APPLICATION OF STEEL BRACED STRUCTURES WITH CONTROLLED ROCKING SYSTEM IN SEISMIC RETROFITTING OF BUILDINGS, CASE STUDY OF A UNIVERSITY BUILDING

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Preventing collapse of structures is one of the targets of conventional seismic design. Although many of buildings after a severe earthquake maintain the life safety performance level, operation of the buildings usually will be impossible due to existence of damages and permanent drifts. Rehabilitation of such buildings has large economic costs as well as long downtime. In the past two decades, researchers have introduced new seismic systems that are known as self-centering systems. These systems in addition to dissipating energy and mitigating structural damage reduce permanent drifts after earthquake. In this case study, the application and efficiency of a self-centering system is evaluated as a retrofit strategy for a building at Shahid Beheshti University in Tehran, Iran. In this research, three methods of retrofitting with external truss structure including controlled rocking on foundation with and without fuses and piles at foundation have been compared. Using nonlinear time history analyses in SAP2000 software, in two earthquake hazard levels, assessment of plastic hinges, horizontal acceleration of stories, and base shear as response parameters corresponding to structural and nonstructural damages have been done. The results show the proper performance of the controlled rocking system to improve response parameters including structural performance levels and its applicability as an alternative retrofitting approach.

In the conventional buildings, failure occurs in the foundation area under earthquake. Usually connection of structural columns to foundation has been provided using a high stiff element, such as a pile. During the earthquake, this stiff connection absorbs a lot of demand and cause failures in the base of structure. Since reparability of the foundation under the structure after the earthquake is difficult, the idea of the lack of connectivity of the columns to the foundation was raised. In new low damage systems, the columns are not connecting to the foundation and allow rocking motion on it. One of the advantages of rocking mechanism of the columns on the foundation is increasing the period of structure, so the structure absorbs less demand during earthquake (Grigorian et al., 2018). Structures with these low damage systems are self-centered and dissipate energy. Self-centering in the system cause negligible permanent deformation. This property is provided in a structure under various factors such as the use of post tensioned tendons, weight of the structure and etc. Also, it causes uniform drift of structure with fewer values. Energy absorption in the structure is provided with yielding steel plates bottom of columns or between the floors and viscous dampers under the columns provided rocking mechanism (Tremblay et al., 2009).

In this case study seismic rehabilitation will be done using a concentrically bracing system (3D truss) outside the building (Sarzamin Consultant Engineers, 2008). Considering the natural and built environment of the building, the proper locations for these lateral load bearing structures was determined. Then, by multiple analyzing and designing, the final position of the new structures was selected. Figure 1 shows the 3D view of the building. The rehabilitation strategies are considered in the following three ways:

1. Putting piles underneath the new external truss structures and the columns connected to it.
2. Allowing the new external truss structure and the columns connected to it to lift from the foundation and placing yielding plates under them.
3. Allowing the new external truss structure and the columns connected to it to lift from the foundation without yielding plates under them.

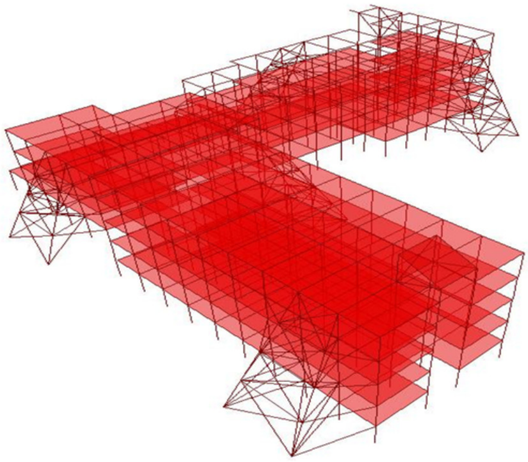

Figure 1. 3D view of the building with external truss structures.

The structure was evaluated by using nonlinear time history analyses at two hazard levels of peak ground acceleration (PGA) of 0.35 g and 0.7 g using seven pairs of earthquake records. Performance levels and floor acceleration spectrum were compared.

Table 1. Records specification.

Earthquake	Station	Year	M	PGA [g]	
				Component 1	Component 2
Duzce, Turkey	Bolu	1999	7.1	0.82	0.73
Imperial Valley	El Centro Array #11	1979	6.5	0.38	0.36
Loma Prieta	Gilroy Array #3	1989	6.9	0.56	0.37
Kobe	Nishi-Akashi	1995	6.9	0.51	0.50
Landers	Yermo Fire Station	1992	7.3	0.36	0.24
Chi Chi	CHY101	1999	7.6	0.44	0.35
Northridge	Beverly Hills - 14145 Mulhol	1994	6.7	0.52	0.42

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