# Assesing The Level of Performance of Elastomeric Antiseismic Devices for Seismic Isolation at The Base

**Pungoci ALEXANDRU**
*Technical University of Constructions Bucharest, 122 – 124 Lacul Tei Ave, 020396, Bucharest, Romania, alexandru.pungoci@yahoo.com*

*Abstract:* - The paper presents the study of elastomeric insulation devices for isolating the base, taking into account the multicriteria correlative evaluations between the dominant characteristics of the external dynamic actions and the essential parameters of the isolated structures.In attempt of alleviate the seismic effects of the Earth on buildings, bridges, etc., over the years, a number of technologies and methods for designing structures resistant to seismic actions have been developed. One such method in continuous evolution is the seismic isolation at the base.All practical sistems of isolation must comply with a number of essential requirments, defined by flexibility, amotization and resistance to exploiting stresses, the three elements actually representing performance criteria.The elastomers supports devices must function properly when subjected to normal environmental conditions and maintenance, during uptime are determined by o resonable economical design.The concept of protection at random dynamic actions is based on limiting degradations, damages, and also avoiding collapses of structural elements, nonstructural elements, of equipments and installation in order to comply with imposed performance criteria.

*Keywords:* - elastomeric insulation devices, rubber, damping, systems

## 1. INTRODUCTION

The objective of the present article is structural and functional compatibilization of the optimal configurations for implementation of the elastomeric antiseismic devices for isolating the base, taking into account the multicriteria correlative evaluations between the dominant characteristics of the external dynamic actions and the essential parameters of the isolated structures.

The main objectives with an essential role in fulfilling the proposed purpose are the following:

- the current state of research and innovative development in the field of elastomeric anti-seismic systems
- structurally functional characterization of elastomeric anti-seismic systems and analysis of the performance requirements for them
- the correlation and optimal establishment of the isolation systems of the base; global performance requirements imposed on elastomeric insulation systems.

## 2. THE CURRENT STATE OF RESEARCH AND INNOVATIVE DEVELOPMENT IN THE FIELD OF ANTI-SEISMIC SYSTEMS

The researches provide engineers with sufficient means to understand how the dynamic response affects the system, but does not provide instructions on solving the nonlinear equations of motion, determined by the system response. In structural engineering, there are specialized programs that solve the problem instead of the engineer.

The opportunity of this article results from the analysis of the existing real situations and the regulations regarding the protection of the population and of the fund built against the dynamic actions caused by the seismic waves, vibrations, shocks.

The need to approach the proposed theme derives from the overall conclusions resulting from the multicriteria comparative analysis of the current stage in the considered field. Opportunity aspects identified complement the idea that in-depth research into the realities of current practice in the field of structures protection against varied and intense dynamic actions, by using elements based on elastomeric composite materials, in order to identify and substantiate advanced methods of systemic compatibility, is still valid.

The objective is the structural and functional compatibility of the optimal configurations for the implementation of elastomeric isolation devices, taking into account the multicriteria correlative evaluations between the dominant characteristics of the external dynamic actions and the essential parameters of the isolated structures.

## 3. FUNCTIONAL STRUCTURAL CHARACTERIZATION OF ELASTOMERIC ANTISEISMIC SYSTEMS AND ANALYSIS OF THE PERFORMANCE REQUIREMENTS FOR THEM

## 3.1. Physical-mechanical characteristics of elastomers

The assumptions that define a mathematical model of the static demanded rubber are:

- homogeneous and isotropic material;
- the rubber is perfectly elastic, for a very wide range of deformations; however, the characteristic curve is nonlinear;
-the rubber is incompressible (the volume deformation is zero).

A fundamental particularity of the rubber mechanics is the variation of the physico-chemical constants of the material, depending on the chemical composition, the test method, the manufacturing technology.

## 3.2. Dependence of the physical-mechanical properties of the rubber on the functional parameters of the mechanical system

Experimentally it has been found that both the temperature and the frequency of the vibration act on the visco-elastic materials in the same sense.

As the temperature rises, there is a shift of the curves in the direction of the pulse increase. In this way, at a decrease in temperature, the same qualitative characteristics can be obtained as by increasing the vibration pulse.

Based on the experiments, we found essential differences in the dynamic behavior of different rubber brands. Also, the experimental researches showed a decrease of the characteristics of amortization of the rubber with the increase of the pulsation.

## 3.3. Constructive and functional characteristics of seismic isolation systems

There are different seismic isolation systems that are designed and built according to: the size of the structure that has to be isolated from the seismic point of view, the complexity of the structure, the degree of loading (horizontal, vertical, longitudinal, transversal), the seismic area in which it is located structure. In order to reduce the strong vertical deformation of the seismic isolation systems of elastomers, they are reinforced with metallic elements, generally in the form of thin steel plates, arranged horizontally. This solution influences in a small measure, the horizontal deformation capacity.

## 3.4. Dissipative characteristics of the elastomeric elements used in dynamic insulation

Table 1 lists the shear coefficients of the base and the displacements for a structure from an area with high seismicity with near-edge effects.

**Tabel 1.** The effect of flexibility and damping

| | The shear coefficient of the base | Total displacement |
|---|---|---|
| Fixed base structure | | |
| Period 0.5 seconds | 1.76 | 4.30” (109) mm |
| Period 1 second | 1.15 | 11.21” (285) mm |
| Isolated structure with 2 seconds period | | |
| 5% damping | 0.57 | 22.43” (570) mm |
| 10% damping | 0.48 | 18.69” (475) mm |
| 20% damping | 0.38 | 14.96” (380) mm |

The damping provided by the rubber hysteresis can be used for calculation, by adopting the concept of "equivalent viscous damping" calculated from the surface of the measured hysteresis curve.

The elastomer has a hysteretic behavior, as shown in fig. 1.

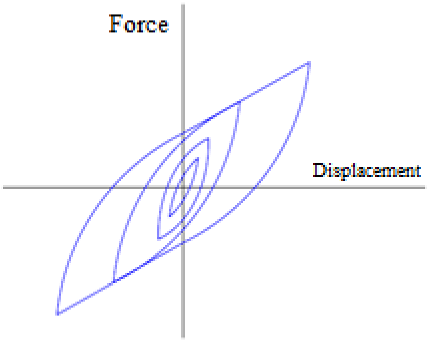

**Figure 1**. The hysteresis diagram on a tire with high damping

Although the characteristics of the rubber insulation systems of led core remain relatively constant over the years, there has been continuous research for the development of rubber components with high damping.

## 3.5. Rheological models and constitutive equations

Based on the viscous-elastic linear theory, the reaction of the environment to the action of force can be obtained by a combination of linear elastic behavior and linear viscous behavior.

In the one-dimensional elastic system, based on Hooke's law, one can write:

$$\sigma = E\varepsilon \tag{1}$$

in which $\sigma$ = tension , $E$= longitudinal modulus of elasticity, $\varepsilon$ = relative deformation
In the linear viscous system, based on Newton's law, the relation is written:

$$\sigma = \eta\dot{\varepsilon} \qquad (2)$$

in which $\eta$ = coefficient of viscosity, $\dot{\varepsilon}$ = relative deformation speed.

### 3.6. Structural and functional degradation of elastomers under the influence of external factors

The aging properties of the insulators can be evaluated by the accelerated aging test due to the thermal effect.

The final resistance of the insulators can be evaluated by the aging test due to the accelerated thermal effects. After 60 years of age, the degradation coefficient of the final shear strength is lower by a few percent compared to the initial properties.

The appearance of heat in the rubber elements depends on several factors and first of all the deformation regime and conditions, the dimensions and shapes of the rubber element, the method of cooling the installation, the technology of execution of the rubber element and the physico-mechanical properties of the material.

## 4. THE CORRELATION AND OPTIMAL ESTABLISHMENT OF THE ISOLATION SYSTEMS OF THE BASE

### 4.1. Global performance requirements for reducing the effects of dynamic actions on structures

The concept of protection at random dynamic actions is based on limiting degradation, damage, as well as avoiding collapses of structural, non-structural elements, equipment and installations in order to achieve the following objectives:

- avoiding loss of human life or injury to people;
- avoiding the interruption of activities and services essential for maintaining the continuity of social and economic life during the earthquake and immediately after the earthquake;
- avoiding the destruction or degradation of cultural and artistic assets of great value;
- avoiding the release of dangerous substances (toxic, explosive);
- limitation of material damages.

**Tabel 2**. Categories of dynamic severity

| Dynamic severity class | The role of the equipment within the system | Performance criteria |
|---|---|---|
| I | “**Fundamental**” – characterizes the function of the equipment and/or of equipment whose exit from the function can directly affect the protection of the building and the environment to the fire, emanations of toxic substances with biochemical effect and/or lethat effect | • Total physical integrity<br>• Normal and total functional capacity<br>• Lack of fire risk, protection of the life and health of the occupants |
| II | “**Essential**” – characterizes the minimum capacity of the equipment to maintain in operation other equipment of significant importance for the building and occupants | • Ensuring the limited physical integrity for maintaining vital equipment in operation<br>• Minimizing fire risks, protecting the life and health of the occupants |
| III | “**Selective**” – characterizes the equipment that ensures the minimum functions of fire safety, hygiene and health | • Physical integrity<br>• Ability to adapt and initialize the operation under specified conditions<br>• Reaction speed |
| IV | “**Critical functional**” – characterizes the equipment that must ensure minimum functions of a building (energy, water, internal transport) | • Physical integrity<br>• Operation at the limit of the last state of service for the building<br>• Increased ability to repair and adapt quickly in case of damage |

### 4.2 Parametric compatibility and optimization requirements for elastomeric insulation systems

The maximum specific deformations of the rubber are over 500% and the global characterization of the rubber deformations proposes to use the general concepts and methods of the finite nonlinear theory of elasticity.

The characteristic curve at axial load can be given in the form $\sigma = \sigma(\lambda)$ or $t = t(\lambda)$, representing respectively the real and conventional tension depending on the longitudinal extension $\lambda = \frac{l}{l_0}$ of the specimen. By noting $P$ axial force and by $A_0$, $A$= the cross-sectional areas before, respectively during deformation (assumed static, so with a loading speed $\frac{dP}{dt} \cong 0$),

$$\sigma = \frac{P}{A}; \quad t = \frac{P}{A_0} \tag{3}$$

The incompressibility condition, assuming that the test achieves sufficiently exactly a homogeneous state of deformation, leads to:

$$A_0 \, l_0 = Al \tag{4}$$

From which

$$\frac{A_0}{A} = \lambda \tag{5}$$

and

$$\sigma = \lambda t \tag{6}$$

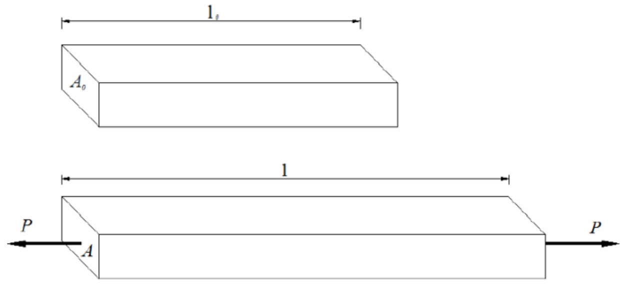

**Figure 2.** Lack of homogeneity of the deformation state - the case of stretching

In the case of compression, in which the piece must be short enough to avoid buckling, it must be possible, through constructive means (lubrication), the possibility of the free transverse movement of the end sections (fig. 3).

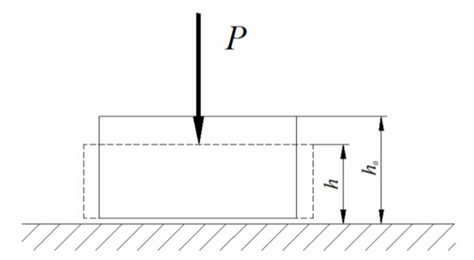

**Figure 3**. Lack of homogeneity of the deformation state - the case of compression

Name $\lambda_1 = \lambda$ extension in the direction of action of the force, for reasons of symmetry

$$\lambda_2 = \lambda_3 = \frac{1}{\sqrt{\lambda}} \tag{7}$$

*Treloar's* meticulous experiences led *Mooney* to adopt a linear elastic potential for rubber

$$\varphi = C_1(I_1 - 3) + C_2(I_2 - 3) \tag{8}$$

The rubber model characterized by the elastic potential is known in the literature as the "Mooney model". The verification of this model consists in confronting its consequences with the experimental data. In the case of axial loading, it results:

$$I_1 = \lambda^2 + 2\lambda^{-1} \;;\; I_2 = 2\lambda + \lambda^{-2} \tag{9}$$

so that

$$\varphi(\lambda) = C_1(\lambda^2 + 2\lambda^{-1} - 3) + C_2(2\lambda + \lambda^{-2} - 3) \tag{10}$$

and by noting $t_1 = t, t_2 = t_3 = 0$,

$$t = 2C_1(\lambda - \lambda^{-2}) + 2C_2(1 - \lambda^{-3}) \tag{11}$$

$$\sigma = 2C_1(\lambda^2 - \lambda^{-1}) + 2C_2(\lambda - \lambda^{-2}) \tag{12}$$

Elastic constants $C_1, C_2$ are connected by a simple relation, imposed by the condition that, for small deformations, it is reduced to the linear law $\sigma = E\varepsilon$ of any elastic body. For small deformations we have:

$$\lambda = 1 + e \quad , \quad \varepsilon \cong e \ll 1 \tag{13}$$

$$\lambda^{-2} = (1 + \varepsilon)^{-2} \cong 1 - 2\varepsilon \tag{14}$$

$$\lambda^{-3} = (1 + \varepsilon)^{-3} \cong 1 - 3\varepsilon \tag{15}$$

from which

$$E = 6(C_1 + C_2) \tag{16}$$

Second, the incompressibility condition is written in the field of small deformations, in the form $\Sigma\varepsilon_i = 0$ or $\mu = 0.5$, where $\mu$ is Poisson's coefficient, so:

$$E = 2G(1 + \mu) = 3G \tag{17}$$

and so

$$G = 2(C_1 + C_2) \tag{18}$$

$G$ being the modulus of transverse elasticity of the rubber, for small deformations. G is easily determined experimentally by testing a cylindrical torque test. In this case $G = \frac{Ml}{\varphi I_p}$ where $M$ it's the torque, $l$ is the length of the piece, $\varphi$ is the relative turning angle of the end sections and $I_p$ is the moment of polar inertia of the section.

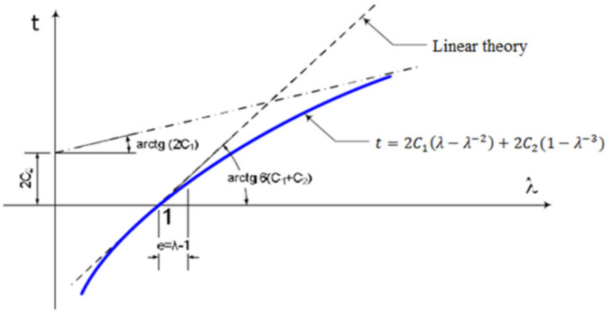

**Figure 4.** Graph of the curve $t = 2C_1(\lambda - \lambda^{-2}) + 2C_2(1 - \lambda^{-3})$

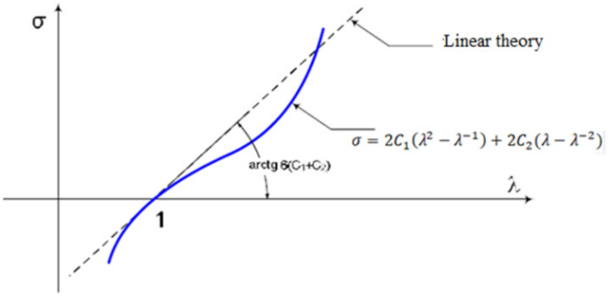

**Figure 5.** Graph of the curve $\sigma = 2C_1(\lambda^2 - \lambda^{-1}) + 2C_2(\lambda - \lambda^{-2})$

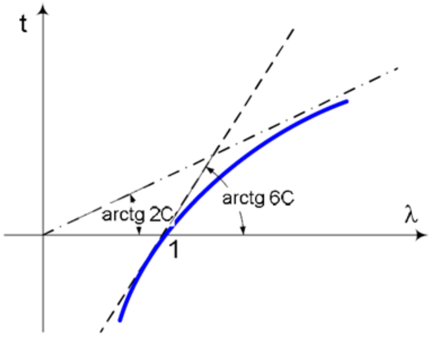

**Figure 6.** Characteristic curve $E = 6(C_1 + C_2)$

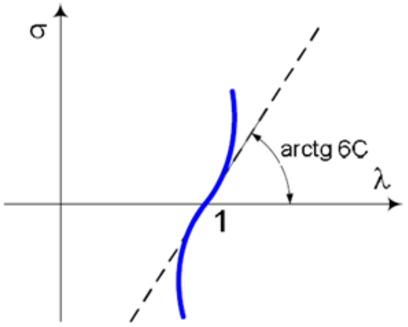

**Figure 7.** Characteristic curve $G = 2(C_1 + C_2)$

$$P = GA_0\left(1 + \frac{\Delta}{l_0} - \frac{1}{\left(1+\frac{\Delta}{l_0}\right)^2}\right) \tag{19}$$

$$P \cong 3GA_0(e - e^2) = EA_0(e - e^2) \tag{20}$$

shows that, compared to linear theory, in which

$$P = \frac{EA_0}{l_0}\Delta = EA_0 e, \tag{21}$$

the relationships above bring nonlinear correction $EA_0e^2$.

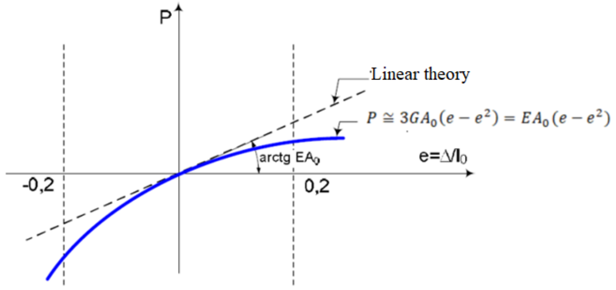

**Figure 8.** Introduction of nonlinear correction $EA_0e^2$ compared to linear theory

## 4.3. Essential requirements regarding the overall configuration of the assembly structure - insulator - terrain

The most common configuration is to install the diaphragm immediately above the insulators. This allows the seismic loads to be distributed on the insulators according to their rigidity. In the basement buildings the insulators are mounted on the foundation and the building is built above them. If the building has a basement, then the options for installing the insulators are at the top end, at the bottom end or in the middle of the basement columns and walls.

For mounting options at the top or bottom of the columns / walls, then the element must be calculated at the given time by the maximum shear force in the insulator. This choice requires large columns or pillars to withstand the loads.

## 4.4. The concept of compatibilization action-isolator-structural response and specific principles

*The requirements* for a practical insulation system consist of two categories of requirements, namely:
1) *The essential requirements* of an insulation system are defined by the following performance objectives:
- flexibility
- damping
- resistance to operational demands.

2) *Additional requirements* such as durability, cost, ease of installation and specific design requirements influence the selection, but in practice, all systems must contain the three essential elements listed.

Compatibilization of the assembly *disruptive action - isolator - structural response*, considered to be an applicative method, it can be structured as follows:

- ***type*** – depending on the type of the element (static / dynamic characteristics)
- ***form*** – depending on the geometry of the element
- ***configuration*** – depending on the geometry of the isolator assembly

The compatibilization must take into account a coherent set of factors that can fully characterize the behavior in operation of the visco-elastic supports.

It should be highlighted the need to use as primary input data, the characteristics of the material (type E, G, μ) which can be "custom" (or to be incorporated "configuration information") resulting in sets of rigid (kx, kz ) available for simulations on simplified models (with concentrated masses).

## 4.5. Ensuring the necessary conditions for the foundation ground

Ensuring the necessary conditions for the foundation ground is done by making a reinforced concrete tank, which is 3-4 m below the ground and must be made on naturally processed land. After digging, the ground must be analyzed from a geotechnical point of view (plasticity, porosity) and in the situation when these characteristics are not satisfactory, ecological stabilizers will be used.

The most important objective is compaction with compactor rollers so that the compaction level to be

98%. The dynamic compaction regime must be ensured by the amplitude and frequency parameters and by the compacting force of the compactor rollers, having the purpose to introduce the land in a stable plastic state (with controllable settlements).

## 5. CONCLUSIONS

The compatibility of the elastomeric devices with several categories of GF + 4 structures was analyzed, as well as bridge and viaduct structures, in the sense that specific structural to reach the level of seismic isolation of 90% during the earthquake.

The specific contribution related to the characteristics of elastomeric seismic devices consists in the fact that the author has established a dynamic test protocol, adapted to the conditions and possibilities in Romania so that the requirements of EN15129 can be met. In this sense, the tests in dynamic regime were performed in a technological order, in the sense of successive modification of the lateral displacement so that all the stages of the test can be completed, 5%, 10%, 50%, 75%, 100%., from the maximum displacement in seismic regime. Also, the dynamic test steps were established based on the dynamic excitation of 3 frequencies 0.1Hz, 0.5Hz, 1.0Hz.

Based on the lifting of the hysteresis loops, during the test were determined the stiffness and damping characteristics for all situations of lateral displacement stress of elastomeric devices, establishing the series of experimental values necessary for the design of dynamic base insulation systems.

I analyzed and there are reinforced concrete structures that can be insulated at the base by elastomeric elements presented in the article. Elastomeric devices can also be used to insulate bridges and viaducts, based on a suitable design so that each elastomeric device is required within the limits of experimentally determined parameters.

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