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OPERATIONAL LONG-TERM MONITORING OF ANTIVIBRATION MATS IN TRIAL SECTIONS OF RAILWAY TRACKS

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Abstract

Five trial sections have been established so far on the railway tracks in the Czech Republic to monitor the operational effectiveness and durability of various types of antivibration mats inserted into the track bed construction. Samples were removed from trial sections and exposed to laboratory tests. The goal of these measurements was to verify the long-term behaviour of antivibration mats exposed to routine railway operation. The obtained pieces of knowledge were used for the preparation of technical specifications and codes for the usage of antivibration mats in the conditions of railway tracks in the Czech Republic.

Key words: *antivibration mat, trial railway section, long-term behaviour, substructure*

1. INTRODUCTION

An efficient measure to protect the surroundings of railway tracks from the effects of vibrations and shocks due to the passing vehicles consists in embedding antivibration mats into the track bed construction. Antivibration mats are planar slab- or strip-shaped elements with a standard thickness of 10 to 50 mm. They are most often produced of natural or synthetic rubber, binder-bonded rubber recyclate or natural materials based e.g. on cork.

Antivibration mats were first used in the 1970s. Since then they have been widely applied by many European railway administrations, for example in France, Switzerland, Austria, Germany, Denmark, Italy, Spain, the Netherlands, outside Europe e.g. in the USA and Australia. In the Czech Republic, experimental testing of antivibration mats in transport engineering goes back to the mid 1990s. In the first phase, they were tested on tram tracks, and later also on railway tracks. The first trial section with antivibration mats inserted into the railway track was established in 2000 near the Horní Počaply railway station. In the following years, this activity was continued and 5 trial sections of this type had officially been established by 2008 (Horníček et al., 2007).

Until 2006, however, no clear regulations for the usage of antivibration mats and the evaluation of their effects based on the monitoring of trial sections had been formulated. Therefore, on the initiative of the Railway Infrastructure Administration, Správa železniční dopravní cesty, s.o. (SŽDC), a research project was launched in 2006 focused on the formulation of regulations for the antivibration mats' application and their incorporation into the SŽDC code of regulations. The project was implemented within the CIDEAS research centre (Centre for Integrated DEsign of Advanced Structures) in 2006 to 2008, at the Department of Railway Structures of the Faculty of Civil Engineering, CTU in Prague in collaboration with other interested bodies. The main focus of the project was to define through operational and laboratory monitoring of already existing trial sections technical specifications for antivibration mats, including the assessment of their characteristics after their long-term exposure to railway traffic.

2. OPERATIONAL MONITORING OF ANTIVIBRATION MATS

With a view to the requirement for safety and long-term geometric rail stability during operation, the embedding of antivibration mats into track bed constructions represents potential risks. To minimize these risks, it was decided to monitor the trial sections with antivibration mats in the track bed under standard operational load. The objective of operational monitoring must be timely discovery of potential negative changes in the characteristics of antivibration mats resulting in successive changes in the behaviour of the entire track bed construction.

2.1. Trial sections

In 2000 – 2007, 5 trial sections were established on the railway tracks in the Czech Republic for long-term operational verification of the efficiency of antivibration mats embedded in the track bed construction (Table 1). A specific type of antivibration mat is always verified in trial sections, following the German model, for a time of minimally 5 years.

Table 1. *Basic information on trial sections*.

Trial section location	Trial section length [m]	Antivibration mat material	Manufacturer
Horní Počaply	200	rubber recyclate	BOHEMIAelast a.s., CR
Starý Kolín	300	rubber recyclate	Pragoelast, s.r.o., CR
Praha – Bělehradská bridges	62	primary rubber	PHOENIX A.G., Germany
Ústí nad Labem	300	rubber recyclate	Renogum Nilos a.s., CR
Kozolupy	500	rubber recyclate	Renogum Nilos a.s., CR

The respective trial sections were fitted with four different types of antivibration mats. The prevailing material used for the production of these antivibration mats was rubber recyclate from disposed car tyres, bonded with a polyurethane-based binder. Antivibration mats made of primary rubber material with a special matrix formed by longitudinal hollow chambers were only used in the trial section on bridges in Prague.

The verification of the efficiency of antivibration mats in the trial sections was performed by measuring the stability of rail geometric parameters using a special continually operating rail spotter, by levelling measurements of the rail height position, the plate load test and the impact load test to determine the load-bearing capacity of individual track bed layers, by taking samples of antivibration mats for laboratory specification of their characteristics, and, at the same time, vibrations were measured in specific structures in the surroundings of railway tracks.

2.2. Taking samples of antivibration mats

In 2006 to 2008, samples of antivibration mats were taken from all trial sections for laboratory testing. The size of the samples always had to be min. 35 x 35 cm. The sampling practice of such test pieces represents a relatively physically demanding and time consuming process, which involves the excavation of space between sleepers to the depth where the mats were inserted, i.e. under the ballast and track bed sub-ballast layer, i.e. mostly to ca 80 cm below the ballast surface (Fig. 1). The sampling

process, therefore, requires the observation of strict safety precautions, particularly under the conditions of intensive railway traffic. Therefore, if possible, samplings are made after traffic closure.



Fig. 1. Sampling of antivibration mat test pieces.

In the trial sections established in 2000 and 2001, samples of antivibration mats were taken after five years of operational verification (Horníček et al., 2007). In the case of the trial section on bridges in Prague, the sample could be taken only thanks to an accident that occurred in March 2008. On that day, a truck got caught by the overhead tram trolley wire under the bridge in Bělehradská Street and pulled it down, and its trailer successively caught on fire that also affected the bridge substructure. Therefore, an overhaul of the whole bridge structure was made in August 2008 with the removal of both the superstructure and substructure including the inserted antivibration mats. This overhaul proved that the antivibration mats had not been damaged by the fire at all (Horníček et al., 2009). In the trial sections established in 2006 and 2007, the samples of antivibration mats were taken during their operational verification (after more than two or more than one year after placement).

The data on the establishment of trial sections, the sampling of test pieces and traffic volumes for the time of the antivibration mat placement are summed up in Table 2. The sample exposed to by far the most intensive traffic load was the antivibration mat test piece taken from the trial section in Starý Kolín.

Table 2. Basic information on trial sections on railway tracks in the Czech Republic.

Trial section	Established in	Sampling date	Operation time [months]	Traffic load [mil. gross tons]
Horní Počaply	May 2000	31.05.2006	72	74.7
Starý Kolín	July 2001	22.05.2007	70	168.7
Praha – Bělehradská bridges	October 2001	24.08.2008	82	76.2
Ústí nad Labem	August 2006	23.10.2008	26	18.8
Kozolupy	August 2007	23.09.2008	13	15.5

2.2.1 Methodology of work sequence during sampling

A uniform execution procedure of field work and measurement was developed to allow for mutual evaluation of the long-term behaviour of individual track bed constructions fitted with antivibration mats.

The trial pit in between sleepers was always situated at the sleeper head. Prior to the start of excavation, impact load tests using a light dynamic plate were performed on the ballast surface over the point of future sampling (at the rail axis and at the sleeper head level). This was followed by the excavation of ballast to the sleeper loading area level. At this level, impact load tests were again performed in the particular rail area. After their completion, the ballast was removed to the level of substructure subgrade, which mostly consisted of crushed stone mixture with a grain size of 0/32 mm. At least one impact load test was always performed on the subgrade surface and a sample of the destroyed structural layer surface was taken to determine its moisture content. This was followed by the removal of the structural layer of crushed stone mixture to the level of the antivibration mat surface. The structural layer material was removed carefully to avoid mechanical damage to the antivibration mat surface. A sample of the structural layer material was taken from the antivibration mat surface to determine its moisture content. Comparing the values reached on both surfaces of the layer, we were able to specify whether the structural layer of crushed stone mixture had the same or different moisture content. Finally, the surface of antivibration mats was cleaned and the cleaned surface again served for the performance of the impact load test.

At this point, the most demanding phase followed, the cutting out of the test sample (in some trial sections even more samples) with dimensions of min. 35 x 35 cm. After documenting, the samples were immediately placed in PVC wrapping to avoid the drying of the samples during their transport to the laboratory. The space arising by cutting out the mat sample on the subgrade surface was used for another impact load test and sampling of soil for laboratory evaluation. The empty space of the cut out sample was then filled by a piece of new antivibration matting of the same production type supplied by the respective manufacturer. Finally, the structural layer material was put back and compacted and the ballast bed was reinstalled, including manual packing of adjoining sleepers.

2.2.2 Knowledge obtained from antivibration mat sampling

The obtained samples of antivibration mats differed from each other by the manufacturing method, the length of exposure to railway traffic and the track bed geotechnical properties. The trial pits and test samples of antivibration mats manifested that in no case had the railway traffic resulted in serious deformations of the track bed construction.

From the position of operational monitoring practice we must say that the majority of works performed were done in the conditions of standard railway operation in the intervals between train passages, without possibilities of long-term traffic closure on the monitored rail. This situation did not allow the performance of the plate load test for the determination of the load-bearing capacity of the track bed layers. Therefore, the impact load test was used instead, which does not require counterbalance and is not so time consuming. The impact modulus of deformation on the ballast surface measured in the trial sections with antivibration mats of rubber recyclate ranged from 50.0 to 78.0 MPa.

The points where trial pits were dug proved that none of the verified antivibration mats had been seriously damaged by the passing traffic. Only local bruises or small cracks due to the contact with ballast grains were discovered on their surface.

It was further manifested that antivibration mats do not wander and all monitored joints were tight. The antivibration mats made of rubber recyclate were saturated with water, and fine particles from the structural layer or the subgrade had penetrated into their pores. Based on this finding, the programme of laboratory tests performed on sampled test pieces was also focused on the assessment of the effect of moisture and colmatage on the characteristics of antivibration mats.

3. LABORATORY MEASUREMENTS OF ANTIVIBRATION MATS

The objective of laboratory testing of antivibration mat test pieces removed from the trial sections was to determine the effect of exposure to railway traffic on selected material and elasticity characteristics. The achieved results were compared with the characteristics of antivibration mats established prior to their placement into the track bed construction. Based on these comparative tests it was possible to determine whether the material as well as elasticity characteristics of antivibration mats are subject to degradation.

3.1. Laboratory testing of material characteristics of antivibration mats

The fundamental material characteristic investigated on the sampled test pieces was volume density. Due to the fact that all test samples of antivibration mats were wet or saturated with water and fouled with fine particles of soils or structural layers, volume density was measured on the following samples:

- naturally wet, treated only by surface removal of coarse impurities,
- dried up to stable weight at a temperature of 35°C,
- dried and mechanically cleared of all fine particles.

3.2. Laboratory testing of elasticity characteristics of antivibration mats

To assess the effect of operational load on the elasticity characteristics of antivibration mats, the following characteristics were determined in laboratory conditions:

- static modulus of deformation E_{stat} in MPa under ČSN 72 1006,
- impact modulus of deformation M_{vd} in MPa under ČSN 73 6192,
- overall static rigidity $C_{(A)stat}$ in N.mm^{-3} under the SŽDC General Technical Specifications (GTS, 2008).

Among the elasticity characteristics of antivibration mats mentioned above, the greatest relevance during evaluation was attributed to overall static rigidity. Overall static rigidity was always determined

on each sampled test piece minimally at two different water saturation states – in the natural wet state, which corresponded to the moisture content at the time of sampling, and at "zero" moisture content, which corresponded to the state after drying. In some test samples, a special series of measurements of overall static rigidity was performed with the aim of determining the effect of fouling by fine particles on the overall static rigidity values.

3.3. Sequence of laboratory work

The test pieces sampled from the trial sections were removed from protective wrapping, cleared of coarse impurities and cut into squares with dimensions of min. 300 x 300 mm. Following this treatment, the test pieces were weighed and their dimensions were measured, including the thickness. This was followed by laboratory testing aimed at the determination of the overall static rigidity (Fig. 2) and the impact modulus of deformation measurement using a light dynamic plate. After the measurements, the test pieces were placed in the laboratory drying oven and dried at a temperature of 35°C until stable weight was reached. Then, the samples were reweighed and remeasured. This was again followed by the measurement of overall static rigidity and the impact load test. In the case that the antivibration mat surface was clogged by fine particles of soil, the impurities were removed from the antivibration mat surface by an industrial vacuum cleaner. Following the performance of this act, the antivibration mat was again weighed and measured.



Fig. 2. Determination of overall static rigidity.

3.4. Achieved results

During the excavation of trial pits, the antivibration mats of rubber granulate were found at a relatively high degree of water saturation. This fact has a significant effect on the overall static rigidity values, as

is confirmed by the results of the measurement of this elasticity characteristic on the antivibration mat samples from the trial sections of Starý Kolín and Kozolupy (Table 3). Prominent changes in overall static rigidity were recorded while comparing the values declared by the manufacturers of specific production types and the values determined on the sampled test pieces of antivibration mats in dry state (Table 4). In the case of mats of rubber recyclates, overall static rigidity values by 47 to 157 % higher were determined. The mats of primary raw materials, on the contrary, showed values by 27 % lower. This type of mats manifested excellent and stable long-term material and elasticity characteristics.

Table 3. Changes in overall static rigidity after drying antivibration mat samples.

Trial section	**Overall static rigidity $C_{(A)stat}$ [N.mm^{-3}]**		**Change [%]**
	as removed	**in dry state**	
Starý Kolín	0.103	0.144	+39.8
Praha – Bělehradská bridges	0.022	0.024	+9.1
Kozolupy	0.126	0.229	+81.7

Table 4. Comparison of overall static rigidity of antivibration matting declared by the manufacturer and determined by the measurement of a sample exposed to operational load.

Trial section	**Overall static rigidity $C_{(A)stat}$ [N.mm^{-3}]**		**Change [%]**
	declared by manufacturer	**in dry state**	
Horní Počaply	0.075	0.193	+157.3
Starý Kolín	0.098	0.144	+46.9
Praha – Bělehradská bridges	0.033	0.024	-27.3
Kozolupy	0.087	0.229	+163.2

4. TOPICAL ISSUES RELATED TO ANTIVIBRATION MATS

The problems of the relationship of material properties of antivibration mats to the magnitude of vibration damping achieved were not resolved within the research project work. In each of the trial sections vibrations were measured in selected adjoining buildings before and after the application of antivibration mats, and reduced vibration levels were achieved in all cases. The results, however, do not lend themselves to unambiguous quantification of the share of the antivibration mat placement in this positive result. The reason for this conclusion is the fact that the insertion of antivibration mats into the track bed construction in all trial sections was always accompanied by overall track modernization (Krejčiříková et al., 2009).

The procedures for the optimization of the characteristics of antivibration mats for the respective track section have not been formulated yet. The number of boundary conditions, such as the geology of the respective section, the track bed composition, the type of protected structure, the properties of antivibration mats, the technical level of operated trains etc., all this forms such a complex problem

that is beyond solution within the objectives of the project. This is the direction of future research in the area of antivibration mats in the Czech Republic.

5. CONCLUSION

As part of the CIDEAS research centre project, test pieces of antivibration mats from the trial section of Starý Kolín were sampled after 6 years of exposure to the railway traffic operation and from the trial section of Praha – Bělehradská bridges after 7 years of operation. The results of laboratory tests performed on these test pieces and the experience obtained from the long-term monitoring of the behaviour of the track bed construction in the test sections have considerably contributed to the development of the draft of the SŽDC General Technical Specifications "Antivibration Mats in the Substructure Body", which came into force on 1st of March 2008 (GTS, 2008). As the GTS "Antivibration Mats in the Substructure Body" came into force, proceedings have currently been under way with individual manufacturers of antivibration mats for granting the "Certificate of approval for use on railway tracks in the Czech Republic".

The research into the problems of antivibration mats revealed a very important issue of long-term monitoring of their material and elasticity characteristics in trial sections in real conditions of railway tracks in the Czech Republic exposed to different traffic loads. In 2010, further sampling of antivibration mat specimens from the trial section of Horní Počaply is planned, i.e. after 10 years from their insertion. Long-term monitoring will further remain in the centre of attention.

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