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A STUDY ON SEISMIC PERFORMANCE OF MULTI-STORY BUILDINGS EQUIPPED WITH UPLIFT-RESTRAINED OPRCB ISOLATORS

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Seismic response of multi story buildings equipped with rolling isolators has been studied by a few some researchers in recent decades (Jangid, 2000; Hosseini and Soroor, 2013). However in none of those studies, the effect of uplift forces on performance of isolators has been considered. Hosseini and Soroor (2013) by using a kind of rolling isolators, called Orthogonal Pairs of Rollers on Concave Beds (OPRCB), for multi story buildings in one-directional motion of isolators showed that the rolling isolators in general are weak against uplift. Mahmoudkhani (2013) proposed a kind of uplift restrainers for OPRCB isolators by using U-shaped elements, and developed the equations of motion in the state of bidirectional motion, considering the effect of forces acting between the U-shape elements and lower, middle, and upper plates during uplift. In this study, the use of Uplift-Restrained OPRCB (UR-OPRCB) isolators for seismic response reduction of multi story buildings is presented, in which three regular square plan buildings with 3, 6 and 9 stories, all having nine columns in their plan were considered. In this way the tendency of building to rocking motion and the resulting compressional and tensile axial forces in the building column, leading to additioinal comprresive force between roller and their beds or uplift of isolator plates can bee taken into account.

To develop equations of motions of multi-story building equipped with UR-OPRCB isolators which have possibility of independent motion in two main horizontal directions, set of Lagrange Equations of motion were used, in which kinetic and potential energy terms are as follow:

$$T = 2m_b\left(R-r\right)^2\left(\dot{\theta}_x^2\cos^4\frac{\theta_x}{2}+\dot{\theta}_y^2\cos^4\frac{\theta_y}{2}\right)+\frac{1}{2}\sum_{i=1}^{n}\left[m_i\left(\dot{u}_{ix}^2+\dot{u}_{iy}^2\right)\right] + \frac{1}{2}m_t\left(R-r\right)^2\left(\dot{\theta}_x^2\sin^2\theta_x+\dot{\theta}_y^2\sin^2\theta_y\right) \quad (1)$$

$$V = \frac{1}{2}k_{bx}\left(R-r\right)^2\left(\theta_x+\sin\theta_x\right)^2+\frac{1}{2}k_{by}\left(R-r\right)^2\left(\theta_y+\sin\theta_y\right)^2+m_t g\left(R-r\right)\left(2-\cos\theta_x-\cos\theta_y\right) + \frac{1}{2}\sum_{i=2}^{n}k_{ix}\left(u_{ix}-u_{(i-1)x}\right)^2+\frac{1}{2}\sum_{i=2}^{n}k_{iy}\left(u_{iy}-u_{(i-1)y}\right)^2+\frac{1}{2}k_{1x}\left(u_{1x}-\left(R-r\right)\left(\theta_x+\sin\theta_x\right)\right)^2 + \frac{1}{2}k_{1y}\left(u_{1y}-\left(R-r\right)\left(\theta_y+\sin\theta_y\right)\right)^2 \quad (2)$$

In Equations (1-2), R and r are respectively the radius of concave beds and rollers, m_b, k_{bx} and k_{by} are respectively mass and stiffness coefficients of the base in x and y directions, m_t is the total mass of the building, m_i is the mass of the *i-th* story, and k_{ix} and k_{iy} are stiffness coefficients, θ_x and θ_y are rotations of rollers, and u_{ix} and u_{iy} are displacements of the *i-th* story in x and y directions. Using the system of the partial differential equations of motion of the buildings subjected to a set of 3-component records, were calculated using Runge-Kutta-Nyström method (Collatz, 1966). Table 1 shows the peak values of drift and acceleration responses in the 9-story building subjected to the employed earthquakes as a sample.

Table 1. Peak values of drift and acceleration responses in the 9-story building

Record	Maximum Drift		Maximum Acceleration (m/s2)		Ratio of drift values (Isolated to Fixed Base)	Ratio of acceleration values (Isolated to Fixed Base)
	Fixed Base	Isolated	Fixed Base	Isolated		
NGA0183	0.00732	0.00621	15.23	6.85	0.85	0.45
NGA0184	0.00688	0.00806	13.68	6.70	1.17	0.49
NGA0230	0.00741	0.00687	14.58	5.69	0.93	0.39
NGA0540	0.01102	0.00916	16.60	6.14	0.83	0.37
NGA0741	0.00666	0.00632	13.94	5.30	0.95	0.38
NGA0752	0.00917	0.00731	11.85	5.57	0.80	0.47
NGA0766	0.00663	0.00516	10.83	4.55	0.78	0.42
NGA0802	0.00723	0.00678	13.93	7.52	0.94	0.54
NGA1505	0.00686	0.00535	10.27	5.65	0.78	0.55

It can be seen in Table 1 that using the OPRCB isolators results in respectively 11% and 55% reduction in drift and acceleration responses, in average, in case of 9-story building. It is worth mentioning that without uplift restrainers, in several cases, the OPRCB isolator could not act properly due to uplift, while with using the uplift restrainers the isolator has performed quite well in the whole duration of the seismic excitation. Based on the numerical results of this study on regular buildings with aspect ratios of around 1.0 to 3.0, equipped with UR-OPRCB isolators, it can be concluded that using uplift-restrained OPRCB isolators can reduce the maximum story drift values around 20%, and the maximum absolute acceleration values around 60% in average

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