THE EXAMINATION OF ELASTOMERIC MATERIALS USED IN VIBROISOLATION AND SOUNDPROOF ISOLATION SYSTEMS IN STRUCTURAL ENGINEERING

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Abstract

Solution of the problem of limiting the spread of the dynamic and acoustic emissions from rail and road traffic requires application of new elastomeric materials are characterized by both high acoustic insulation as well as being part of vibroisolation system between the source of vibration associated with the movement of vehicles and construction engineering structure. In the new solutions of vibro- and sound-proof, isolation based on the new elastomer materials should be taken into account a strong correlation between physico-mechanical properties of these material and the values of static and dynamic load, which effect on these materials. Another problem, which is associated with the use of elastomer materials, is the influence of the volume of used item on their physico-mechanical parameters. Therefore, the use of elastomer materials in vibro- and sound-proof isolation systems requires at the stage of selecting of materials a number of studies that will allows specifying the properties of materials for a specific application. A properly conducted process of selection of materials will help to achieve the desired effect, which is to build a well-functioning vibro- and sound-proof isolation system. Without a properly conducted process of selection of materials can be achieved counterproductive result. In the paper, the results of experimental studies carried out to determine the physico-mechanical elastomer material that could be used as a flexible bearing in structural engineering constructions are presented. Flexible nodes bearing can be classified as the latest generation of vibroisolation systems. The studies were also performed to assess the possibility of using such materials in sound-proof isolation in concert halls and conference rooms. In the paper, the new methodology of assessment of physico-mechanical elastomer materials that could be a standard for the design of vibro- and sound-proof isolation systems and based on such materials in the newly designed civil engineering structures.

Keywords: *vibroisolation systems, sound-proof isolation systems, elastomeric materials, structural engineering*

1. Introduction

Solution of the problem of limiting the spread of the dynamic and acoustic emissions from rail and road traffic requires application of new elastomeric materials are characterized by both high acoustic insulation as well as being part of vibroisolation system between the source of vibration associated with the movement of vehicles and construction engineering structure. In the new solutions of vibro- and sound-proof isolation based on the new elastomeric materials [5, 6], much cheaper than natural rubber, should be taken into account a strong correlation between physico-mechanical properties of these material and the values of static and dynamic load, which affect on these materials. Using these solutions can have a positive effect in the reduction of sound energy and vibration amplitude provided that these materials are the correctly selected.

In the paper, the results of experimental studies of physico-mechanical properties of test samples made of elastomeric materials Cisador B and Cipremont produced by Calenberg Ingenieure Company are presented. A methodology for testing new elastomeric materials used in Department of Robotics and Mechatronics AGH [7, 8], which should be a standard in the selection of the parameters of vibro-acoustic properties of the newly designed sound-proof and vibration isolation systems of mechanical structures is also presented in this paper.

2. Description of conducted researches

There are many rubbers elements, elastomeric materials and plastic products, which comply with the mechanical properties assumed in the design and construction of mechanical structure. This finding is very important, but not sufficient for the selection and application of rubber and elastomeric elements for vibration isolation purposes. In addition to sufficient strength, the vibration isolation element must meet a number of other general requirements and the additional requirements of the plastics used as part of vibration isolation system. Some of them are physico-mechanical properties of these materials [9]. The main objectives of the conducted experimental study were:

1) investigating of the relationship between the surface (volume) of the sample and its deflection depending on the value of the initial compressive stress and the calculation of Young's modulus as a function of these parameters,
2) determination of dynamic stiffness of the Cisador B elastomeric material samples with a thickness of 30 mm,
3) determination of dynamic stiffness of the Cipremont elastomeric material samples with a thickness of 35 mm,
4) dynamic tests of samples of elastomeric materials in the frequency range from 4 to 20 Hz with interval of 2 Hz;

during the studies, the following tests were performed for each sample of elastomeric material:

1) studies of the dynamic properties of elastomeric material samples on static and dynamic testing machine,
2) determination the characteristics of physical and mechanical properties of elastomeric material samples on the basis of the registered sample deformation depending on the load,
3) description of research results.

During the experimental studies the static and dynamic testing machine INSTRON 8872 (Fig. 1) was used with software Instron Bluehill and Wave Matrix.

Fig. 1. Static and dynamic testing machine INSTRON 8872

The testing machine allows to application of maximum axial force equal to 10 [kN] and registration of deformation and strength of a sampling rate of up to 5 [kHz]. The machine used in the experimental studies has up-to-date certificate of calibration forces head and has been classified to class 0.5 of metering devices.

3. Experimental study of physico-mechanical parameters of elastomeric materials

Preliminary studies of elastomeric materials were related to examine the relationship between the surface (volume) of test samples of materials and the deflection as a function of applied initial compressive stress. Therefore, a series of nine measurements for each of the test samples was done to identify those relationships. A description of the measurements of test samples of Cisador B and Cipremont material is presented in Tab. 1.

Tab. 1. Description of performed preliminary measurements

Measurement number	Area of test sample [mm^2]	Thickness [mm]	Initial compressive stress [MPa]
CISADOR B			
1	1400	30	0.00625
2	2800		
3	5600		
4	1400	30	0.01250
5	2800		
6	5600		
7	1400	30	0.025
8	2800		
9	5600		
CIPREMONT			
1	1400	35	0.025
2	2800		
3	5600		
4	1400	35	0.125
5	2800		
6	5600		
7	1400	35	0.250
8	2800		
9	5600		

Figure 2 shows the obtained results of the deformation of the test samples of Cisador B and Cipremont material.

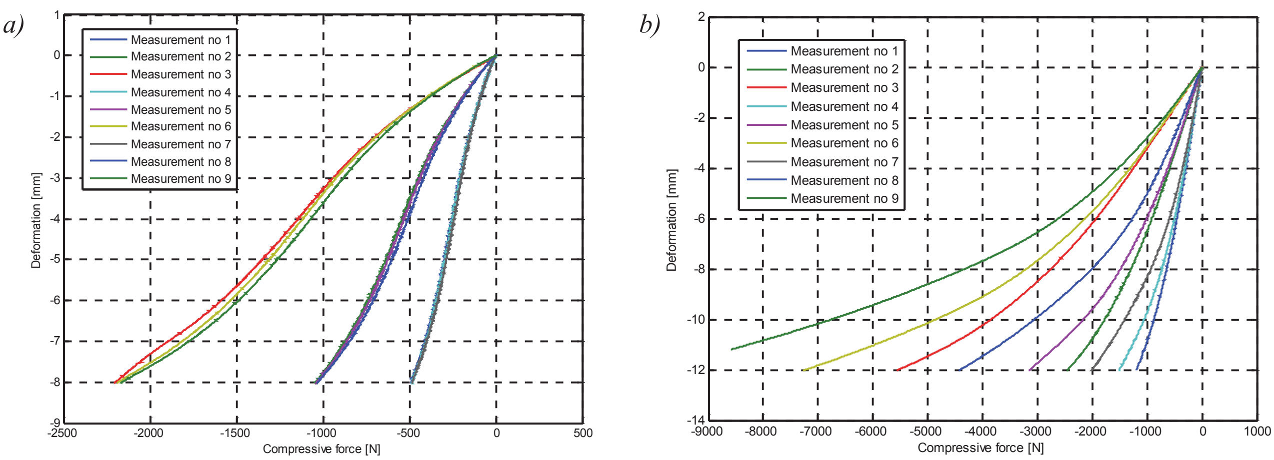

Fig. 2. Deformation of the test samples of Cisador B (a) and Cipremont (b) material

Values of the Young's modulus of tested samples of elastomeric materials are presented in Tab. 2.

Tab. 2. Values of the Young's modulus of tested samples of elastomeric materials

Measurement number	Area of test sample [mm^2]	Thickness [mm]	Initial compressive stress [MPa]	Young's modulus [MPa]
CISADOR B				
1	1400	30	0.00625	2.04
2	2800			2.18
3	5600			2.33
4	1400	30	0.01250	2.02
5	2800			2.12
6	5600			2.27
7	1400	30	0.02500	2.03
8	2800			2.22
9	5600			2.34
CIPREMONT				
Measurement number	Area of test sample [mm^2]	Thickness [mm]	Initial compressive stress [MPa]	Young's modulus [MPa]
1	1400	35	0.025	3.97
2	2800			4.29
3	5600			5.36
4	1400	35	0.125	5.72
5	2800			6.20
6	5600			7.48
7	1400	35	0.250	7.49
8	2800			8.53
9	5600			9.21

Based on preliminary studies, it is clear that in the case of Cisador B material there are not clear differences in the mechanism of the deformation depending on the sample size and the preload. In addition, the Young's modulus values are similar.

This is quite different in the case of Cipremont material. For this material, from the performed measurements it is clear that the value of the initial stress and the size of the sample changes both the nature of the deformation and values of the physical-mechanical properties (Young's modulus). Therefore, for this material, it is necessary to carry out detailed studies prior to its use in the specific mechanical structure.

Then, after consultation with the research, which was one of the largest Polish construction companies it was finally established that physico-mechanical parameters of elastomeric materials will be determined for the samples with the largest area with compressive stress equal to 0.06 N/mm^2 and 0.25 N/mm^2 for Cisador B material and 0.50 N/mm^2 and 1.50 N/mm^2 for Cipremont material.

During the next stage of the studies the physico-mechanical characteristics of elastomeric materials Cisador B and Cipremont were determined.

The photographies of the target test sample of Cisador B material consisted of two layers with a thickness of 15 mm each lying loosely one upon the other and the target test sample of Cipremont material are shown in Fig. 3. The main geometric dimensions of the test samples are presented in Tab. 3.

Studies conducted to determine some physical and mechanical parameters of the elastomeric mats were divided into two main stages:

a) b)

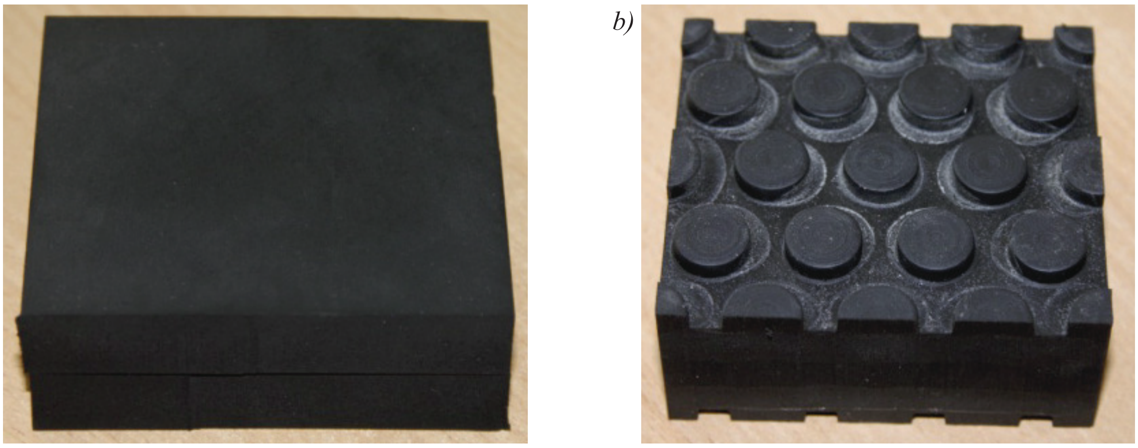

Fig. 3. Photographies of test sample of material Calenberg Cisador B (a) and material Calenberg Cipremont (b)

Tab. 3. The geometrical dimensions of the target test samples

No.	Material	Width [mm]	Length [mm]	Thickness [mm]	Area [mm^2]
1	Cisador B	70	80	30 (2 layers put together)	5600
2	Cipremont	70	80	35	5600

1) first stage – determination of dynamic modulus of elastomeric mat test samples depending on the specified preload,
2) second stage – determination of the modulus of elasticity, modulus of dynamic stiffness and damping coefficients of elastomeric mat test samples subjected to harmonic load depending on the specified preload.

The study was conducted for two values of preload for each of the materials – for Cisador B material the initial load values were equal 0.06 N/mm^2 and 0.25 N/mm^2 and the for the Cipremont material – 0.5 N/mm^2 and 1.5 N/mm^2.

Research carried out in the first stage consisted of an load test from the zero value to the value predetermined preload level of the test samples with the speed of movement of the piston of the testing machine equal to 1 mm/s and simultaneous registration the dependency between the samples deformation and the value of the compressive force.

The value of the dynamic elasticity modulus of the test sample for a given value of the preload $E_{dyn}(\sigma_D)$ was calculated using the following formula:

$$E_{dyn}(\sigma_D) = \frac{\sigma_D}{\varepsilon}, \tag{1}$$

where:
ε – relative linear deformation of the sample, $\varepsilon = (d / d_0)$,
d_0 – initial thickness of the sample,
d – linear deformation of the sample under the initial load of σ_D.

The values of dynamic elasticity modulus calculated on the basis of measurements for the Cisador B and Cipremont materials are presented in Tab. 4.

Tab. 4. The values of dynamic elastic modulus of Cisador B and Cipremont materials

CISADOR B			CIPREMONT		
No.	Preload value, σ_D [N/mm^2]	Dynamic elasticity modulus, E_{dyn} [N/mm^2]	No.	Preload value, σ_D [N/mm^2]	Dynamic elasticity modulus, E_{dyn} [N/mm^2]
1	0.06	2.19	1	0.5	3.72
2	0.25	1.42	2	1.5	12.25

In the second stage of the studies, the test sample was first compressed by axial force to the given preload value σ_D. Then the preload value was maintained for 5 minutes for relaxation of the sample and to ensure uniformity of the load. After this time, the sample was subjected to sinusoidal harmonic load with amplitude equal to 0.1 mm and frequency f changing from 4 to 20 Hz with interval of 2 Hz. During the researches the simultaneous registration of the samples deformation as well as the value of the compressive force was performed.

The value of the dynamic elastic modulus of the test sample for a given value of the preload and frequency $E_{dyn}(\sigma_D,f)$ was calculated using the following formula:

$$E_{dyn}(\sigma_D, f) = \frac{P_{\max} \cdot l}{A \cdot \Delta l}, \tag{2}$$

where:

$P_{\max}$ – the force value that causes the maximum variation of the thickness of the sample,
l – thickness of the sample under the preload σ_D,
A – area of the sample under the preload σ_D,
Δl – maximum change in thickness of the sample under the action of force $P_{\max}$.

The values of dynamic elasticity modulus calculated in the frequency range from 4 to 20 Hz on the basis of measurements for the Cisador B and Cipremont materials are presented in Fig. 4.

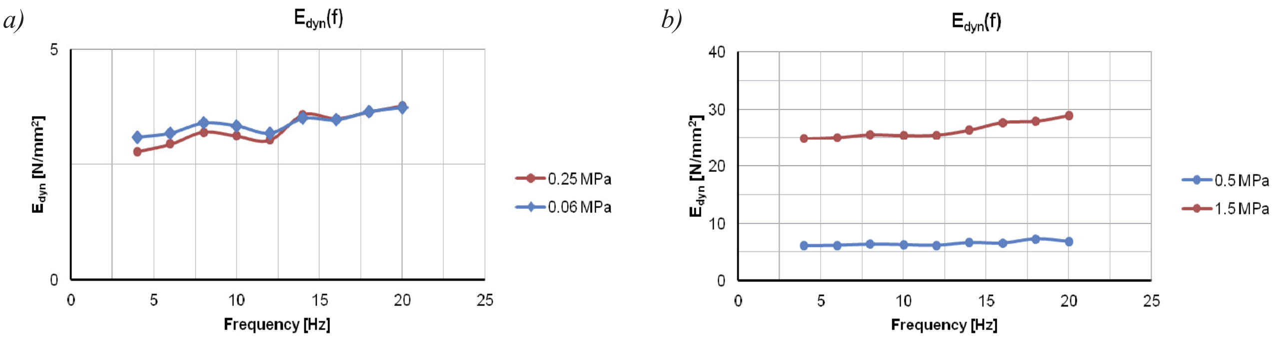

Fig. 4. The values of dynamic elasticity modulus of Cisador B (a) and Cipremont (b) materials

Next the value of the dynamic elasticity volume modulus of the test sample for a given value of the preload and frequency $C_{g,dyn}(\sigma_D,f)$ was calculated using the following formula:

$$C_{g,dyn}(\sigma_D, f) = \frac{E_{dyn}(\sigma_D, f)}{d_0}, \tag{3}$$

where $E_{dyn}(\sigma_D,f)$ is the value of the dynamic elasticity modulus of the test sample for a given value of the preload and frequency.

The values of dynamic elasticity volume modulus calculated in the frequency range from 4 to 20 Hz on the basis of measurements for the Cisador B and Cipremont materials are presented in Fig. 5.

In the next step, the values of the dynamic damping coefficient of the test sample for a given value of the preload and frequency $\vartheta(\sigma_D,f)$ were calculated using the following formula:

$$\vartheta(\sigma_D, f) = \frac{C_{g,dyn}(\sigma_D, f) \cdot \sin\varphi_{F,z}}{4 \cdot \pi \cdot f} \cdot \sqrt{\frac{g}{C_{g,dyn}(\sigma_D, f) \cdot \sigma_D \cdot \cos\varphi_{F,z}}}, \tag{4}$$

where:

$C_{g,dyn}(\sigma_D,f)$ – value of the dynamic damping coefficient of the test sample for a given value of the preload and frequency,
f – given frequency,
$\varphi_{F,z}$ – phase angle between the axial force and deformation corresponding to this force.

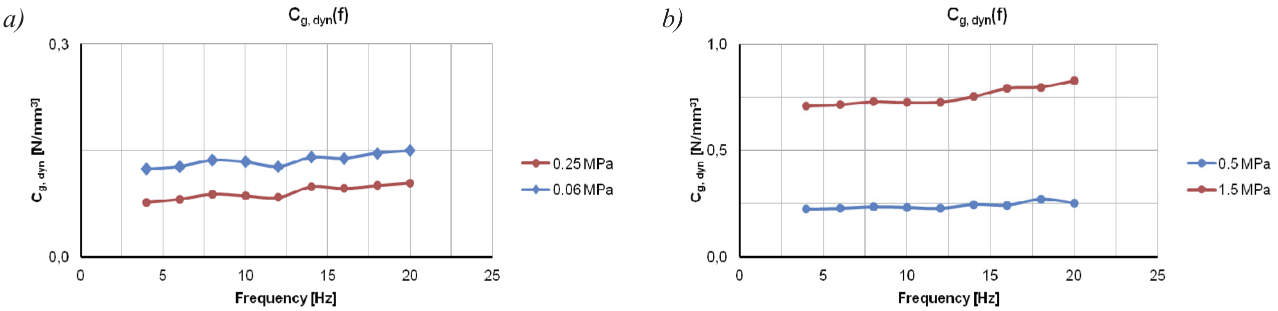

Fig. 5. The values of dynamic elasticity volume modulus of Cisador B (a) and Cipremont (b) materials

The values of dynamic damping coefficient calculated in the frequency range from 4 to 20 Hz on the basis of measurements for the Cisador B and Cipremont materials are presented in Fig. 6.

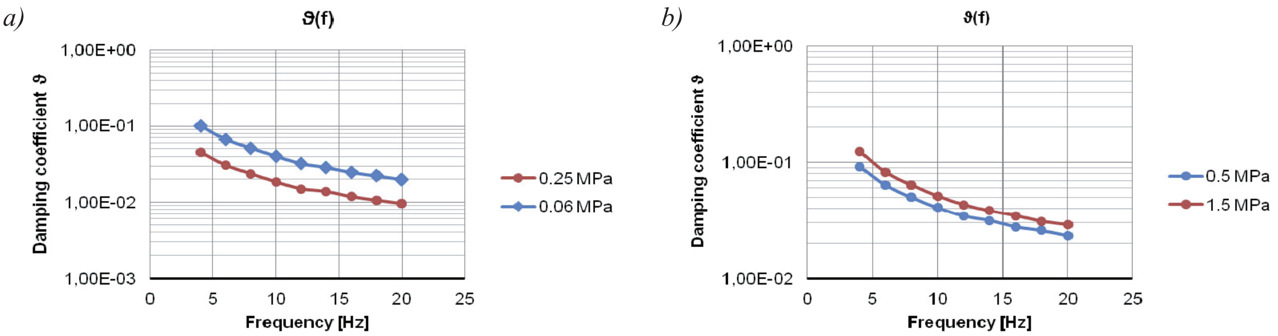

Fig. 6. The values of dynamic damping coefficient of Cisador B (a) and Cipremont (b) materials

4. Summary

The results of experimental laboratory studies of test samples of elastomeric materials Cipremont and Cisador B conducted by authors confirmed results of studies conducted by the manufacturer [1-4]. The differences in results may be due to:
1) the size of the test samples
2) the nonlinear properties of tested elastomeric materials,
3) the conditions of measurement.

Based on the research it can be concluded that the elastomeric materials are highly non-linear materials and very sensitive to the conditions in which they work, the size of used mats and the load applied to them. Changes in physical and mechanical properties as a function of the mats size, load and frequency range must be considered in designing the structure with using of them.

Based on the experimental results of elastomeric materials examinations can be concluded that the use of such materials in vibration isolation and sound-proof isolation systems requires the following:
1) accurately determining the initial compressive stress, which will be introduced to the element, made from elastomeric materials,
2) proper selection of the area (volume) of an elastomeric element, which will be used, so that the initial static deflection at a given initial load does not exceed the value of several percent,
3) static and dynamic experimental tests of samples of materials proposed to be used from the viewpoint of proper selection of flexible elements used in vibration isolation and sound-proof isolation systems.

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