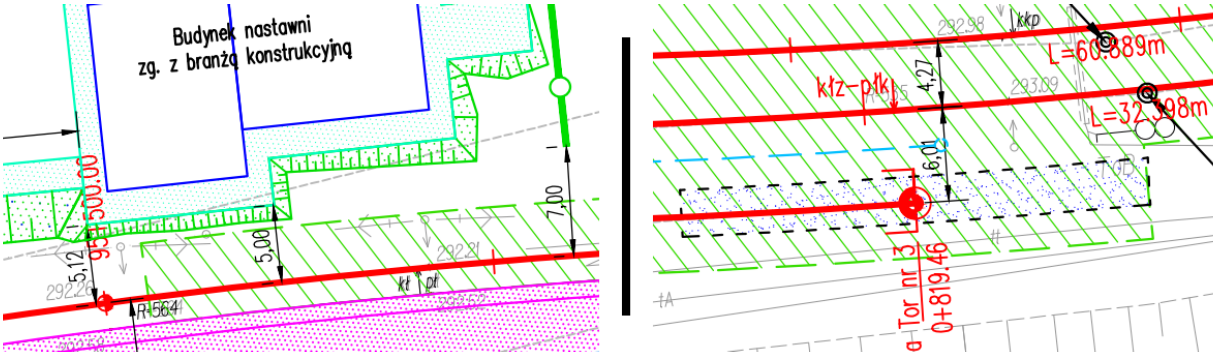


2. Proposed arrangement of special track structures in the planned tram route in Luxembourg, for [7]

In December 2017 the first part of the route was opened, between the depot located in the north-eastern part of the city, and the Pfaffenthal - Kirchberg railway station, and after the construction in 2021 the trams are to run from the airport to Cloche d'Or, therefore the project is still underway.

Selection of the surface type - an example less positive

In 2017, design documentation for the reconstruction of the track system of one of the railway stations in southern Poland was made. According to the author, the selection of measures to protect against vibration and noise was made arbitrarily in it, not looking at the assumed effects, only suggesting the use of a specific product present on the market. The course of proceedings presented in it does not seem appropriate both in terms of limiting the choice of the track construction itself ("the most effective solution is to provide a direct horizontal insulation - substructure of under ballast mats") or vibration isolating material and its structure ("homogeneous, foamed flexible polyurethane ";" grooves or internal cavities are not acceptable "). There are also doubts about the spatial layout of the designed mats: they were not used on a bridge structure with a girders construction, located approximately 20 m from the frontage of the tenement houses; the mat breaks off at the length of the proposed control room, located about 7m from the axis of the track outside a fairly narrow arc, but its arrangement is provided under the take-off track ended with a stop trestle, and even outside it, although the project does not mention its future extension (Fig. **3**).



3. Two fragments of the plan discussed in the text, the hatching in green color, the range of laying the vibration isolating mat were marked

On this basis, it can be assumed that the type and scope of the proposed solution were not subject to in-depth analysis. It should be concluded that since no clearly defined effect of limiting impacts on buildings near the tracks is assumed, it will also be impossible to properly assess the effects of the implemented solutions, which basically makes the whole undertaking dubious from an engineering point of view. The considerations included in the above paragraph are out of date if the documentation submitted for analysis was incomplete or was later supplemented with additional studies unknown to the author during the creation of this work. A comparison of the two above examples leads to the conclusion that the proper mode of designing the vibration isolation solutions is recognizing the existing condition, establishing the desired effects in the form of maintaining vibration and noise below certain values, and then - if necessary - choosing a specific solution in the form of an improved track surface or additional trackside infrastructure. Unfortunately, reverse practices are often practiced, based on secondary parameters (thickness of vibration isolation mat, static and dynamic stiffness, stiffening coefficient, the indication of a specific material, etc.), while numerical values of damping effects remain undetermined, i.e. the use of a specific solution counts and not its effectiveness.

New approach - designing stiffness of pads

As indicated in the examples included in the introduction, the selection of the right vibration isolating solution is a multifaceted issue, with a high degree of complexity and a wide-ranging front of preparatory works. No less important is the right algorithm, which results in an effective solution. Meanwhile, the complexity of issues related to the proper selection of vibration protection is constantly increasing. A relatively new phenomenon on the market is the possibility of individually designing the stiffness of both the rail pad and the panel spacer (i.e. placed between the ribbed washer, which is the anchoring plate and the underlay).

The current approach is based on the use of fastening as a system. The classic way of choosing a solution is to use Table 3.2 in the regulations [11], and then to go to the technical standards contained in Annex 2 of the regulations [8], Tables 1- 6. Depending on the technical standard of the surface, the available types of fastenings are SB, Skl, and K, without indicating specific criteria for selecting the components of these rail fastening systems. Meanwhile, due to both the progressive specialization of railway lines, from conducting light passenger traffic with high frequency to lines loaded with intensive goods traffic, it seems advisable to implement auxiliary criteria to support a more precise selection of individual components. Quite imprecise wording included in chapter II parish 3 regulations [8]: "The pavement's structural standard defines the minimum technical requirements for construction materials for a given class of tracks, that is: the type of rails, sleepers and fastenings, the maximum spacing of sleepers and the minimum thickness of the ballast layer under the underlay, as well as technical parameters of the materials mentioned" can be understood intuitively in the case of spacing of sleepers or bedding thickness, but how to compare the minimum technical requirements of SB and Skl fasteners? The second fact causing certain difficulties is the gradual evolving from the base solutions of whole families of products, having a common or similar shape, but with completely different characteristics, which the technical standards do not take into account at all. Another issue is the increasingly rapid development of new and modernized foreign components of the track, including attachments, which so far are not present on the domestic market. All this not entirely clear course of action is a serious barrier to the introduction of new solutions and favors a rather conservative design schematic.

Advances in material technology of plastics now allow the implementation of elements of relatively small size, the characteristics of which can be precisely designed. This applies both to the mechanical properties of the material, such as stiffness or elongation, but also to its internal structure in the form of properly spaced microbubbles of the desired diameter. The highest repeatability of the structure is now provided by three-dimensional printing, however, due to costs, this technology is currently not applicable to the production of hundreds of thousands of repeatable railway accessories. However, skillful control of the process of plastics production and processing allows maintaining a sufficiently high repeatability of products, with the possibility of offering the entire series of elements created from a common raw material. An example of this is the under-rail spacers and underlayments under the ribbed washer made of foamed EPDM (a polymer made of ethylene-propylene-diene monomers).

According to the manufacturer [1], these materials can be used in principle in all types of rail transport, from tram traffic to high-speed rail, thanks to the possibility of almost individual selection of stiffness of the rail spacing in a wide range from 20 to 200 kN/mm, and the panel spacers from 5 to 60kN/mm. The combined use of both types of spacers gives a wide range of combinations, which allows for the most effective damping of rail vibrations in the indicated third bands, and thus eliminating adverse effects on the environment. It should be mentioned, however, that the use of virtually all track vibration isolating techniques results in increased rail deflection, which can cause accelerated defects, in particular, fatigue, in them [6]. The durability of the material characteristics of the described spacers and their suitability, regardless of the influence of environmental factors, had to be confirmed by appropriate tests, which are described below.

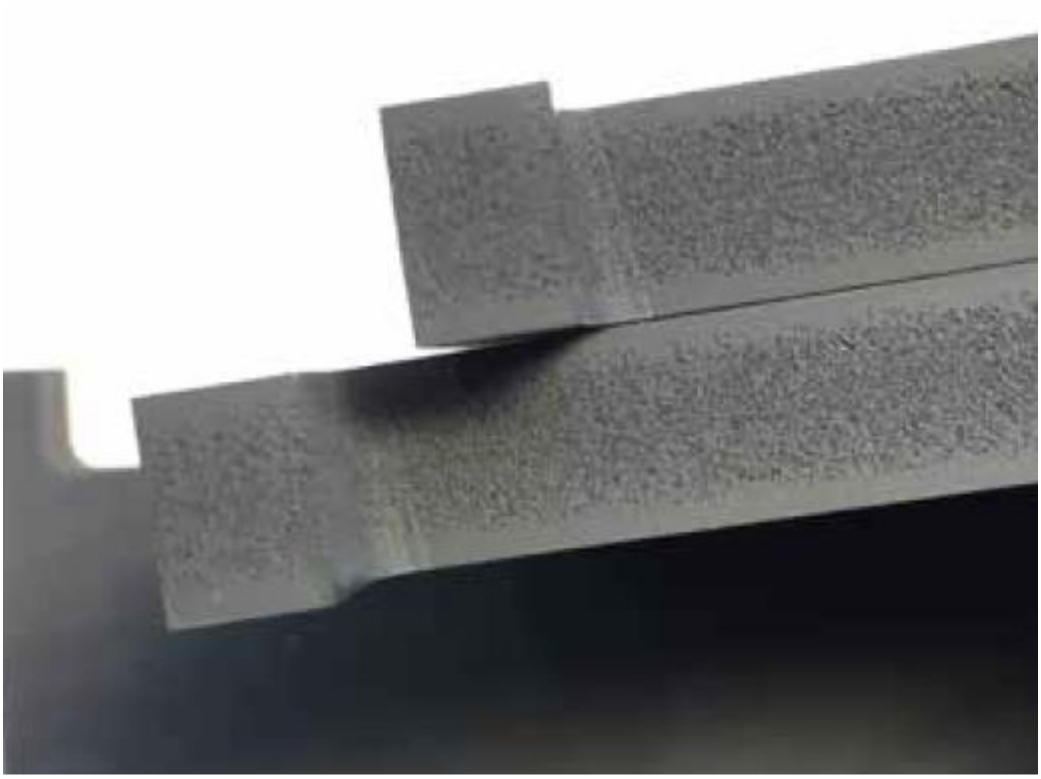
Laboratory tests of pads

The durability of material characteristics of products is one of their most important features. It leads to the unchanging work of the construction of the track as a whole during the whole period of its long-term exploitation. It is important that the parameters of materials, especially elastic, do not change significantly also under the influence of low and high temperatures or humidity. Therefore, orders from customers who want to check their products accurately sometimes exceed the standard requirements contained in the study [2] or [9]. In the mentioned provisions, the method of determination of static stiffness Cstat 18/68 is particularly interesting, wherein graphical representation it is the secant of the load curve in the hysteresis loop between 18 and 68kN, of which the minimum value is treated as the equivalent of loading the spacer by tightening the fastening springs, while the maximum comes from multiplying the design force of 85kN by a factor of 0.8 [4].

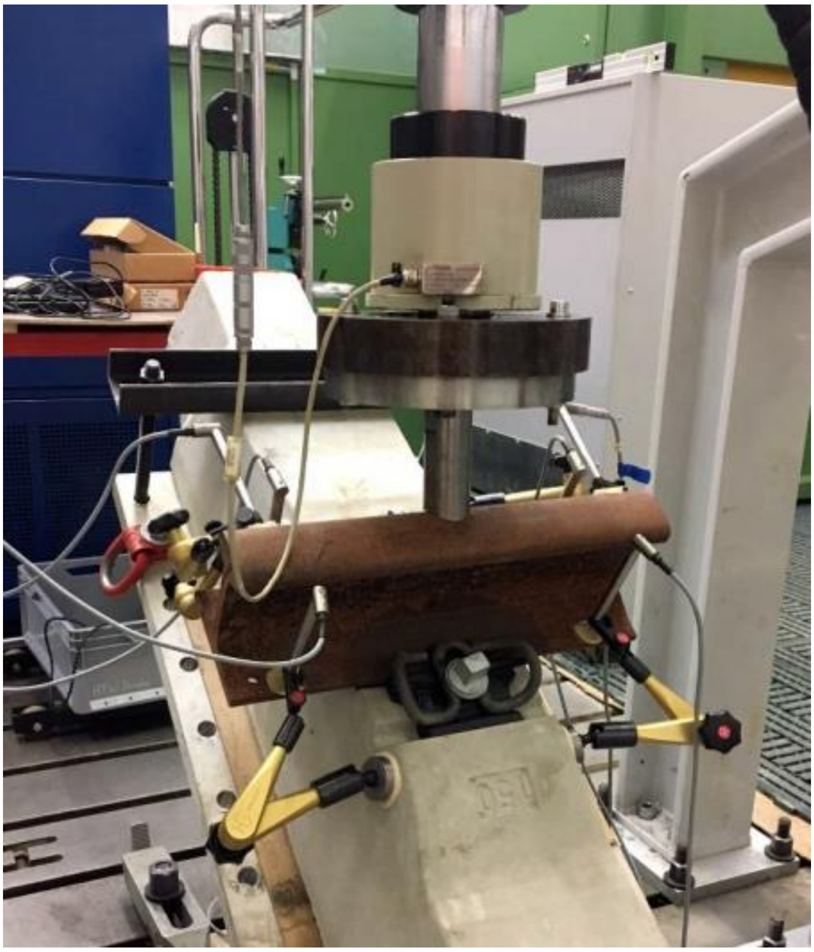
The study [4] presents the measurement method and the results of the examination of rail pads. As part of the tests, it was determined:

- static vertical stiffness at room temperature,
- dynamic vertical stiffness at room temperature,
- degree of material fatigue after 3 million cycles,
- re-static vertical stiffness at room temperature after fatigue test,
- again dynamic vertical stiffness at room temperature after fatigue test.

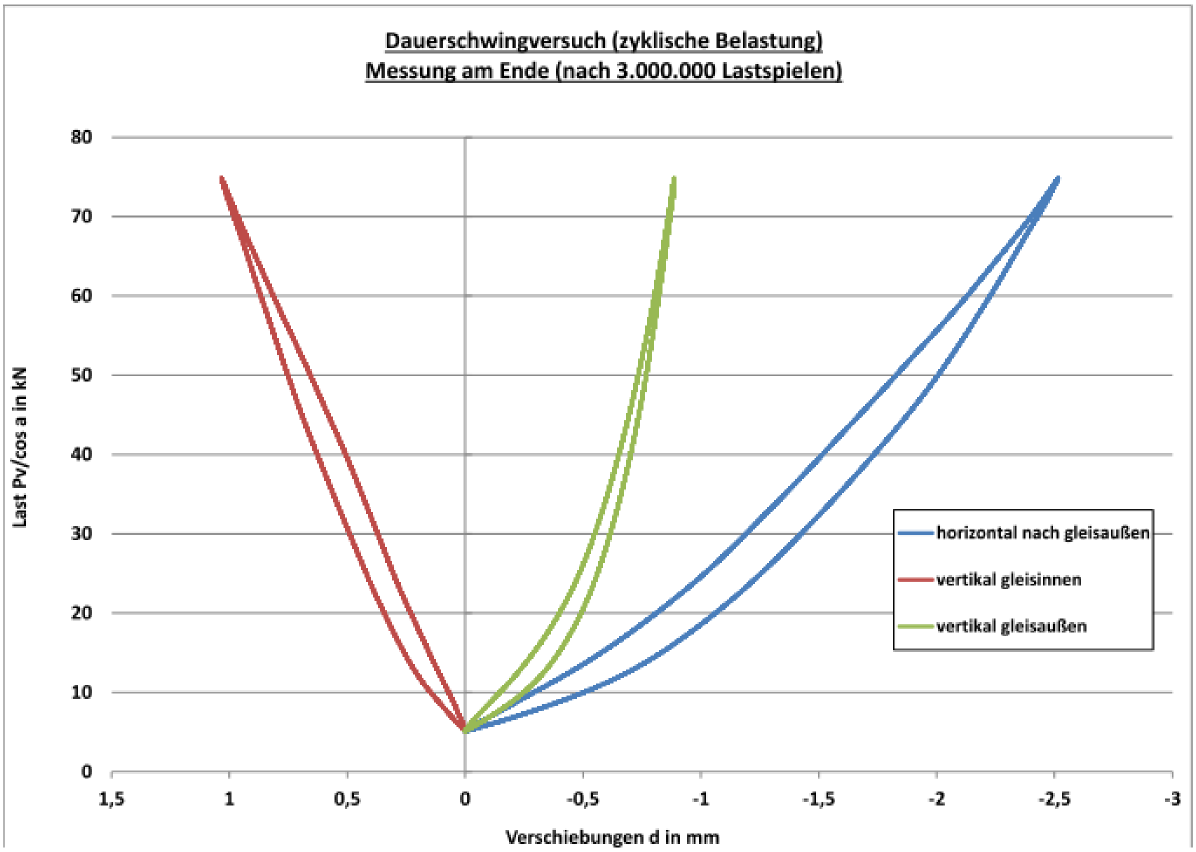
The tests were carried out in a real Skl type attachment (photo **5**) and in a hydraulic press. In the course of the measurements, it was found that the dynamic deterioration coefficient for the three tested vibration frequencies, i.e. 5, 10 and 20 Hz, remains unchanged and amounts to 1.1, which is a favorable value (the permissible value is as much as 1.5). Due to the measurement method in which, through the diagonal arrangement of the rail under the actuator, it is possible to simulate vertical and horizontal forces acting on the spacer, it is possible to simultaneously measure displacements in the vertical direction outside the track, vertical inside the track and horizontal outside the track. In other words, by applying force to the head of the rail at an appropriate angle the rail is rotated in the attachment. An exemplary graph illustrating dependence displacement - load after fatigue test is shown in Figure **6**.



4. Side view of the pad spacer with foamed EPDM [1]



5. Measuring stand for fatigue tests of inserts [4]



6. The exemplary graph of dependence displacement - load after 3 million cycles, test on the bench with photo 5. The blue color shows the horizontal displacement outside the track, red - vertical to the inside of the track, green - vertical to the outside of the track, behind [4]

As a result of the measurements, it was found that the fatigue test had no significant effect on the characteristics of the washer - an increase in static stiffness was found by only 1.7% with an acceptable value of 15%. Also, a comparison of dynamic stiffness before and after the test leads to the conclusion that the standard requirements are preserved with a very large margin. The study [5] presents the measurement method and the results of the research of sub-floor spacers. As part of the tests, it was determined:

- static vertical stiffness at room temperature, 50, 0, -10 and -20oC,
- dynamic vertical stiffness at room temperature for 5, 10 and 20 Hz,
- dynamic vertical stiffness at 50, 0, -10 and -20 oC at 10 Hz,
- degree of material fatigue after 3 million cycles,
- re-static vertical stiffness at room temperature after fatigue test,
- again dynamic vertical stiffness at room temperature after fatigue test.

The tests were carried out in a hydraulic press using appropriate coatings in the form of abrasive paper. The results of static measurements prove that the influence of temperature on the stiffness of the spacer is significant - it varies in the range from approx. 32kN / mm at -20 ° C, to 22kN / mm at 50 ° C, all the time remaining within the limit values. As a result of dynamic measurements, it was found that the dynamic deterioration coefficient is also related to the ambient temperature, assuming values from 1.72 at -20 ° C, to 1.00 at 50 ° C. Also these values are freely within acceptable limits.

Summary

More and more often there are projects in which the use of vibration isolating elements and systems is thought out, economical, purposeful and effective. This direction should be judged as right for two reasons: firstly, there is growing public awareness regarding the protection of buildings and people against the harmful effects of vibrations and noise. Secondly, currently modernized and built infrastructure of railways very often runs through intensively urbanized areas, where emission levels with much lower values are expected than on non-urban routes. Market expectations go from the expectations of the producers who are able to shape the properties of their products in a very precise way. Unfortunately, despite constant progress and improvement, both on the part of producers and project cadres, there are construction projects where vibration isolating is placed without understanding the essence of its operation or an in-depth analysis of inputs and benefits.

The laboratory research examples presented in the work show that the domestic market cannot keep pace with the progress coming from other countries. Above all, there is a lack of sufficiently clear rules and guidelines for the use of special track components and trackside infrastructure, including vibratory protection measures. Foreign studies are imported to save the situation, but they do not form a coherent whole and do not sufficiently cover this complex issue to a large extent. There is no indication of the primary purpose of these measures: maintaining the negative impact of vibrations and noise on people and buildings below the limit values. Detailed elaborations or pre-emptive effectiveness simulations are performed only in very few cases, there is also a lack of the requirement to make corrections in the documentation until the project assumptions are achieved.

Source materials

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[2] Deutsche Bahn Standard DBS 918 235

[3] DIN 45673: Mechanical vibration – Resilient elements used in railway tracks

[4] Fengler W., Sami Elmaci M.: Bericht 17.11a: Ermittlung der Dauerfestigkeit einer elastischen Zwischenlage Zw 1000 (Calenberg) an einem Stützpunkt in Anlehnung an [DBS 918 235]. TU Dresden, 05.2017

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