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THE BEHAVIOUR OF ELASTOMERIC BEARINGS UNDER LOAD COMBINATIONS

BY

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Abstract. This paper presents experimental tests to determine the shear modulus of elastomeric bearings at different values of the vertical force and horizontal displacements.

The elastomeric bearings were designed for an experiment on scale models for the shaking table tests. The elastomer had a hardness of 60 Sh A

Two sets of tests were carried out. The first was the application of a compressive force on the elastomeric bearings with values between 10,...,60 kN and the applied horizontal displacement with values of 14 mm and 17 mm. For the second test, the compression force was 60 kN and the horizontal displacements were equal to 17 mm, 34 mm and 43 mm.

Following the experimental tests, it resulted that the shear modulus of elastomeric bearing has different values depending on the maximum applied displacement. If the vertical force applied to the bearing increases, the shear modulus decreases.

Key words: base isolation; shear modulus; hysteresis curves; experimental tests.

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1. Introduction

An elastomeric bearing must fulfil the following characteristics: to have high vertical flexibility, high vertical stiffness, to ensure the adherence of elastomers for large displacements over the permissible limit and to withstand a large number of alternating loads cycles.

The elastomers are materials which have similar mechanical particularities with incompressible liquids, whose Poisson's ratio is 0.5. Therefore these bearings are made by reinforcing metal plates to prevent the horizontal deformations of the material. The idea to introduce thin metal plates in elastomeric bearings belongs to French engineer Eugène Freyssinet (Kelly *et al.*, 2011).

The Mullins effect is a phenomenon that occurs when the elastomer is subjected to cyclic loadings and characterized by a decrease of the material stiffness during charging (Fig. 1). The stabilization of hysteresis curve occurs after several loading and unloading cycles.

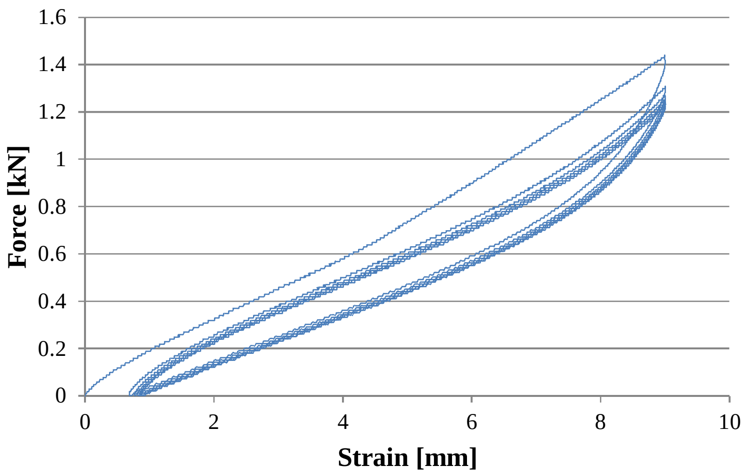

Fig. 1 – The Mullins effect.

The Mullins effect is partially recoverable at ambient temperature in long time (several days) or in a few hours at a temperature close to the vulcanisation temperature (Ramier, 2004). The study of the Mullins effect is important for understanding the behaviour of elastomeric bearings during shear deformation.

The aim of this paper is to analyse the behaviour of elastomeric bearings under vertical loads (compression) and horizontal loads (shear).

2. Shear Test

2.1. Materials and Equipment

The tested elastomeric bearings had 100 × 100 mm plane dimensions and consisted of 6 elastomer layers with 8 mm thickness interspersed with metal plates with 95 × 95 mm plane dimensions and 3 mm thickness. The outer metal plates had a 8 mm thicknesses (Fig. 2). The elastomeric bearings have been provided by the firm S.C. FREYROM S.A. The elastomer had a hardness of 60 Sh A and a bearing capacity of 80 kN.

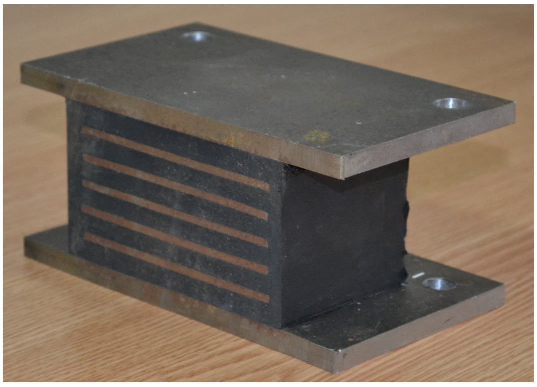

Fig. 2 – The elastomeric bearing.

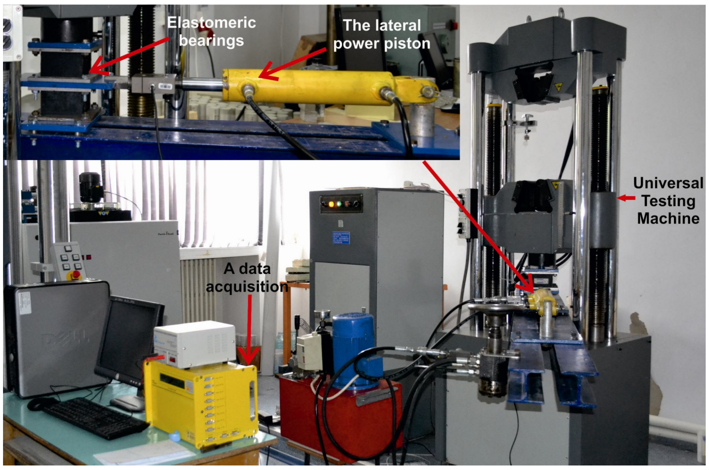

Fig. 3 – The test equipment.

An universal machine was used for test, having a capacity of 600 kN that ensured the constant vertical force applied on the bearings, during the application of the horizontal forces. A special installation that allows alternating cycles in static regime was used for horizontal action (Fig. 3).

According to EN 1337-2006, the experimental test consisted in measuring the shear deformation for a pair of bearings subject to progressive shear forces; the shear modulus was determined and the bearing surfaces were examined for defects after the maximum load. Thus, an average pressure of 6 MPa was applied and the bearings were subjected to shear at a constant speed, to the maximum test deformation v_{xm} ($0.7T_q \leq v_{xm} \leq 0.9T_q$) which was then reduced to zero. The compressive force has been removed and the bearings were left for five minutes, then were tested again to shear at $v_{xm.}$ The vertical force and the horizontal displacement were recorded continuously.

The secant shear modulus was determined by the relationship (ASRO, 2006):

$$G = \frac{(\tau_2 - \tau_1)}{(\gamma_2 - \gamma_1)}, \tag{1}$$

where: $\tau_{1,2}$ is the shear stress; γ_2 – the shear strain at a displacement of 0.58 of the elastomer layer thickness; γ_1 – the shear strain at a displacement of 0.27 of the elastomer layer thickness.

2.2. Results

The experimental tests were aimed to determine the influence of vertical force on the horizontal stiffness of elastomeric bearings. In this regard, two sets of tests were carried out.

The first consisted in the application of a compressive force on the elastomeric bearings with values between 10,...,60 kN and the applied horizontal displacements of 14 mm and 17 mm, that is 0.3 and 0.35 of the elastomer layers thickness.

A number of six loading-unloading cycles were carried-out and the force-displacement curves for the elastomeric bearings were plotted (Figs. 4 and 5).

The shear modulus values of elastomeric bearings were determined using the force-displacement curves between 2 mm and 12 mm displacements. The values are presented in Table 1.

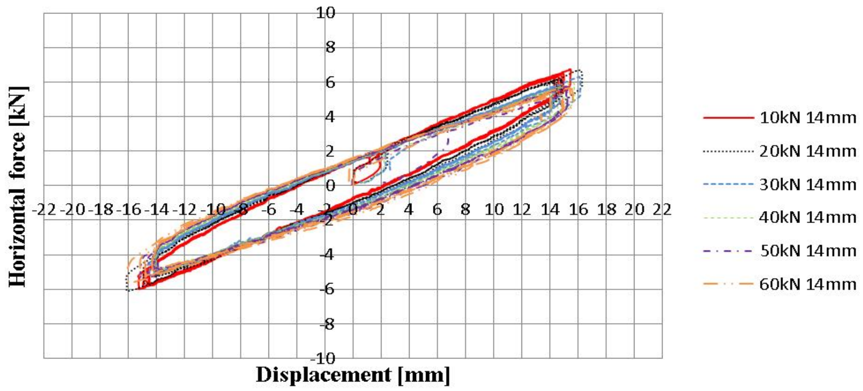

Fig. 4 – Force-displacement curves for 14 mm displacement.

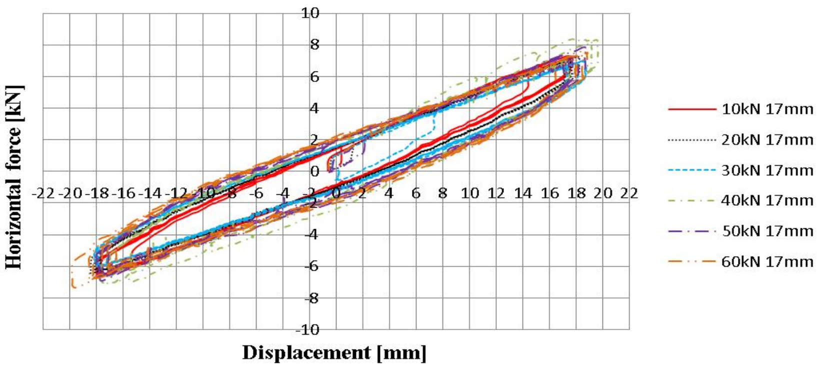

Fig. 5 – Force-displacement curves for 17 mm displacement.

Table 1
The Shear Modulus Values for Elastomeric Bearings

Vertical force, [kN]	Horizontal displacement, [mm]	G, [MPa]
10	14	0.89
20	14	0.80
30	14	0.74
40	14	0.68
50	14	0.68
60	14	0.63
10	17	0.85
20	17	0.77
30	17	0.71
40	17	0.74
50	17	0.70
60	17	0.61

For the second test, the compression force was 60 kN and 17 mm, 34 mm and 43 mm horizontal displacements, that is 0.35, 0.7 and 0.9 of the elastomer layers thickness (Fig. 6).

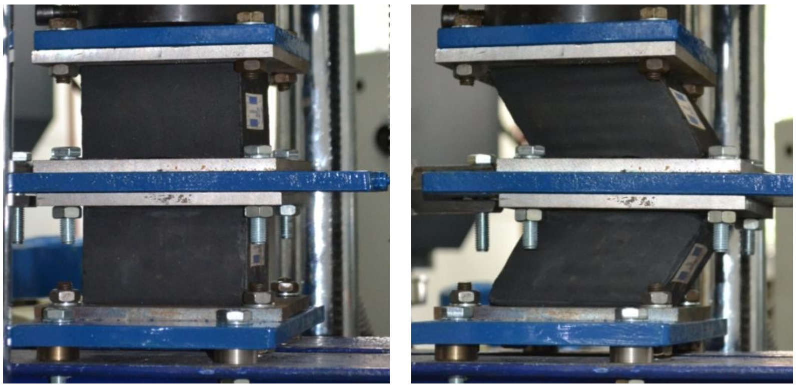

Fig. 6 – The undeformed and deformed shape of the bearing at 34 mm displacement.

A number of six loading-unloading cycles were carried-out and the force-displacement curves for the elastomeric bearings were plotted (Fig. 7).

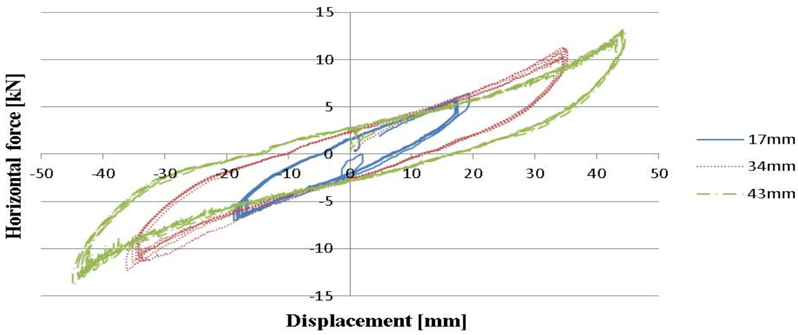

Fig. 7 – Force-displacement curves for elastomeric bearings.

The shear modulus values for the elastomeric bearings are presented in Table 2.

Table 2

The Shear Modulus Values for Elastomeric Bearings

Test type	*G*, [MPa]
60 kN 17 mm	0.60
60 kN 34 mm	0.58
60 kN 43 mm	0.45

After experimental research, the bearing surfaces were examined for defects after the maximum load (Fig. 8).

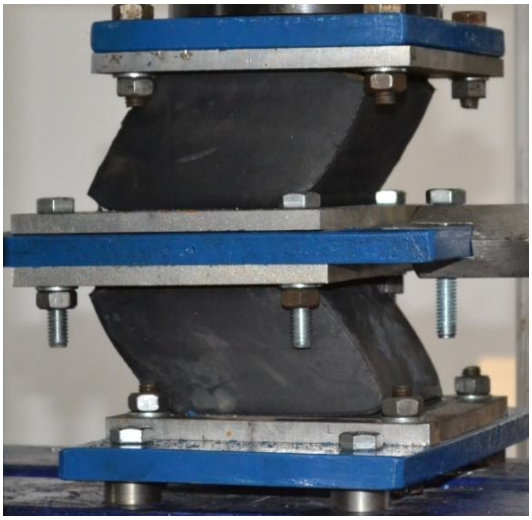

Fig. 8 – Elastomeric bearing degradation at 43 mm displacement.

3. Conclusions

Following experimental research, the effect of vertical forces variation on the horizontal stiffness of elastomeric bearings was analysed.

If the vertical force applied to the bearing increases, the shear modulus decreases. If the vertical force increases, the area of the hysteresis curve at horizontal actions increases.

When the value of vertical force was 60 kN and the horizontal displacement increased, the secant shear modulus decreased.

The shear modulus of the elastomeric bearing resulted 0.58 MPa at a 34 mm displacement and decreased to 0.45 MPa at a 43 mm displacement, which means a 29% decrease. This phenomenon is explained by the rupture, at initial elastomer displacements, of sulphur bridges which link the molecular chains and the elastomer becomes more flexible in following cycles of deformation.

The shear modulus of the elastomeric bearing presents different values depending on the maximum applied displacement, even to the horizontal displacement limit, according to standards, that is 0.7 of the elastomer layers thickness.

At 17 mm displacement (0.35 of the elastomer layers thickness), detachments of the bearing from the outer metal plates have been observed.

At displacements greater than 24 mm (0.5 of the elastomer layers thickness), bending tendency appeared (Fig. 8).

REFERENCES

Kelly J.M., Konstantinidis D.A., *Mechanics of Rubber Bearings for Seismic and Vibration Isolation*. J. Wiley a. Sons, London, UK, 2011.

Ramier J., *Thèse: Comportement mécanique d'élastomères chargés, Influence de l'adhésion charge – polymère, Influence de la morphologie*. L'Ecole Doctorale Matériaux de Lyon, Paris, 2004.

* * * *Aparate de reazem pentru structuri.* Partea 3. *Aparate de reazem din elastomeri.* Asociația de Standardizare din România, SR EN 1337-3-2006.

COMPORTAREA REAZEMELOR DIN ELASTOMERI SUB COMBINAȚII DE ÎNCĂRCĂRI

(Rezumat)

Se prezintă încercarea de laborator pentru determinarea modulului de elasticitate transversal al reazemelor din elastomeri la diferite valori ale forței verticale şi ale deplasărilor orizontale.

Reazemele din elastomeri au fost concepute pentru un experiment pe modele la scară pe platforma seismică. Elastomerul utilizat a avut duritatea de 60 Sh A.

S-au efectuat două seturi de încercări. Primul a constat în aplicarea unei forțe de compresiune asupra reazemului din elastomeri cu valori cuprinse între 10,…,60 kN, iar deplasarea orizontală aplicată a avut valori de 14 mm şi 17 mm. Pentru al doilea set forța de compresiune aplicată a fost de 60 kN şi deplasarea orizontală de 17 mm, 34 mm şi 43 mm.

În urma încercărilor experimentale a rezultat că modulul de elasticitate transversal al reazemului din elastomer prezintă valori diferite în funcție de deplasarea maximă aplicată. În cazul în care forța verticală aplicată reazemului creşte, modulul de elasticitate transversal scade.