AN INVESTIGATION ON THE UPLIFT FORCES IN BUILDINGS EQUIPPED WITH OPRCB ISOLATORS

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

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

Mansour ZIYAEIFAR
Associate Professor, Structural Engineering Research Center, IIEES, Tehran, Iran
mansour@iiees.ac.ir

Keywords: Uplift Forces, Empirical Formula, Time History Analysis, Nonlinear Regression, Near Fault Earthquakes

Orthogonal Pairs of Rollers on Concave Beds (OPRCB) isolators have been introduced as new low-cost rolling isolation systems that do not need high-tech for manufacturing (Hosseini and Kangarloo, 2007). Hosseini and Soroor (2011, 2013) performed experimental and numerical studies to investigate the seismic response of 2D structures equipped with OPRCB isolators. Hosseini and Soroor (2013) expressed that uplift is an important problem in the case of near-fault earthquakes in which separation of rollers from their beds happens in excitations with vertical acceleration higher than 1.0g. With regard to the effect of building aspect ratio on behavior of isolators, He et al. (2013) conducted study on dynamic response of large and small aspect ratio isolated buildings. Their experimental results reveal that the aspect ratio is an important factor on the axial load action on isolators and the tension stress of the lead-rubber bearings. They expressed that the superstructure flexibility of the large aspect ratio building-isolation system and the effects of the axial force variation of the lead-rubber bearings should be carefully considered for design.

To evaluate the uplift forces in the OPRCB bearings, in this study a set of regular steel multi-story buildings, installed on OPRCB isolators, were considered subjected to near-fault earthquakes. The axial forces in bearings of the buildings were obtained from 342 Time History Analysis (THA) cases. The ratio of tensile force in columns is quite dependent on the location of column in the building. Because of the difference between the axial gravity forces in each bearing, the following coefficient has been proposed for tensile forces:

$$\text{Tension Index}=\frac{\text{Gravity Reaction Force}-\text{Minimum Reaction Force}}{\text{Gravity Reaction Force}} \quad (1)$$

The Tension Index of larger than one means the tendency of occurrence of uplift. The Tension Index, obtained from Equation (1), based on the THA results, ranged from 0.3676 to 2.3564. Regarding that the THA is a very time-consuming process, in this study empirical formula has been proposed in order to estimate the Tension Index for studying the uplift restraining. Empirical formula for predicting the Tension Indexes has been developed by using nonlinear regression analysis, based on six main parameters, including PGA in three perpendicular directions, the volume of structure, and r in two directions. Combining these six main parameters in the forms of squared value, products, and some other mathematical combinations have led to 22 parameters to be used in the regression analysis. By using nonlinear regression analysis, the following equation has been derived for the Tension Index.

$$Tension\ Index = -2.79500 + \sum_{i=1}^{22} b_i Z_i \quad (2)$$

In Figure (1) the predicted Tension Indexes, are compared with their observed values. For evaluation of accuracy and performance of the predictions a few statistical indexes, including Standard Deviation *(SD)*, Relative Standard Deviation *(R-SD)*, Mean Absolute Error *(MAE)*, Root Mean Square Error *(RMSE)*, Relative Root Mean Square Error *(R-RMSE)* and finally, Index of Agreement *(IOA)* have been calculated as follow (Willmott, 1982). The statistical indicators of the mentioned index are given in Table (1), which again show the good performance for the proposed formula.

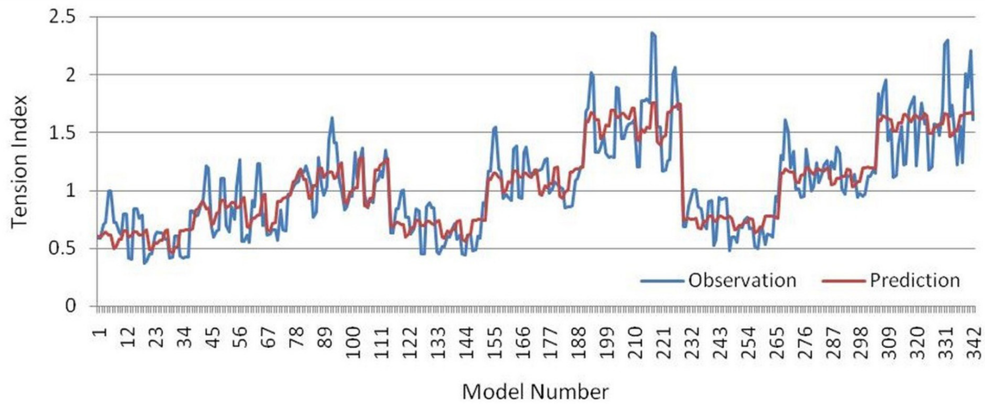

Figure 1. The predicted and observed values of the Tension Index

Table 1. Statistical indicators for the Equation (2)

Statistical Indexes	Observation		Prediction					
	SD	R-SD	SD	R-SD	MAE	RMSE	R-RMSE	IOA
Tension index	0.409	0.392	0.361	0.346	0.152	0.191	0.183	0.923

The satisfactory accuracy of the proposed formula was confirmed by statistical indicators. Validity of the proposed formula was checked by using a new structural model.

REFERENCES

He WF, Liu WG, Yang QR and Qin C (2013) Study on Dynamic Response of Large and Small Aspect Ratio Isolated Buildings, *The Structural Design of Tall and Special Buildings*, DOI: 10.1002/tal.1146

Hosseini M and Kangarloo K (2007) Introducing Orthogonal Roller Pairs as an Effective Isolating System for Low Rise Buildings, *Proceedings of the 6th International Conference on Earthquake Resistant Engineering Structures (ERES 2007)*, Bologna, Italy

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

Willmott CJ (1982) Some Comments on the Evaluation of Model Performance, Bulletin of the American Meteorological Society, 63(11): 1309-1313