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EXPERIMENTAL TEST OF ELASTOMERIC BEARINGS USED IN BASE ISOLATION

BY

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Abstract. The performance of bearings used in base isolation depends on the material of which they are composed, the mechanical characteristics and the stability of the bearing.

This paper presents an experimental test to determine the shear modulus of elastomeric bearings. The experimental test was carried out on different types of elastomeric bearings, namely: simple elastomeric bearing (EB), lead elastomeric bearing (LB), elastomeric bearing with sand core (SB) and elastomeric bearing with iron filings core (IB).

The elastomeric bearings have been provided by the firm S.C. FREYROM S.A. The elastomer had a hardness of 60 Sh A.

Following experimental tests, the highest values of vertical and horizontal stiffness were obtained in the case of elastomeric bearing with sand core and the lowest were achieved in the case of elastomeric bearing with iron filings core.

Key words: elastomer; elastic modulus; horizontal stiffness, vertical stiffness, hysteresis.

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1. Introduction

The seismic base isolation system increases the fundamental period of the structure and dissipate the energy produced by the earthquake, limiting the forces transferred to the superstructure.

The design of the bearing depends on the geometry and material properties. Most seismic isolation systems use materials such as natural/ synthetic elastomers or teflon in the case of sliding bearings (Kelly, 2001).

The essential characteristic of elastomeric bearings is the high ratio between vertical and horizontal stiffness. This is possible due to metal plates which are designed to prevent the lateral deformations (Kelly *et al*., 2011).

According P100-1/2013, the bearings must fulfil one or more functions: transmission of vertical load under a large lateral flexibility and a high vertical stiffness, energy dissipation, ability to return to its initial position and limitation of the lateral displacements produced by service lateral loads that are not caused by the earthquake.

The shear modulus of the elastomer bearing is an important parameter in their design. The horizontal stiffness of the bearing, the recovery force and the dynamic properties of isolation depend on this characteristic.

The aim of this paper is to determine the vertical and horizontal stiffness of elastomeric bearings under vertical and horizontal load combinations.

2. Experimental Test

2.1. Materials and Equipment

The tested elastomeric bearings consisted of 6 elastomer layers with 8 mm thickness interspersed with metal plates with 3 mm thickness. The outer metal plates had a 8 mm thicknesses (Fig. 1). The elastomeric bearings have been provided by the firm S.C. FREYROM S.A.

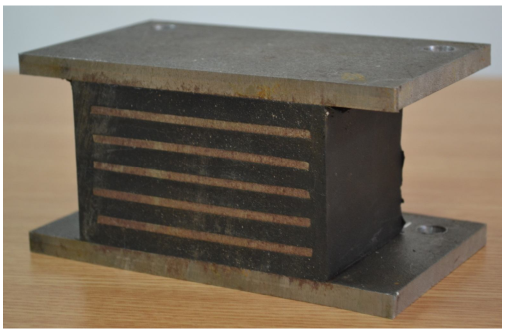


Fig. 1 – The elastomeric bearing.

The experimental research was to determine the stiffnesses of elastomeric bearings. The test equipment consisted of: two bearings, an universal testing machine that ensured the vertical force application on bearings, a special installation for horizontal force application, a force transducer, a displacement transducer and a data acquisition and processing system (Fig. 2).

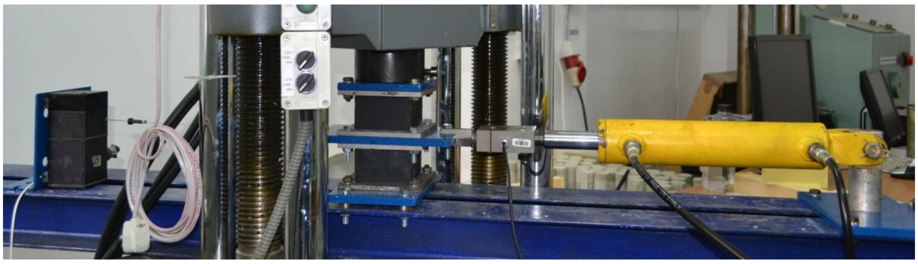
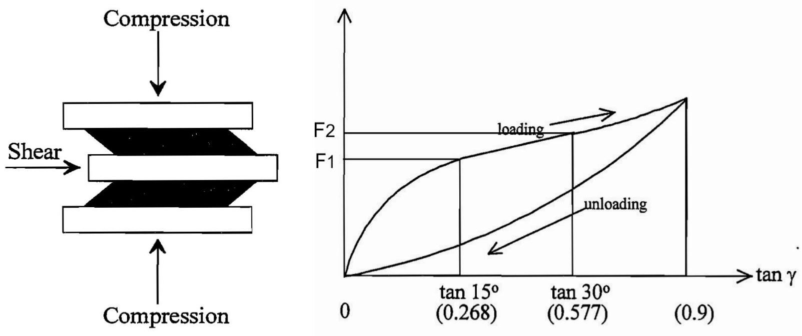


Fig. 2 – The test equipment.

2.2. Method

The shear modulus of elastomeric bearing is determined using the last load curve, on the linear section between tan 15° and tan 30°, meaning between 0.27 and 0.58 of the elastomer layers height (Arditzoglou *et al.*, 1995), (Fig. 3).



a *b*

Fig. 3 – *a* – The bearing in compression and shear; *b* – the loading-unloading curve (Arditzoglou *et al.*, 1995).

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

$$G = \frac{(\tau_2 - \tau_1)}{(\gamma_2 - \gamma_1)}, \text{ [MPa]}, \quad (1)$$

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.

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

$$\tau = \frac{F_x}{A}, \text{ [MPa]}, \tag{2}$$

where: F_x is the shear force, [N]; A – the compression area (cross-sectional area of bearing), [mm^2].

When the test is carried out on two bearings placed back to back, the applied force is $2F_x$ and area $2A$.

The shear strain is:

$$\gamma = \frac{v_x}{T_q}, \tag{3}$$

where: v_x is the displacement; T_q – the total initial thickness of elastomer.

The experimental test was carried out on different types of elastomeric bearings, namely:

a) simple elastomeric bearing (EB);
b) lead elastomeric bearing (LB);
c) elastomeric bearing with sand core (SB);
d) elastomeric bearing with iron filings core (IB).

According to EN 1337-2006, the experimental test consisted in applying a pressure of 6 MPa and the bearings were subjected to shear at a constant speed, to the maximum test deformation v_{xm} ($0.7T_q \leq v_{xm} \leq 0.9T_q$).

Thus, the applied compressive force of the elastomeric bearing had a value of 60 kN and the horizontal displacement was 0.70 of the elastomer layers thickness. A number of six loading-unloading cycles were carried-out and the force-displacement curves of elastomeric bearings were plotted.

2.3. Results

The displacement of the simple elastomeric bearings and the force-displacement curves are represented (Figs. 4 and 5).

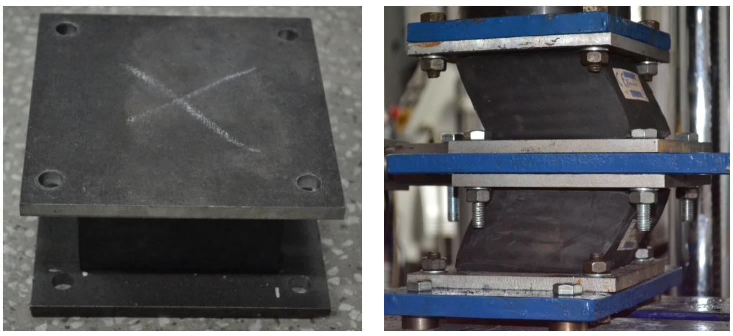


Fig. 4 – The simple elastomeric bearing displacement.

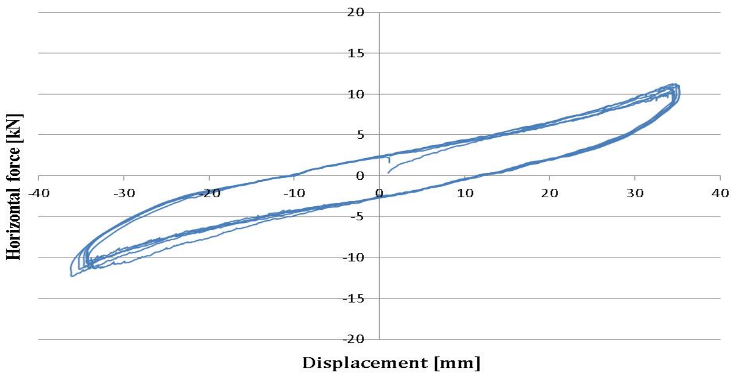


Fig. 5 – The force-displacement curves of simple elastomeric bearing (EB).

The displacement of the lead elastomeric bearings and the force-displacement curves are represented (Figs. 6 and 7).

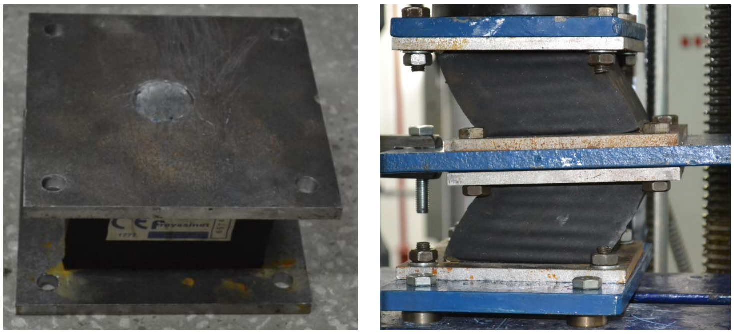


Fig. 6 – The lead elastomeric bearing displacement.

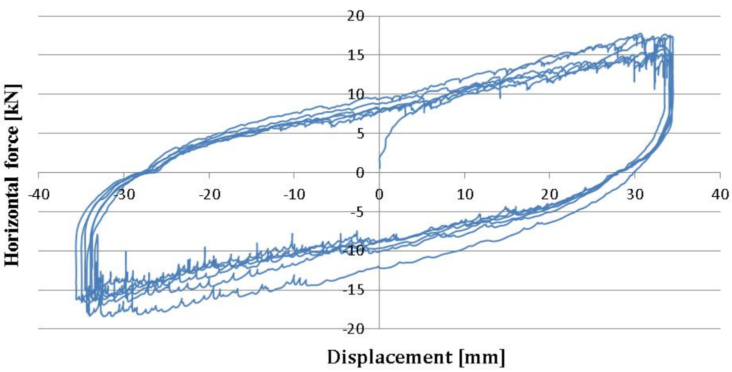


Fig. 7 – The force-displacement curves of lead elastomeric bearing (LB).

The displacement of the elastomeric bearing with sand core and the force-displacement curves are represented (Figs. 8 and 9).

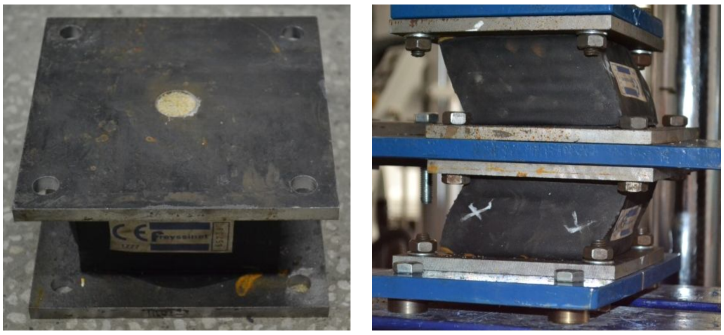


Fig. 8 – The displacement of the elastomeric bearing with sand core.

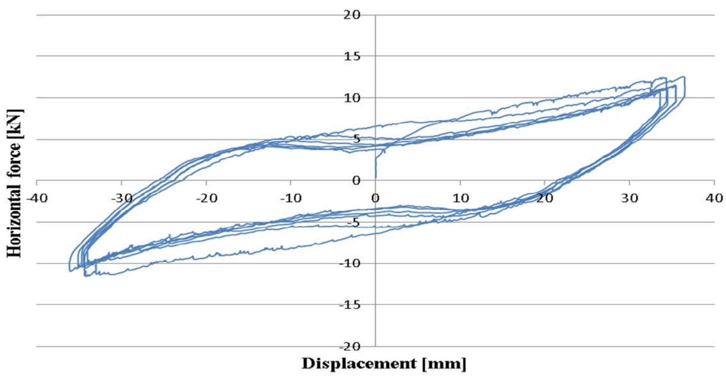


Fig. 9 – The force-displacement curves of elastomeric bearing with sand core (SB).

Following experimental test of elastomeric bearing with sand core, the sand was milled (Fig. 10).

Fig. 10 – The sand before and after the test.

The displacement of the elastomeric bearing with iron filings core and the force-displacement curves are represented (Figs. 11 and 12).

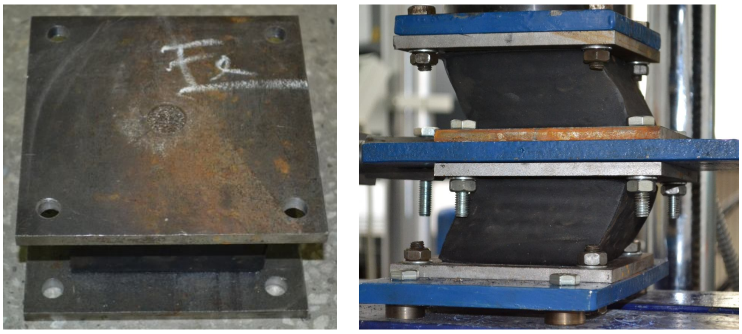


Fig. 11 – The displacement of the elastomeric bearing with iron filings.

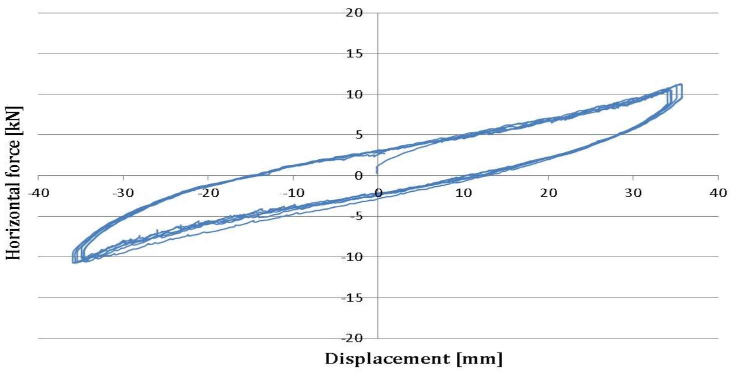


Fig. 12 – The force-displacement curves of elastomeric bearing with iron filings (IB).

The values of elastic moduli and the stiffnesses of elastomeric bearings are presented in Table 1.

Table 1

The elastic moduli and stiffnesses values for elastomeric bearings

Bearing type	F_1 kN	F_2 kN	v_1 mm	v_2 mm	G MPa	K_H N/mm	d_v mm	E_c MPa	K_V N/mm
SB	4.64	8.24	12.96	27.85	0.58	117.04	12	35.62	7,186.95
LB	10.61	14.12	12.96	27.83	0.57	115.02	10	35	7,063.04
SB	5.56	9.64	12.95	27.83	0.66	133.18	17.5	40.53	8,178.26
IB	5.37	8.22	12.98	27.85	0.46	92.82	17	28.25	5,700

Where: F_1 is the initial shear force; F_2 – the final shear force; v_1 – the displacement corresponding to F_1 force; v_2 – the displacement corresponding to F_2 force; K_H – the equivalent horizontal stiffness of the elastomeric bearing; K_V – the equivalent horizontal stiffness of the elastomeric bearing; E_c – the compression modulus of elastomer.

The horizontal and vertical stiffness of the elastomeric bearing was determined with the relationships (Kelly, 1997):

$$K_H = \frac{AG}{T_q}; K_V = \frac{AE_c}{T_q}, \tag{4}$$

The compressed area of elastomer, in the case of lead elastomeric bearing, was determined by the difference between the elastomer surface and core area (INCERC, 2002).

3. Conclusions

This paper presents an experimental test to determine the stiffness of elastomeric bearings, namely: simple elastomeric bearing (EB), lead elastomeric bearing (LB), elastomeric bearing with sand core (SB) and elastomeric bearing with iron filings core (IB).

Following experimental tests, the highest values of vertical and horizontal stiffness were obtained in the case of elastomeric bearing with sand core and the lowest were achieved in the case of elastomeric bearing with iron filings core.

The shortest vertical displacement and the higher horizontal force resulted in case of lead elastomeric bearing.

In case of lead elastomeric bearing, the largest area of hysteretic curve was obtained, the lead having a high energy dissipation capacity.

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CERCETĂRI EXPERIMENTALE A REAZEMELOR DIN ELASTOMERI UTILIZATE LA IZOLAREA BAZEI

(Rezumat)

Performanța reazemelor utilizate la izolarea bazei depinde de materialul din care sunt compuse, de caracteristicile mecanice şi stabilitatea reazemului.

Lucrarea prezintă încercarea experimentală pentru determinarea rigidității reazemelor din elastomeri. Experimentul s-a realizat pe diferite tipuri de reazeme din elastomeri, şi anume: reazem din elastomer simplu (EB), reazem din elastomer cu miez de plumb (LB), reazem din elastomer cu miez din nisip (SB) şi reazem din elastomer cu miez din pilitură de fier (IB).

Reazemele din elastomeri au fost puse la dipoziție de societatea S.C. FREYROM S.A. Elastomerul utilizat a avut duritatea de 60 Sh A.

În urma cercetărilor experimentale, valorile cele mai mari ale rigidității verticale şi orizontale s-au obținut în cazul reazemului din elastomeri cu miez de nisip, iar cele mai mici s-au obținut la reazemul cu miez din pilitură de fier.