A TYPE OF UPLIFT RESTRAINER FOR THE OPRCB ISOLATORS

Mahmood HOSSEINI
Associate Professor, Structural Engineering Research Center, IIEES, Tehran, Iran
hosseini@iiees.ac.ir

Sadegh MAHMOUDKHANI
Adjunct Lecturer, Department of Earthquake Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
s.mahmoudkhani@srbiau.ac.ir

Keywords: U-Shape Uplift Restrainers, Finite Element Analyses, Nonlinear Regression Analysis, OPRCB Isolator, Uplift Forces

It is well-known that most of seismic base isolation devices are weak against uplift, and this is more crucial in case of roller-based devices. Retraining seismic base isolators against uplift has been a concern for researchers since late 80s, and some preliminary studies have been conducted in that time. Studies in this regard have been continued in 90s and also during the last decade. With regard to uplift restraint, Nagarajaiah et al. (1992) conducted an experimental study to evaluate the feasibility of using a sliding isolation system with uplift restraint devices. Roussis and Constantinou (2006) proposed an uplift-restraining friction pendulum seismic isolation system, called XY-FP isolator. Orthogonal Pairs of Rollers on Concave Beds (OPRCB) isolator is a recently introduced seismic isolating system which in their original form is weak against uplift (Hosseini and Soroor, 2013). They have expressed that uplift is an important problem in the case of near-fault earthquakes in which separation of rollers from their beds happens.

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. In order to improve the uplift behavior of the OPRCB isolators, in this study, a set of four U-shaped elements with some specific features has been employed between the lower and middle plates, and also another set of those elements between the middle and upper plates (see Figure (1)).

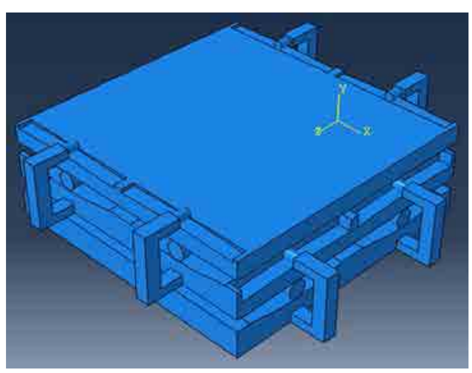

Figure 1. The use of U-shaped elements for restraining the OPRCB isolators against uplift

As it is seen in Figure (1), the lower part of each U-shape element is fixed to the edge of corresponding lower plate by a rigid connection, and its upper part is in contact with the top surface of the corresponding upper plate by a roller, which can move on the convex surface provided at the top surface of the upper plate near its edge. To obtain the geometric form of the convex surface it is necessary to calculate its vertical ordinate versus the horizontal displacement of the rollers in each direction, as shown in Figure (2).

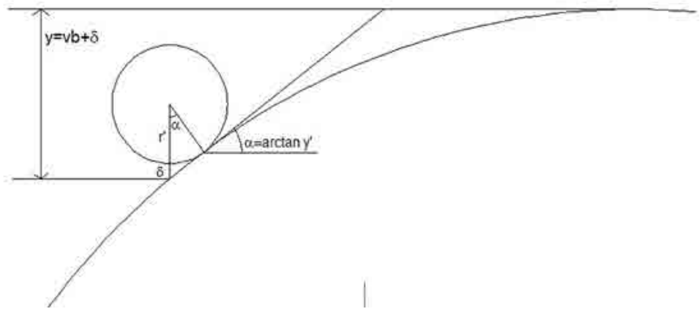

Figure 2. The convex surface provided at the top of upper plates of the OPRCB isolators

Referring to Figure (2), the algebraic equation of the convex surface can be obtained as follow:

$$y = v_b + r'\left(\sqrt{1 + y'^2} - 1\right) \tag{1}$$

Regarding that solving the differential Equation (1) is very difficult by analytical method, it was tried to substitute the desired function y by an approximate function numerically as follow:

$$C_{upper} = \left(R^2 - u_b^2\right)^{0.5} - R + v_b - \delta \tag{2}$$

where u_b and v_b are, respectively, horizontal and vertical displacement of the top plate of each set of rollers of the OPRCB isolator, given by Hosseini and Soroor (2011). In above equations, R and r are respectively the radius of the concave bed and rollers of the OPRCB device, and δ is given by:

$$\delta = bu^2 \tag{3}$$

Parameter b in equation (3) was obtained numerically by second order regression analysis with respect to R, r and θ values, using a reasonable range for each one.

$$b = (-3.8200E-02) + (1.4681E-03)R - (1.9085E-04)(R-r) - (1.4180E-05)R^2 \tag{4}$$

To make sure that b value has enough precision, a finite element analysis were done, which indicates that the upper roller keeps in touch with the upper curved surface all the time during the lateral movement of the rollers. Based on the numerical results of this study, obtained from FEA of the uplift restrainers' parts (verified base on modeling Bernoulli and Timoshenko beams by SOLID elements), it can be concluded that using the proposed uplift restrainers can effectively prevent the OPRCB isolators from uplift. The restrainers studied in this research can tolerate up to around 8.4 ton upward forces; however, by using stronger parts it is possible to easily bear higher values. It is worth mentioning that manufacturing the proposed U-shaped restrainers and creating the required curveture on the top plate does not need high technology.

REFERENCES

Hosseini M and Soroor A (2011) Using Orthogonal Pairs of Rollers on Concave Beds (OPRCB) as a Base Isolation System—Part I: Analytical, Experimental and Numerical Studies of OPRCB Isolators, *The Structural Design of Tall and Special Buildings*, 20(8): 928-950

Hosseini M and Soroor A (2013) Using Orthogonal Pairs of Rollers on Concave Beds (OPRCB) as a Base Isolation System-Part II: Application to Multi-Story and Tall Buildings, *The Structural Design of Tall and Special Buildings*, 22(2): 192-216

Nagarajaia S, Reinhorn A and Constantinou M (1992) Experimental Study of Sliding Isolated Structures with Uplift Restraint, *Journal of Structural Engineering*, 118(6): 1666-1682

Roussis PC and Constantinou MC (2006) Uplift-Restraining Friction Pendulum Seismic Isolation System, *Earthquake Engineering & Structural Dynamics*, 35(5): 577-593