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THE BEHAVIOUR UNDER COMPRESSION OF ELASTOMERS USED IN BASE ISOLATION BEARINGS

BY

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Abstract. The compression modulus of elastomers used in seismic base isolation depends on the dimensions and the composition of those materials.

The paper presents experimental results on the behaviour under compression of four types of elastomers: CR (chloroprene/neoprene rubber) with 64 Shore A hardness; NR (natural rubber) with 65 Shore A hardness; NR/BR (natural rubber/butadiene rubber) with 63 Shore A hardness; NR/BR/SBR+PA/PE Fibres (natural rubber/butadiene rubber/styrene butadiene rubber and polyamide/polyethylene fibres) with 65 Shore A hardness. Elastomeric specimens with a diameter of 28.5 mm and thickness of 13 mm and specimens with a diameter of 28.5 mm and thickness of 13 mm were tested.

The compression test was carried out in four situations: in the first case the elastomeric specimens were bonded with epoxy adhesive to metal plates, in the second case the elastomeric specimens were fixed without adhesive on two metal plates, in the third case the specimens have not been provided with plates and in the fourth case a thin layer of lubricant was applied between the elastomeric layer and the test machine plates. The compression modulus of elastomeric specimens was determinated according to SR EN 1337-2006.

Key words: elastomer; base isolation; elastomeric bearings; compression modulus.

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1. Introduction

Natural and synthetic rubber, such as neoprene, chloroprene are predominantly used in elastomeric bearings for the seismic base isolation.

The idea to introduce successive layers of rubber and metal plates for elastomeric bearings reinforcement belongs to the French engineer Eugène Freyssinet (Kelly *et al.*, 2011).

The failure of one elastomeric bearing is caused by the fatigue phenomenon of elastomer, the rupture or failure of metal plates, the detachment or buckling of the bearing. Therefore, the design codes specify the allowable stress in compression and shear, the deformations limit, the minimum thickness of metal plates and evaluation criteria of bearing stability (Yoon *et al.*, 2012).

The compression modulus of elastomers used in base isolation bearings depends on the material dimensions (shape factor), the elastomer composition and the amount of filler material, etc. Generally, the manufacturers of elastomeric bearings use the hardness as an indicator for vertical stiffness. If the hardness is greater then the elastic modulus is higher.

The specialty literature presents a number of relationships to determine the compression modulus, however to achieve a bearing device, experimental tests according to standards are required to check the elastomer characteristics (Oanea *et al.*, 2013).

2. Experimental Test

2.1. Materials and Equipment

The compression test was carried out on four elastomeric specimens with different compositions:

a) CR – chloroprene/neoprene rubber with 64 Shore A hardness;

b) NR – natural rubber with 65 Shore A hardness;

c) NR/BR – natural rubber/butadiene rubber with 63 Shore A hardness;

d) NR/BR/SBR+PA/PE fibres – natural rubber/butadiene rubber/styrene butadiene rubber and polyamide/polyethylene fibres with 65 Shore A hardness.

The materials were provided by S.C. FREYROM S.A., which is the manufacturer of bearings for seismic base isolation and bearings for bridges. The elastomeric specimens tested have a diameter of 28.5 mm and a thickness of 13 mm and with a diameter of 28 mm and a thickness of 6.5 mm.

The compression test was performed in four cases, namely

a) the elastomeric specimens were bonded with epoxy adhesive to metal plates;

b) the elastomeric specimens were fixed without adhesive on two metal plates;

c) the specimens have not been provided with plates;

d) a thin layer of lubricant was applied between the elastomeric layer and the test machine platens.

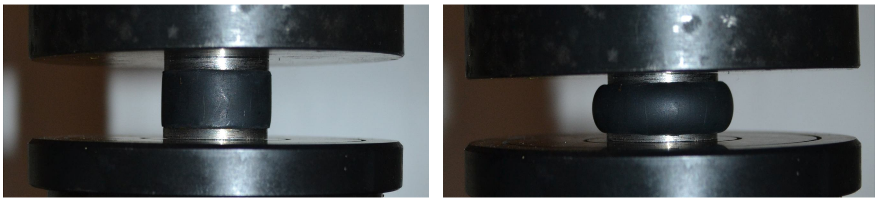

Fig. 1 – The elastomeric specimen bonded to metal plates: the undeformed *vs*. deformed shape.

Fig. 2 – The elastomeric specimen fixed without adhesive to metal plates: the undeformed *vs.* deformed shape.

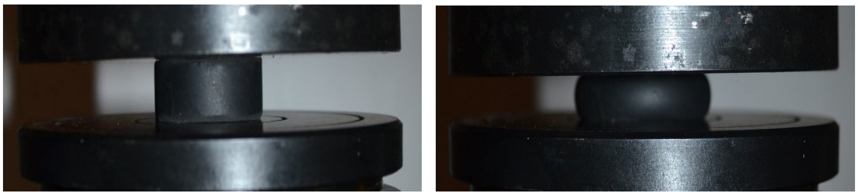

Fig. 3 – The elastomeric specimen fixed without metal plates: the undeformed *vs*. deformed shape.

Fig. 4 – The elastomeric specimen with lubricant: the undeformed *vs*. deformed shape.

The compression test of elastomer specimens was achieved with a Controlled Electro Mechanism Universal Testing Machine WDW. The compression load was progressively applied with a speed of 0.05 kN/s and the maximum value was 2 kN.

The undeformed and deformed shape of the elastomeric specimens in the four cases can be seen (Figs. 1,…,4).

2.2. Results

Ten cycles of loading–-unloading were performed and the stress-strain curves of elastomers were drawn. The stress–strain curves of specimens bounded to metal plates are shown in the case of elastomers with a thickness of 13 mm and 6.5 mm (Figs. 5,…,8).

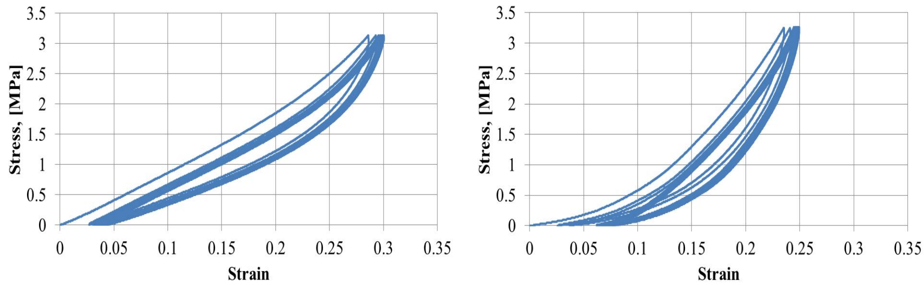

Fig. 5 – Stress–strain curves of CR sample of 13 mm and 6.5 mm thickness.

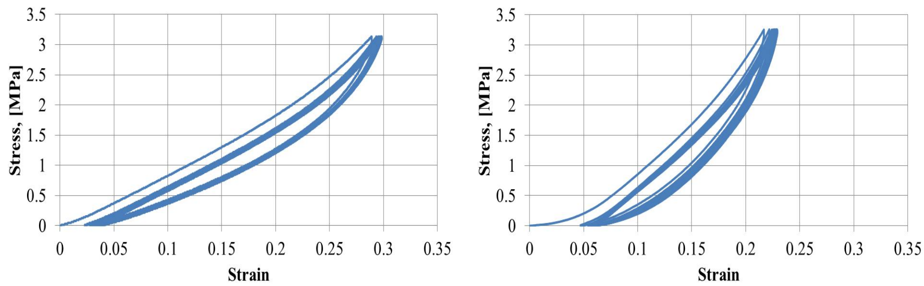

Fig. 6 – Stress–strain curves of NR sample of 13 mm and 6.5 mm thickness.

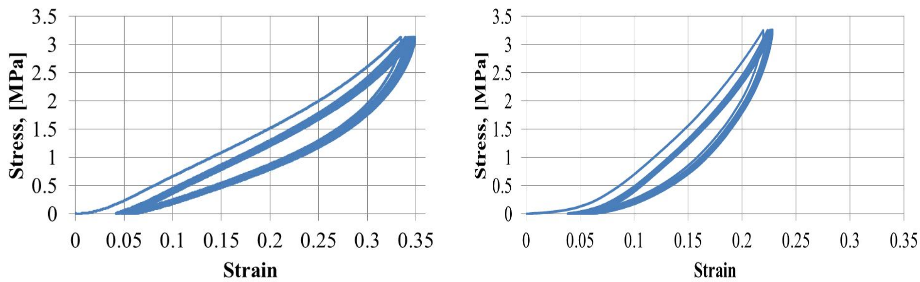

Fig. 7 – Stress–strain curves of NR/BR sample of 13 mm and 6.5 mm thickness.

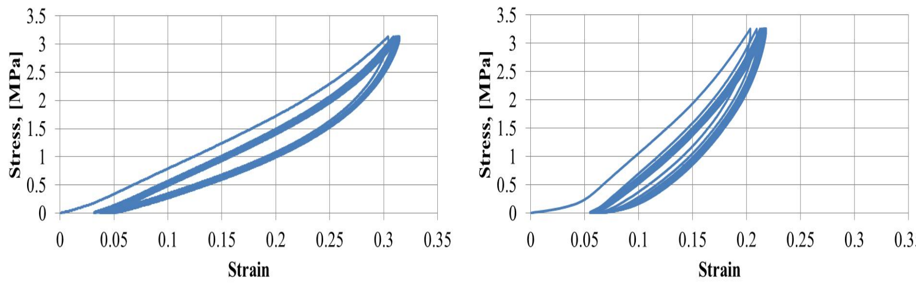

Fig. 8 – Stress–strain curves of NR/BR/SBR+PA/PE fibres sample of 13 mm and 6.5 mm thickness.

According SR EN 1337-2006, the secant compression modulus is determined by the relationship (ASRO, 2006)

$$E_{cs} = \frac{\sigma_{c2} - \sigma_{c1}}{\varepsilon_{c2} - \varepsilon_{c1}}, \quad (1)$$

where: σ_{c2} is the normal stress at maximum load; σ_{c1} – the normal stress at 1/3 of the maximum load; ε_{c2} – the deformation at maximum load; ε_{c1} – the deformation at 1/3 of the maximum load.

The secant compression modulus values are presented in the Tables 1,...,4 for the four types of elastomer in the four cases.

Table 1
Secant Compression Modulus Values for Bounded Specimens

h, [mm]	E_{cs}, [Mpa] CR	E_{cs}, [Mpa] NR	E_{cs}, [Mpa] NR/BR	E_{cs}, [Mpa] NR/BR/SBR+PA/PE fibres
13	14.35	14.26	12.53	13.85
6.5	24.63	22.92	24.96	26.00

Table 2
Secant Compression Modulus Values for Specimens Fixed to Plates

h, [mm]	E_{cs}, [Mpa] CR	E_{cs}, [Mpa] NR	E_{cs}, [Mpa] NR/BR	E_{cs}, [Mpa] NR/BR/SBR+PA/PE fibres
13	12.00	12.07	10.40	11.25
6.5	17.23	14.34	20.80	16.40

Table 3
Secant Compression Modulus Values for Specimens without Plates

h, [mm]	E_{cs}, [Mpa] CR	E_{cs}, [Mpa] NR	E_{cs}, [Mpa] NR/BR	E_{cs}, [Mpa] NR/BR/SBR+PA/PE fibres
13	10.37	11.55	9.90	11.43
6.5	14.00	12.08	10.73	12.70

Table 4
Secant Compression Modulus Values for Specimens with Lubricant

h, [mm]	E_{cs}, [Mpa] CR	E_{cs}, [Mpa] NR	E_{cs}, [Mpa] NR/BR	E_{cs}, [Mpa] NR/BR/SBR+PA/PE fibres
13	9.72	8.93	8.00	8.23
6.5	15.47	13.76	14.64	14.57

5. Conclusions

The aim of this study was to analyse the behaviour under compression of elastomers in different cases.

As a result of the laboratory tests it was found that the highest values of the compression modulus were obtained in the case when the specimens were bonded to metal plates, thus the role of reinforcement of the elastomers used in base isolation bearings was highlighted. The lower values of compression modulus resulted in the case of specimens with lubricant. The difference of modulus values in the two cases for the specimens with a thickness of 13 mm was: 48% for CR, 60% for NR, 57% for NR/BR and 68% for NR/BR/SBR+ PA/PE fibres.

The NR and NR/BR/SBR+PA/PE fibres have the same hardness, but different values of compression modulus were obtained because those materials have different fillers (PA/PE fibres).

The compression modulus values for the elastomeric layers with a thickness of 6.5 mm resulted greater than those with a thickness of 13 mm, observing the influence of the shape factor.

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COMPORTAREA LA COMPRESIUNE A ELASTOMERILOR UTILIZAȚI LA REAZEME PENTRU IZOLAREA BAZEI

(Rezumat)

Modulul de elasticitate la compresiune al elastomerilor utilizați la izolarea seismică a bazei depinde de dimensiunile şi compoziția acestor materiale.

Se prezintă rezultatele experimentale privind comportarea a patru tipuri de elastomeri la solicitarea de compresiune: CR (cauciuc cloroprenic/neoprenic) cu duritate 64 Shore A; NR (cauciuc natural) cu duritate 65 Shore A; NR/BR (cauciuc natural/cauciuc butadienic) cu duritate 63 Shore A; NR/BR/SBR+Fibre PA/PE (cauciuc natural/cauciuc butadienic/cauciuc butadien stirenic şi fibre de poliamidă/polietilenă) cu duritate 65 Shore A. S-au testat epruvete din elastomeri cu diametre de 28.5 mm şi grosimi de 13 mm şi epruvete cu diametre de 28 mm şi grosimi de 6.5 mm.

Încercarea de laborator s-a realizat în patru situații: în primul caz epruvetele din elastomer au fost lipite cu un adeziv epoxidic de plăcuțe metalice, în cel de-al doilea caz epruvetele au fost fixate fără adeziv de două plăcuțe metalice, în cel de-al treilea caz epruvetele nu au fost prevăzute cu plăcuțe, iar în cel de-al patrulea caz s-a aplicat un strat subțire de lubrifiant între stratul de elastomer şi platanele maşinii de încercat. Modulii de elasticitate la compresiune ale straturilor din elastomeri s-au determinat conform SR EN 1337-2006.