DYNAMIC EQUATIONS OF BIDIRECTIONAL MOTION OF THE UPLIFT-RESTRAINED OPRCB ISOLATOR

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Rolling-based seismic isolation has been acknowledged by several researchers and practicing engineers because of their ease of manufacturing and low-cost construction. The equations of motion for this type of isolators have been derived for 2D state (one horizontal direction of motion considered for rollers) for rollers with either circular or non-circular section on flat beds. Also rollers on non-flat beds such as pair of rollers on concave beds (OPRCB) (Hosseini and Soroor, 2011) or V-shape beds (Wang et al., 2014) all in the state of one directional motion of rollers have been studied. Hosseini and Soroor (2013) showed that rolling-based isolators are weak against uplift, and expressed that in case of relatively tall buildings, particularly when subjected to near-fault earthquakes with high vertical ground acceleration, the rolling isolators lose their proper function due to uplift forces which result in separation of columns bases from rollers. To prevent this phenomenon, it is necessary to add some specific parts to the isolators between the upper and lower plates to keep them and rollers all in touch together all the time during earthquake. Mahmoudkhani (2013) proposed a kind of restrainers for OPRCB isolators by using U-shaped elements, and developed the equations of motion of OPRCB isolators in the state of bidirectional motion of rollers, considering the effect of forces acting between the U-shape elements and lower, middle, and upper plates of OPRCB isolators during uplift. In this study, the derivation of formulations and the response of Uplift-Restrained OPRCB (UR-OPRCB) isolators are presented.

For one-directional oscillation of OPRCB isolators the equation of motion has been derived by Hosseini and Soroor (2011). On that basis the main components of horizontal motion of the UR-OPRCB as well as its vertical motion can be stated as Equations (1) to (3):

$$\mathrm{u_{bx}} = (R-r)(\theta_x + \sin\theta_x) \tag{1}$$

$$\mathrm{u_{by}} = (R-r)(\theta_y + \sin\theta_y) \tag{2}$$

$$\mathrm{v_b} = (R-r)(2 - \cos\theta_x - \cos\theta_y) \tag{3}$$

Using these values for calculating the kinetic and potential energies (T and V) as well as the work of non-conservative forces (W) and considering the two horizontal components of motion of each isolator's plates as the generalized coordinates (q_i) the set of Lagrange equations of motion can be written as Equation (4):

$$\frac{\mathrm{d}}{\mathrm{dt}}\left(\frac{\partial T}{\partial \dot{q}_i}\right)-\frac{\partial T}{\partial q}+\frac{\partial V}{\partial q_i}=Q_i \quad (4)$$

Based on the developed Lagrange equations of motion a computer program was developed for seismic response calculation of UR-OPRCB isolator subjected to 3-component earthquake excitations, by using Runge-Kutta-Nyström method (Collatz, 1966). For time history analyses a set of earthquake records were selected, and the maximum response values were obtained numerically, and the results are given in Table 1.

Table 1. Maximum Acceleration Response (MAR) and Maximum Displacement Response (MDR) values of the considered UR-OPRCB to selected earthquakes

Record	MAR (m/s^2)		MDR (cm)		MAR/PGA	
	In x direction	In y direction	In x direction	In y direction	In x direction	In y direction
NGA0183	3.28	2.37	13.56	6.05	0.56	0.54
NGA0184	2.76	2.37	9.75	12.15	0.59	0.69
NGA0230	2.27	1.99	4.85	4.02	0.53	0.48
NGA0540	3.02	2.43	2.59	4.57	0.50	0.51
NGA0741	3.03	3.03	2.74	5.83	0.58	0.64
NGA0752	3.18	2.52	6.32	3.67	0.61	0.58
NGA0766	1.91	2.25	5.44	12.98	0.53	0.72
NGA0802	3.59	1.94	12.43	4.80	0.72	0.62
NGA1505	Sliding		Sliding		Sliding	

It can be seen in Table 1 that maximum acceleration values have been decreased between 29 to 52 percent due to isolation. Also it can be seen that using the proposed isolators has resulted in relatively small MDR values. In case of NGA1505 record, shown in the last row in Table 1, sliding happened in isolators between rollers and their concave bed base on the relationship proposed by Hosseini and Soroor (2011). However, this phenomenon can be prevented by using larger size for the isolators.

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