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VARIETY OF RHEOLOGICAL MODELS USED IN THE ISOLATION OF THE BASE FOR EARTHQUAKE CHALLENGED CONSTRUCTIONS

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Abstract: *There are presented the results of the researches performed for the optimization of the base isolation systems for residential buildings, bridges and viaducts. Thus, there were analyzed the types of elastomeric anti-seismic devices and fluid viscous damper which, through a suitable connection system, can ensure the isolation degree of over 95%. For this purpose, there were assessed the possibilities of the viscous-elastic isolation systems for the seismic prone regions in Romania. The paper presents the possible variants with the results of the assessment calculation of the dynamic isolation parameters.*

Key words: *base isolation, antiseismic devices, rheological schemes*

1. INTRODUCTION

The linear/non-linear viscoelastic rheological schematization may be accomplished by the appropriate connection of a number of individual anti-seismic devices developed and certified according to standard EN15129/2018.

For the base isolation systems, there are used elastic elastomeric devices (HDRB, LRB) and viscous fluidic dissipating devices (FVD), in the assumption of linear behaviour. Thus, five composite models were analytically approached: Voigt-Kelvin (E/V), Maxwell (V-E), Zener (E-V) /E, Hooke Voigt-Kelvin E-(E/V), Newton Voigt-Kelvin V-(E/V). The dynamic model has only one degree of freedom, taking into account the fact that the overall structure of the building behaves as a non-deformable rigid, with the mass m of the superstructure relative to the insulation interface.

Excitation is chosen as instantaneous acceleration $\ddot{x}_0$ or instantaneous displacement $x = x(t) = X_0 sin\omega t$ corresponding to the first spectral mode (fundamental) of the spectral composition of earthquake.

Both k equivalent elastic rigidity as and sell as c equivalent amortization from the "series-parallel" composed connection of all individual devices. For each case, analytical relations of calculation have been established so that the evaluation of the isolation performances may be done under the conditions of a realistic analysis of the dynamic behaviour.

2. SEISMIC DYNAMIC ISOLATION PARAMETERS

Table 1 presents five composite rheological models. Thus, for each solution there is presented the dynamic schematics with the rheological model of the support and connection system, with the representation of the instantaneous displacements of the remarkable points, namely:

- instantaneous displacement $x = x(t) = X_0 sin\omega t$ corresponds to the mobile landmark O of the foundation embedded in the ground, being generated by the seismic movement of the ground in the unidirectional direction with respect to axis $O_1 X$, considered fixed.
- instantaneous displacement $x = Asin(\omega t - \varphi)$ corresponds to the point A of the concentrated mass m, defined in relation to the mobile landmark O.

- instantaneous displacement of the connection point B, defined by $y = B\sin(\omega t - \theta)$ in relation to the mobile landmark O.

The analyzed case study has five complex rheological variants, with the following individual characteristics:

a) equivalent horizontal rigidity k = 4,8 MN/m;

b) equivalent viscous amortization c = 1,5 MNs/m;

c) mass m = 3MKg;

d) own period T_0 =5s; own frequency f_0 = 0,2 Hz ; own pulse; ω_0 = 0,4 π rad/s;

e) parameters of cinematic excitation of the first spectral mode (fundamental):

- acceleration a_1 = 0,3g ≅ 3m/s^2
- land displacement amplitude $X_1 = X_0$ = 0,3 m
- excitation pulse ω= π rad/s; excitation frequency f=0,5 Hz ; excitation period T=2,0 s

The analysis of the response parameters to the excitation of the first given seismic spectral mode can be synthesized by the following characteristic physical measures, namely:

- amplitude A of moving on direction O_1X of the construction as non-deformable rigid;
- dynamic transmissibility T, în %;
- dynamic isolation I=1-T, în %;
- maximum viscous deformation V, in m;
- maximum dissipation force, in the viscous system, F_D , în KN;
- maximum transmitted force, to the building, Q_0 , în KN;
- energy dissipated per cycle W_d, in KJ/cycle;

3. CASE STUDY

Based on analytical studies and the establishment of parametric calculation relationships, in the hypothesis of the linear behaviour of the rheological systems that model isolation systems of the base in table 1, the following results can be highlighted:

a) for the rheological models consisting of two simple elements E and V, Voigt-Kelvin (E/V) in parallel or Maxwell (EV) in series it is found that the dynamic isolation is favorable in the Maxwell case compared to the Voigt-Kelvin case.

b) for the rheological models made up of three simple elements E and V, to which multipliers N or M can be applied as real and positive numbers, the following are noted:

- Zener (E-V)/E model the lowest degree of isolation 69% compared to the other two Hooke-Voigt Kelvin E-(E/V) and Newton-Voigt Kelvin V-(E/V), in exchange the energy disipated on cycle is 2322 KJ/cycle is the highest.
- the composite models E-(E/V) și V-(E/V) are more efficient for N - 1 and și respectively M = 1 ensuring a comparatively high degree of dynamic isolation of 90 %, but with dissipation energies, relatively low, of approximately 340 KJ/cycle.

4. CONCLUSION

Based on the analytical researches of rheological and dynamic modelling, as well as the experimental results in the specialized laboratories accredited and / or notified in the EU, taking into account the parameters of dynamic isolation, transmitted forces, dissipation forces and dissipated energy per cycle, the following conclusions can be drawn:

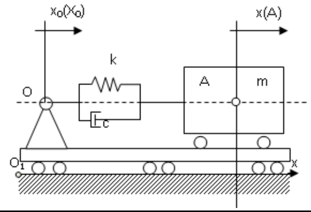
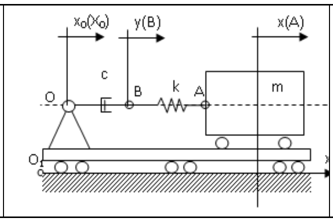
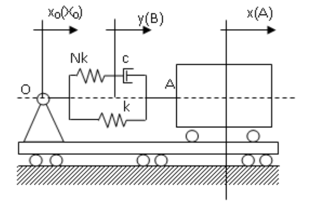
a) the degree of dynamic isolation to values of over 85% can be substantially achieved by the final connection in series of a system of fluid dissipators with c equivalent constant. This case can be achieved based on schematic models as follows: V-E and V-(E/V) with M = 1

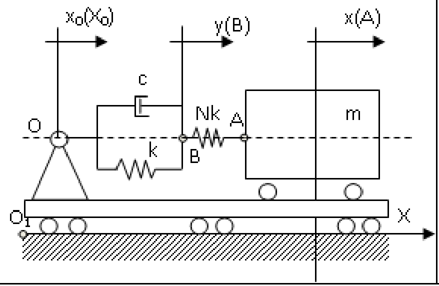
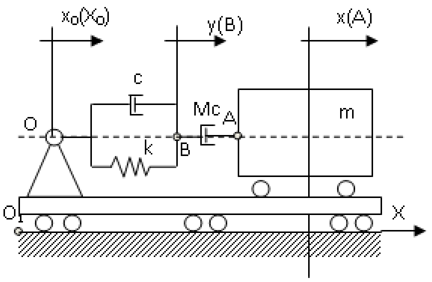
b) the energy dissipated per cycle can be realized with rheological systems as E/V, (E-V)/E and V-(E/V) with $M = 0$, with adverse effects by transmitting relatively high maximum forces on the building.

c) the effect of multipliers N = M = 10 is highlighted in the last two columns of table 1.

Compared to the above, the present study for five dynamic isolation systems at the base, distinct as technical solution, may be the precursor stage of a linear dynamic analysis in choosing and defining the leaning and viscoelastic connection scheme to given seismic actions. The parameter valuescorrespond to some anti-seismic devices made in ITALY, GERMANY, ROMANIA.

Table 1

			
Parameters of dynamic system: $k=48\cdot10^5$N/m; $c=15\cdot10^5$Ns/m; $m=3\cdot10^6$kg; Parameters of own vibrations: $T_0=5$s; $f_0=0{,}2$Hz; $\omega_0=0.4\pi$ rad/s; Parameters of fundamental component of seismic excitation: $T_e=2.0$s; $f_e=0.5$Hz; $\omega_e=\pi$ rad/s; $a_1=0.3g$; $X_1=X_0=0.3$m			
	Voigt – Kelvin (E/V)	Maxwell CKM (V-E)	Zener (E=V)/E
Maximum displacement of mass A, m	0.079	0.036	0.093$^{**)}$
Transmissibility T, %	26	12,2	31
Degree of dynamic isolation I, %	74	87,8	69
Maximum viscous deformation V, m	0.32	0.23	0.39
Maximum viscous force F_D, kN	1536	1104	1885
Maximum force transmitted Q_0, kN	2165	1104	4200
Dissipated energy W_d, kJ/cycle	1544	797	2322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	Hooke – Voigt – Kelvin E-(E/V)		Newton – Voigt – Kelvin V-(E/V)	
Maximum displacement of mass A, m	N=10	N=1	M=10	M=1
	0.072$^{*)}$	0.033	0.069	0.031
Transmissibility T, %	24	11	23	10
Degree of dynamic isolation I, %	76	89	77	90
Maximum viscous deformation V, m	0.031	0.148	$V_1^c=0.3$ $V_2^{Mc}=0.15$	$V_1^c=0.3$ $V_1^{Mc}=0.06$
Maximum force transmitted F_D, kN	146	713	$F_{D1}^c=1140$ $F_{D2}^{Mc}=279$	$F_{D1}^c=672$ $F_{D2}^{Mc}=288$
Maximum force transmitted Q_0, kN	2162	1008	7358	892
Dissipated energy W_d, kJ/cycle	15.27	332	1759	340

*) B=0.027m; **) N=1

Note: Fluidic device parameters are: $c_0=375$ kNs/m; F=350 kN; $v_{max}=0.95$m/s

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Varietatea modelelor reologice utilizate la izolarea bazei pentru construcții solicitate la seism

Rezumat : Se prezintă rezultatele cercetărilor efectuate pentru optimizarea sistemelor de izolare a bazei pentru clădiri de locuit, poduri şi viaducte.

Astfel, au fost analizate tipurile de dispozitive antiseismice din elastomer şi dispozitive disipatoare fluidice care printr-un sistem de conexiune adecvat să poată asigura gradul de izolare de peste 95%.

În acest scop au fost evaluate posibilitățile de realizare a sistemelor vâscoelastice de izolare pentru regiunile de cutremure din România. În cadrul articolului se prezintă variantele posibile cu rezultatele calculului de evaluare a parametrilor de izolare dinamică.

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