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WORKING CHARACTERISTICS OF THE SPECIAL ISOLATION DEVICES AGAINST VIBRATORY ACTIONS

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ABSTRACT

The actual researches for finding optimal antiseismic protection solutions are straightening to the few areas of activity: the first area of research is the base isolation of buildings or theirs parts, against the vibrations and earthquake actions. The second area of activity, in anti-seismic protection domain, is the isolation of vital equipments of public buildings endowment, against the seismic waves or undesirable vibrational movements. In essence, the antiseismic systems manufacturing are based on suitable ensembling of individual elements with elastic and damping properties, so that at standard earthquakes spectral composition should be avoid the resonance dynamic response. This paper emphasize a technical solution of isolation elastic system, copyrighted in Romania, which are capable of very low natural frequency, so that it is possible low tunnig of ensemble of building - isolation system.

1. Introductory remarks

The antivibrational and antiseismic passive elastic isolation systems have a very large area of constructive and functional composition. In this paper the author present a novative solution for enlarge the static and dynamic deflection under the external loads. The main aim of this complex constructive shape is to enlarge the deflection of the general support system, during that the maximum deformation on the each constitutive elastic element, remain in the admisible domain (which have, in usual cases, small values).

All the systems achieved and used for passive antiseismic and antivibrational protection of vital equipments, until present, are characterized both through the elastic performances according to obtain necesary natural frecquency (lowest values) on direction of dynamic degrees of freedom, and through the dissipative performancies so that the energy damping should substantial decrease the shock impact on the seismical wave direction.

The author tested o lot of elements and systems, more or less complex, based on the rubber elements, with the final scope to determine the optimal configuration which could assure the real isolation against the vibration and/or seismic type waves.

Basically, these antiseismic systems are based on suitable ensembling of individual elements or sub-systems, with proper elastic and damping characteristics, so that at standard dynamic loads spectral composition should be avoid the resonance dangerous phenomenon.

This paper emphasize a technical solution of insulation elastic system, copyrighted in Romania, which are capable of very low natural frequency, so that it is possible low tunnig of the entire ensemble of building - insulation system.

One way of characterize this systems is the isolation degree. In this study the author treat the problem of seismic isolation for vital equipments from public building endowment, using a new and innovator antiseismic isolation system. One of the proposed scope of this entire research is obtaining the isolation degree values over the 90%.

In this paper are treats only one passive type of isolation system. The working principle of this systems are based on the elastic capability of the rubber elastic elements to assume the exciting loads energy and transforming it into the potential energy. In Figure 1 it is presented a 3D model of the anti-vibrational system that will be analysed in this paper.

The proposed device have a regular polygon shape, with six nodes (see Figure 1). Each node consist from one rubber torsion element. The link between two joining nodes was maded using of a rigid levers.

This device is the base element of the complex isolation elastic system, which accomplish both the antivibrational, and the antiseismic system. Depending of the essential parameters values of the considered equipment, it could be adopted the appropriate number of the isolation elastic systems.

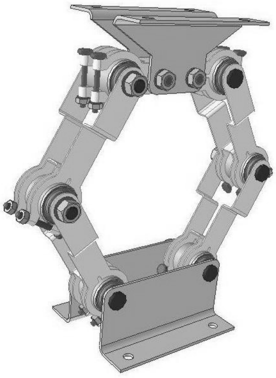


Figure 1. Antivibrational passive elastic system with special polygonal configuration

2. Computational model

In Figure 2 is presented a schematic model for deformation and equivalent rigidity calculus of one isolation elastic element.

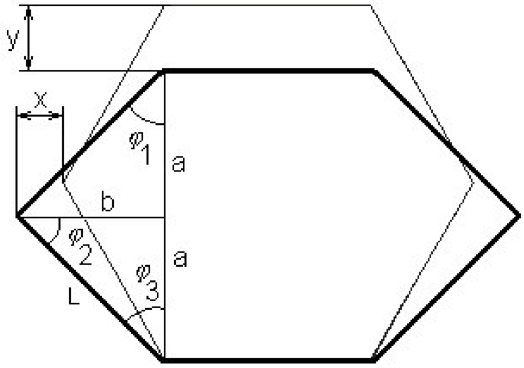


Figure 2. Dynamic model for calculus

Using the expression of trigonometrical function for φ_2 angle, both in initial position and in the final (work position), it can be write

$$\sin\varphi_2 = \frac{a}{l} = \frac{a_0 - \frac{y}{2}}{l} \Rightarrow y = 2a_0 - 2l\sin\varphi_2 \qquad (1)$$

$$\cos\varphi_2 = \frac{b}{l} = \frac{b_0 + x}{l} \Rightarrow x = l\cos\varphi_2 - b_0 \qquad (2)$$

But

$$a_0 = l\sin\varphi_{02}, \quad b_0 = l\cos\varphi_{02},$$

thus that the previous expressions becomes

$$x = l\cos\varphi_2 - l\cos\varphi_{02} \qquad (3)$$

$$y = 2l\sin\varphi_{02} - 2l\sin\varphi_2 \qquad (4)$$

The potential energy of deformation for the system is

$$V^{def} = 2\left[\frac{1}{2}k_1^{\varphi}\varphi_1^2 + 2\left(\frac{1}{2}k_2^{\varphi}\varphi_2^2\right) + \frac{1}{2}k_3^{\varphi}\varphi_3^2\right] \qquad (5)$$

where $k_1^{\varphi}, k_2^{\varphi}, k_3^{\varphi}$ - torsion rigidity coeficients for the three rubber elastic anti-vibrational elements, and it can consider that $k_1^{\varphi} = k_2^{\varphi} = k_3^{\varphi} = k^{\varphi}$. The φ_1, φ_2 and φ_3 angles have the next dependencies:

$$\varphi_1 + \varphi_2 = \frac{\pi}{2} \Rightarrow \varphi_1 = \frac{\pi}{2} - \varphi_2 \qquad (6)$$

$$\varphi_3 + \varphi_2 = \frac{\pi}{2} \Rightarrow \varphi_3 = \frac{\pi}{2} - \varphi_2 \qquad (7)$$

and if we consider that the $\varphi_2 = \varphi$ and $\varphi_{02} = \varphi_0$, whereupon the relation of the potential energy of system deformation become

$$V^{def} = k^{\varphi}\left[2\left(\frac{\pi}{2} - \varphi\right)^2 + 2\varphi^2\right] \qquad (8)$$

Taking into account the (2) expression of vertical deformation of system, and substitute the φ angle in the previous relation, obtain the final expression for potential energy of system deformation:

$$V^{def} = k^{\varphi}\left(\frac{\pi^2}{2} + 4\arcsin^2\frac{\Delta y}{2l} - 2\pi\arcsin\frac{\Delta y}{2l}\right) \qquad (9)$$

where Δy is the height of the system in work position:

$$\Delta y = y_o - y = 2l\sin\varphi_o - y \qquad (10)$$

Consider an equipment with *m* mass. The total energy of isolation system deformation for this case is

$$V^{total} = -mgy + V^{def} \qquad (11)$$

From successive derivation of the previous expression it can deduce the elastic force, respectively the equivalent rigidity, expressions, for the considered isolation system:

$$F_y = \frac{2k^{\varphi}}{\sqrt{4l^2 - \Delta y^2}}\left(\pi - 4\arcsin\frac{\Delta y}{2l}\right) + mg \qquad (12)$$

$$k_y = \frac{2k^{\varphi}}{2l^2 - \Delta y^2}\left[\begin{array}{l}\pi\Delta y\sqrt{4l^2 - \Delta y^2} + \\ + 4\Delta y\left(4l^2 - \Delta y^2\right)^2 \arcsin\dfrac{\Delta y}{2l} - 4\end{array}\right] \qquad (13)$$

3. The analysis of the results

For experimental model we adopted the next parameter values: m = 80 kg, l = 130 mm, $\varphi_0 = 30^o$, k^{φ} = 100 Nm. Consider the relation (13) of equivalent rigidity on vertical direction, it was analysed the behaviour of the system in two cases.

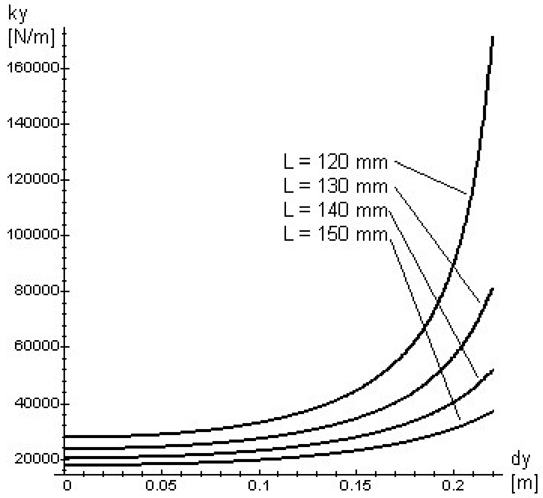


Figure 3. Evolution of equivalent rigidity of elastic isolation system - case I

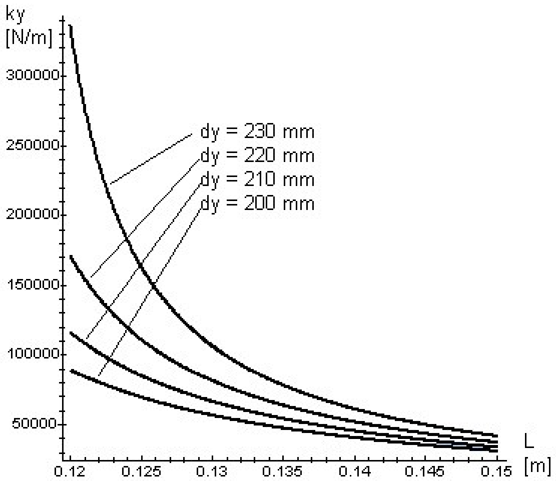
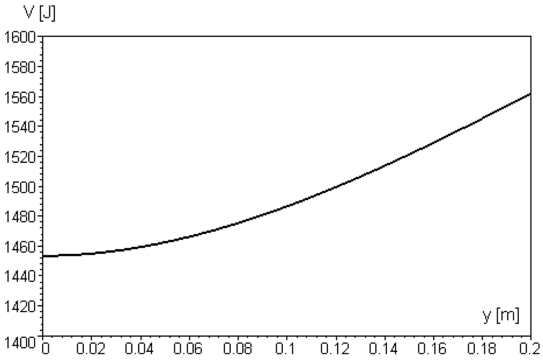


Figure 4. Evolution of equivalent rigidity of elastic isolation system - case II

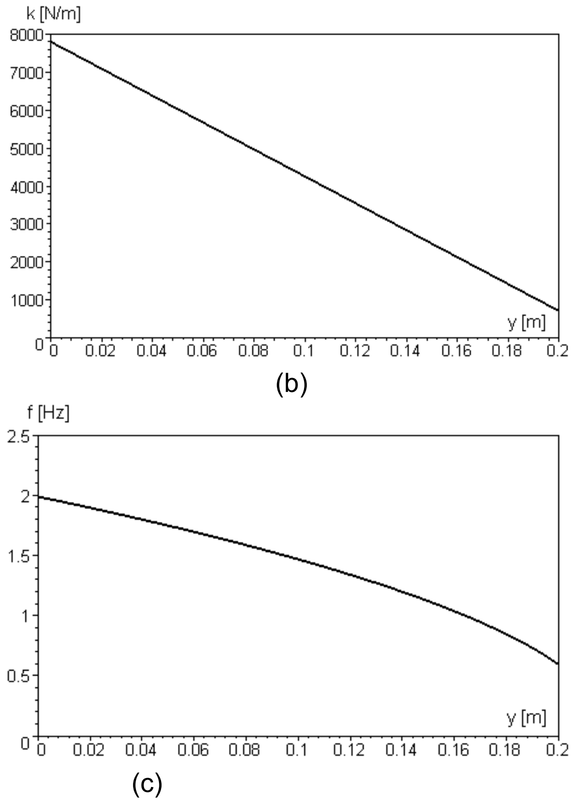
In first case it is consider that the length of the rigid levers between the rubber elements have four possible values: 120, 130, 140, 150 mm, and it was represented the evolution of equivalent rigidity coeficient, for the whole system, as a function of system deformation (or the height of the system in work position).

In second case, the independent variable it was considered the length of the levers, and the parameter it was taked as the maximum of the system deformation (minimum value for charged system elevation).

From these two graphical diagrams result the fact that it can be possible to design this kind of elastic isolation system thus that the natural frecquency of entire ensemble should be very lower and it is possible low tunnig of ensemble of building - protected equipment.



(a)



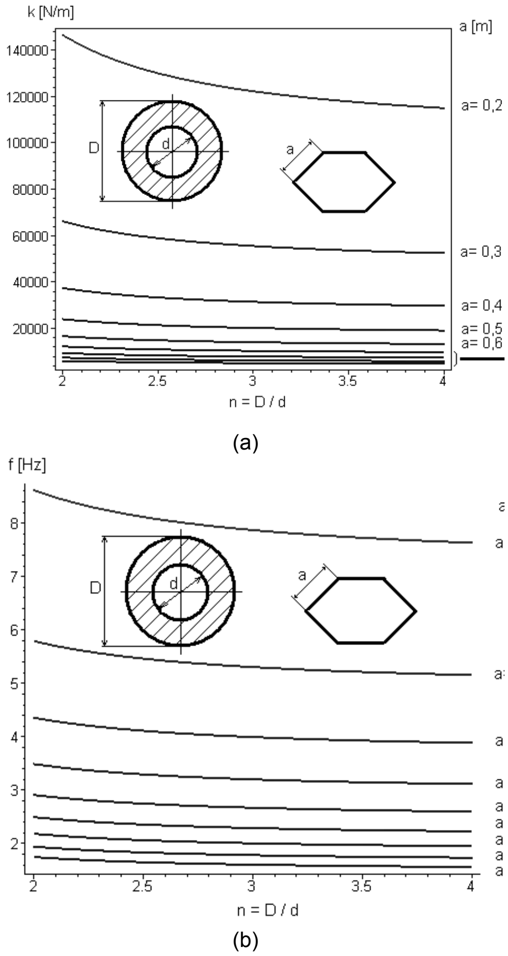
(b)

(c)

Figure 5. The evolutions of the global deformation energy, of the rigidity, and of the natural frequency

The diagrams from Figure 5 depicted the evolutions of the global deformation energy, of the rigidity, and of the natural frequency, for the proposed system. The independent parameter for all three graphs is the elevation of the system on initial position.

In Figure 6 is depicted the relationship between the structural parameters of the elastic rubber element - the ratio *n=D/d* between the inner and the outer diameters of the rubber elements, and the length of the lever *a* - on the equivalent rigidity, respectively on the natural frequency of the isolation device. It must be mentioned that for the entire analysis, presented in this paper, it was considered an isolation device with two active sides, and fully six elastic elements (with 40 mm length, and 50 mm innner diameter).



(a)

(b)

Figure 6. The relationship between the equivalent rigidity (a), respectively the natural frequency (b), and the ratio between the elastic element diameters, with the lever length parameter

4. Concluding Remarks

The global analysis of the diagrams depicted in Figure 6 leads to the next conclusions: to decrease the natural frequency value of the complex polygonal shape isolation device, it is necessary that both the level length, and the ratio between the inner and the outer diameters should be enhanced.

This computational approach of the polygonal shape insulation device it was necessary for theoretical fundamentation of the structural behaviour under the charge, taking into account the software simulation of the dynamics, and the experimental tests on realistic situations, that was developed by the author. The entire sets of data leads to the final conclusion that this kind of devices assures the technical conditions for using these on practice.

Acknowledgements

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