ELASTIC SYSTEM FOR VIBRATION LEVEL REDUCTION

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In this paper one presents the process of designing an elastic system consisting of elastic plates / slates inlaid between rail and sleeper / support plate, between support plate and sleeper, between sleeper and boxing material and between cover plate and concrete platform. Elastic plates / slates absorb vibrations / noises from railway tracks. These vibrations propagate in railway tracks as well as in the basic structure of railway and civil construction foundations in the surrounding area. Concrete railway sleeper are rigid compared with steel sleeper or still timber and so it need impact attenuation. In subway area the noise and vibrations levels are an important issue. This project is applied in SC Metrorex SA Bucharest subway network.

1. INTRODUCTION

The noise and vibration in railway are produced by the cyclic dynamic forces between wheels and rails. These forces vary depending on several parameters, out of which the most important are: wheel – rail contact surface characteristics, weight on axle and train speed (frequency of exerting the force). Vibrations propagate both within the rail and the basic structure of the railway, as well as within the foundations of the buildings in the vicinity. In the long run, these vibrations have a destructive effect both on the rails and on the trains, as well on the buildings in the vicinity. On the other hand, the issue is of particular importance when the railway is in towns and cities, when building underground lines and ground metropolitan trains, or in the vicinity of dwellings and public buildings, where maximum noise levels must be observed [1, 4].

Therefore, an ever larger number of railway companies world-wide are seeking solutions to reduce the vibration / noise levels in railroad traffic. Railway elasticity is obtained by both making an elastic foundation and using elastic fastening devices as well as by using elastic small plate / plates, which are secured between rail and sleeper / support plate, between support plate and sleeper, between sleeper and ballast and between flagstone plate and concrete platform.

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Their function is to absorb high frequency vibrations in railways over long periods of time (over 15 years) under temperate natural climate and low temperature and to reduce the vibration levels with up to 10 dB per each elastic level [2, 5].

According to the European Community requirements, the physical and mechanical characteristics of the elastic small plates / plates meant to reach train speed of up to 100 km/h are as follows [1]:

- Hardness:
  – as presented: min. 65^o ShA;
  – 7 days after, at –40^o C: difference of max. 10^o ShA;
- Breaking stress:
  – as presented: min. 120 daN/cm^2;
  – after accelerated ageing: min. 100 daN/cm^2;
- Breaking elongation:
  – as presented: min. 250 %;
  – after accelerated ageing: min. 180 %;
- Elasticity modulus 100%:
  – as presented: 30-50 daN/cm^2;
  – after accelerated ageing: ± 40 % as compared to initial value;
- Keeping characteristics after accelerated ageing:
  – breaking stress: min. 70 %;
  – breaking elongation: min. 60 %.

Elastic systems for fixing the railway lines:

– reduce the vibration level that is transmitted from the railway line to the railway structure;

– reduce the vibrations that are transmitted to the steel beams from the bridges and to the structure of the tunnels that are crossed by the rail way.

Fig. 1 – Elastic systems for fixing the railway lines.

2. EXPERIMENTAL

The experimental tests were carried out in order to create an elastic system that may be introduced in the subway infrastructure in order to reduce the vibration and noise level [1, 4].

- Assembling place: Bucharest subway (rolling track);
- Type of fixing: indirect – elastic;
- Line type: 49, with the possibility of extension to the 60 and 65 types;
- Traverse type: biblock concrete traverse;
- Speed rates smaller or equal to 130 km/h and weight per axle between 20 and 30 tones, and independent on these values, on curves with small radius.

Depending on its utility, the elastic system (Fig. 2) may be composed of 3 types of plates:

- resilience plate – PR3, placed under the base of the railway;
- resilience plate – PR2, placed between the base metallic plate and the reinforced concrete traverse;
- cellular resilience plate – PR1, placed under the reinforced concrete traverse.

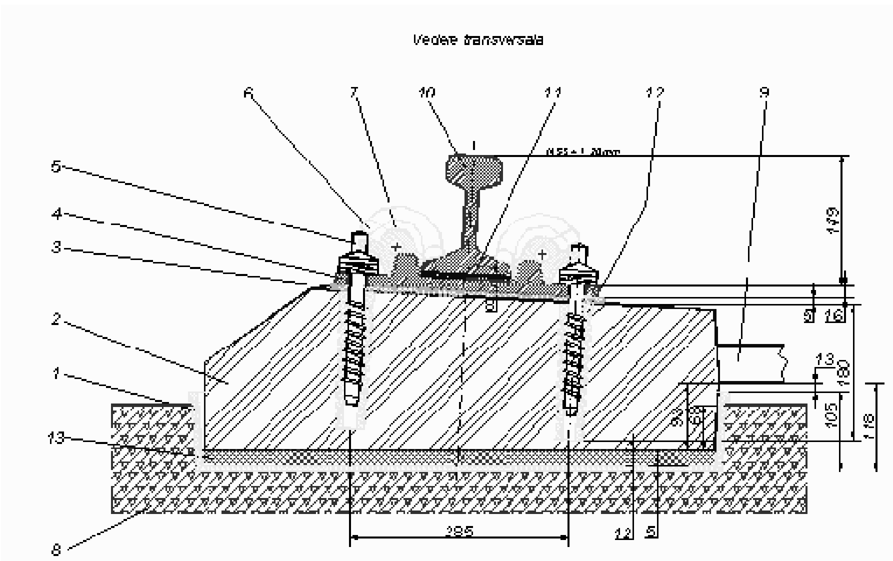
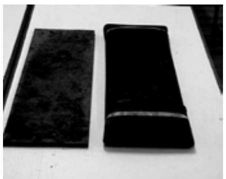
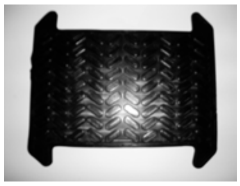


Fig. 2 – Concrete traverses with anti-vibrant elastic elements:
1 – anti-vibrant protection box; 2 – concrete traverse type 2BC – 4; 3 – elastic anti-vibrant plate with 4 holes, placed under the base plate – **PR2 type**; **4** – simple plate without slope; 5 – screwed rail spike B5; 6 – elastic clamp; 7 – support piece PANDROL; 8 – monolithic concrete; 9 – blochet cross-piece; 10 – railway type 49; 11 – elastic plate – **PR3 type**; 12 – Dowel B5; 13 – anti-vibrant elastic plate – **PR1 type**.

TYPE OF PLATES





PR1 and galosh PR2 PR3



These plates are made up from UREPAN 643 G thermoplastic elastomer, supplied by RHEIN CHEMIE RHEINAU GmbH.

UREPAN 643G product is a thermoplastic elastomer that has the property of creating transversal bonds with peroxide, and the resulted product is used for obtaining of technical articles with good tearing strength and abrasion resistance and with excellent resistance toward swelling and ozone.

UREPAN 643G is processed using the standard processing methods. The cast articles can be obtained by compression or by transfer casting or by injection. The extruded articles must be vulcanized, in absence of vapors or atmospheric oxygen (vulcanization in continuous salt bath).

The recommended additives used for UREPAN 643G are:

- transversal fixing co-agent: RHENOFIT TAC / S-70;
- processing promoter: AFLUX 25, AFLUX 54;
- plasticizers ULTRAMOL I, RHENOPREN EPS;
- anti-hydrolysis agents: RHENOGRAN P.50.

These additives are registered by RHEIN CHEMIE RHEINAU GmbH, Dusseldorf, Germany.

PR2 and PR3 plates can be easily assembled and replaced when the current maintenance activities are carried on. PR1 plate can be assembled during the top overhaul activities, by disassembling the railways and by removing the concrete split traverses.

The plates that form the elastic system (PR3; PR2; PR1) are processed according to the proper recipes used for the polyurethane based thermoplastic elastomer; for PR2 and PR1 plates, maximum 30% grained raft is added [1, 5].

The raw materials and the materials are guaranteed by the sub-suppliers through quality certificates and conformity statements.

The shape, the dimensions and the execution tolerances of the elastic elements that compose the system are according to the designs 1, 2, 3, according to P_3F STAS 9220 – 81 (limit deviations to dimensions, class 3 for middle precision dimensions). The dimension tolerances are presented in Table 1.

Table 1

Dimension tolerance

Geometric feature (dimensions)	Tolerances [mm]
Length (*L*)	±5
Width (*l*)	±2
Thickness (*g*)	±0,5

For evaluating the real behavior of the PR3 plate type, 130 plates of this type were assembled, for 24 months, on one of the most intensely circulated lines of the Bucharest subway [3, 4]:

- Piata Unirii 1 – Izvor inter-station between 4+600 km and 4+650 km;
- The bonding between Semanatoarea – Depou Ciurel subsurface between 0+500 km and 0+550 km.

The laboratory tests were made on these elastic plates in order to determine their physical-mechanical features and it was observed that they established similar values with those obtained in the case of TIFLEX plates, imported from England and that are currently used in the subway lines sectors.

By using these plates, with an increased elasticity, the vibration and noise levels were reduced. This fact was proved by an analytic study realized considering the previous measurements, carried on after introducing these plates in the subway lines. The diminishing of the vibrations were measured, the reference measure was the RMS acceleration recorded on the line for the corresponding direction (vertically, transversally and longitudinally). The attenuations were expressed on the vertical direction between the line-traverse, line-foundation, and line-wall. For the horizontal direction, they were expressed between the line and the wall.

- *Assembling place 1* North Railway Station 1 Basarab 2 intersection – Rolling track on crushed stone, wood traverses covered, on the inferior part, by anti-vibrant material of 2cm thickness. The anti-vibrant plates of 0.5 cm thickness were placed under the base plate and the 0.5cm thickness ones under the railway line. The fixing of the line on the traverse is made by elastic fixing of Pandrol type.
- *Assembling place 2 Basarab 2 Grivita intersection* – Rolling track on concrete. Concrete blockets equipped with anti-vibrant material (2cm thickness) at the superior part, protected by rubber galosh, with streaks on all the lateral faces,

placed under the railway line. The anti-vibrant plates (0.5 cm thickness) are placed under the base plate and under the railway line. The fixing of the line on the traverse is made by elastic fixing of Pandrol type.

- *Assembling place 3 1Mai line 2 station* – The rolling track is the same as in the case of the assembling place 1.

3. RESULTS

The physical-mechanical and dielectric features of the polyurethane thermoplastic elastomer mixtures used for creating the plates that compose the elastic system are presented in Table 2.

Table 2

Physical-mechanical and dielectric features

Physical-mechanical and dielectric parameters	Tolerance conditions ST 605/2005/initial values		
	Types of plates		
	PR1	PR2	PR3
Appearance - exterior - in section	- burr less, clean, smooth, without holes or lack of material, that can be visually observed; - without holes or embedding of extraneous materials, that can be visually observed;		
Hardness, [°Sh A] - in present state - after 7 days at –40ºC	min. 40/54 -	85±5/82 -	min. 65/65 ±10° Sh A
Residual strain [%] for: - 50% extension; - 50% compression (24h in desiccators at 100ºC)	- -	- -	max. 25/20 max. 30/ 28
Tensile strength [MPa] longitudinally/transversally - in present state, - after accelerated ageing (96 hours at 100ºC)	min. 3/7 min. 3/5	min. 7/9 min. 7/8	min. 12/15 min. 10/12
Elongation at break [%] longitudinally/transversally - in present state, - after accelerated ageing (96 hours at 100ºC)	min. 200/220 min. 150/155	min. 200/225 min. 150/150	min. 250/270 min. 180/185
Maintenance of the features after the accelerated ageing (96 h la 100ºC) [%]: - resistance to rupture - resistance to elongation	- -	- -	min. 70/90 min. 60/70

Table 2 (continued)

Electrical isolation resistance, [Ω] - in dried state - in wet state	 min. $10^8/{>}10^8$ min. $10^8/{>}10^8$	 min. $10^8/{>}10^8$ min. $10^8/{>}10^8$	 min. $10^8/{>}10^8$ min. $10^8/{>}10^8$
The elasticity model at 100% elongation [MPa] - In present state - After ageing (96 hours at 100ºC)	 - -	 - -	 min. 3/4 max. 5/4.5
Force-strain curve	-	-	To be recorded in the domain stated in F UIC 864/5-1986-0
Shape and dimensions [mm]: - length - width - thickness	 690±5 240±2 20±0.5	 381±3 160±1.3 5±0.5	 202±1.6 126±1.3 6±0.25
Labeling	The products are labeled on the rebate, embossed at 6 mm × 0.5 mm dimensions		

The experimental results obtained by SC Metrorex SA, Bucharest, after 6, 12, 18 and 24 months of usage of these plate on the rolling track of the subway are presented in Fig. 3 (the PANDROL fixing type using rigid grips) and in Fig. 4, were the fixing was made using elastic clamps).

The visual analysis of the aspect of the PR3 plates, after being removed from the rolling track of the subway when the tests were finished, showed the existence of a strain only in the case of PANDROL fixing type using rigid grips.

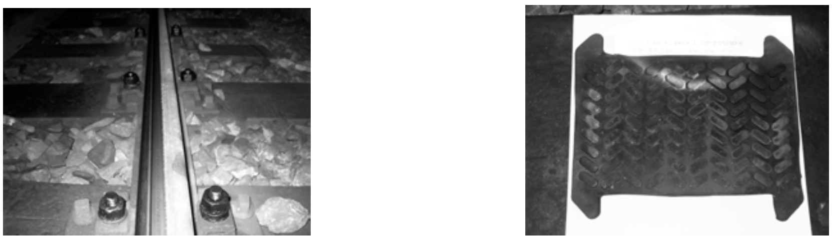


Fig. 3 – PANDROL fixing type using rigid grips and deformed PR3 plate.

Fig. 4 – PANDROL fixing type using elastic clamps and PR3 un-deformed plate.

The average values of the attenuations recorder for every assembling place are given in the Table 3.

Table 3

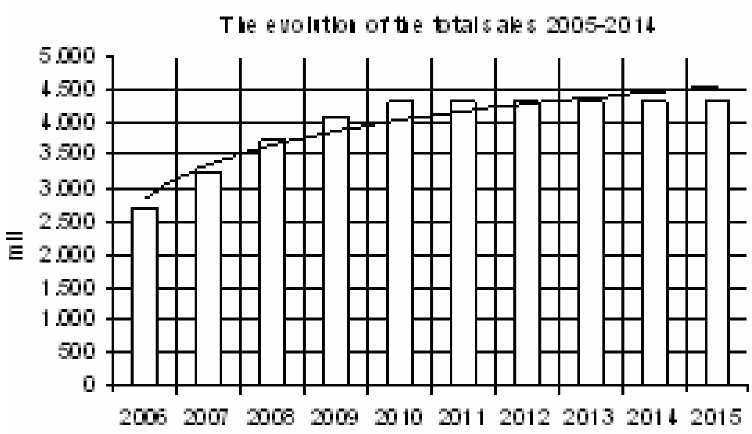
Average attenuations on the assembling place

Assembling place	Direction	Attenuation between:	Attenuation (dB)
1	Vertically	Railway-traverse	8.4
	Vertically	Railway-foundation	-
	Vertically	Railway-wall	59.3
	Transversally	Railway-wall	31.6
	Longitudinally	Railway-wall	28.3
2	Vertically	Railway-traverse	10.9
	Vertically	Railway-foundation	44,00
	Vertically	Railway-wall	47.6
	Transversally	Railway-wall	24.2
	Longitudinally	Railway-wall	25.1
3	vertically	Railway-traverse	7.8
	vertically	Railway-foundation	44.6
	vertically	Railway-wall	53.2
	transversally	Railway-wall	34.3
	Longitudinally	Railway-wall	32.0

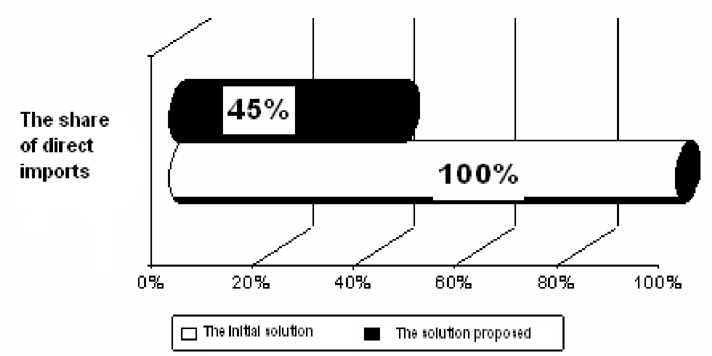
3. DISCUSSION

Economical effects are given by three important parameters:

a) The evolution of the total sales

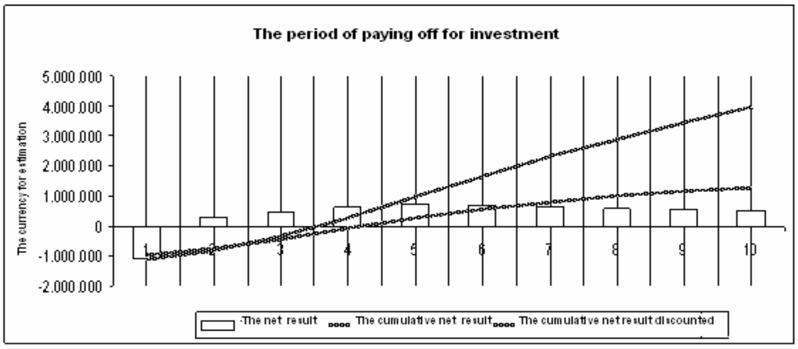


b) Diminishing of the imports with 1.1 million GBP/year



c) The recovery period of the total costs from production: 2.7 years.

The recovery period for the total investment in research and expansion of the production capacity: 3.5–4 years, at the actual demand.



4. CONCLUSIONS

The polyurethane thermoplastic elastomer is delivered as granules, which are processed by the corresponding methods, by means of the traditional devices used in the thermoplastic materials industry. The most important processing methods are by casting, by injection, extrusion and calendaring.

The products obtained using the polyurethane thermoplastic elastomer were the first synthetic materials exhibiting better elastic properties that in the case of the natural rubber, that were processed by the thermoplastic method.

The polyurethane thermoplastic elastomers are widely used due to their properties:

– good elasticity on all the hardness domain;
– flexibility on all the temperature domain;
– good resistance to ageing;
– good resistance to oils, fats and a lot of solvents;
– excellent resistance to fatigue;
– a higher elasticity modulus compared with the natural rubber.

The Young elasticity modulus depends on the ratio between the hard and soft segments.

The soft segments (the value of the hardness being between 70 and 80° Shore A) contain, in weight, a quantity of diisocyanates varying between 20 to 25%, while the hard segments (the value of the hardness being between 65 and 80° Shore D) contain, in weight, a quantity of diisocyanates that reach 55% (or higher).

The hard segments from the polyurethane thermoplastic elastomer macromolecule are responsible for the behavior exhibited at high temperatures, while the soft segments for the behavior at smaller temperatures.

The polyurethane thermoplastic elastomer has a better attenuation capacity than in the case of the natural rubber materials, which are very elastic.

The railway subway system causes high frequency oscillations that are responsible for damaging the elements that compose the railway lines and also the structure of the nearby buildings. The vibrations are transmitted to the railway line, to its base structure and also to the foundations of the nearby buildings. The repeated impact of the train wheels on the railways traverses may reduce the traverses lifetime and may damage the ballast. In extreme cases, the traverses may be damaged. The concrete traverses are rigid compared to the steel or wood traverses, and, for this reason, they require an attenuation of the impact in order to prevent the early destruction of the concrete.

The actual structure of the railway lines, and especially of the subway line, made up using concrete flag , leads to a reduced elasticity of the line – materialized in its elastic response (static or dynamic), having as effect, mainly, the next major problems:

– supplementary loadings for the main elements of the line (fixing devices, traverses, etc.);
– increase of the pressure on the traverse base;
– early destruction of the line quality;
– early destruction of all the elements composing the line (fixing devices, traverses, lines etc), including the line prism or the concrete flag)
– supplementary interventions for preserving the lines, at shorter time intervals;
– high noise and vibration level.

The elastic plate, the main element that composes the fixing device of the railway line, may be modified in order to increase the elasticity of the track.

In the case of the ballast prism railway line, 2 elastic plates (with high elasticity) are needed, at the line – support plate and support plate-traverse levels.

For the concrete line subway, the third elastic level, placed at the traverse base, must be introduced.

By analyzing the structure of the subway lines in different locations (CF and METROU) and from the vibrations and noise measurements made on the experimental sections at METROREX, it was concluded that the usage of the high elasticity plates reduces the noise and vibration levels.

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