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COMPARISON OF THE EARTHQUAKE RESILIENCE OF ECCENTRICALLY AND CONCENTRICALLY BRACED FRAMES BUILDINGS

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Special Concentrically and Eccentrically Braced Frame (SCBF & EBFs) systems are widely used in steel structures. Choosing between these two lateral loading systems to deal with the seismic loads is one of the major challenges of the engineers before the steel braced structure construction. Various criteria have been proposed to reach a proper decision in the field of choice between these two bracing systems. In most of previous studies, functional targets including structural criteria such as stories drift and story acceleration obtained from a nonlinear analysis were used to compare seismic performance of structures. Most of these criteria were sought to ensure life safety during the earthquake. While the importance of the life safety issue has always to be ensured, other criteria associated with the financial damage caused by the repairs or replacement of the structure, the interruption in trade, the timeout period of services and activities should be considered to lead to a reduction in earthquake hazard and increment in the social resilience (Calvi et al., 2014). On the other hand, it is necessary to present the criteria that are easily understandable to owners and decision-makers in the construction field. Also, assessing the costs of natural disasters and recovery time can be effective in managing crisis management. In recent years, the FEMA P-58 project has been developed to respond to this need to provide a method for calculating direct financial losses and repair time after the earthquake, and in the following developed PACT software for this purpose.

In addition to direct financial losses, there is considerable vulnerability due to the downtime of the structure, which is defined as the period required reaching a performance level after the earthquake (Hutt et al., 2015). In order to consider the direct and indirect aspects of damage caused by natural disasters, resilience concept has been proposed as a new criterion for designing and evaluating the performance of structures. Bruneau et al. (2007) introduced a framework in earthquake engineering where the structure seismic performance is calculated by measuring a decision variable, resilience, which combines the rest of the variables. Based on what is shown in Figure 1, the resilience is calculated as the surface below the diagram of functionality after the earthquake occurs.

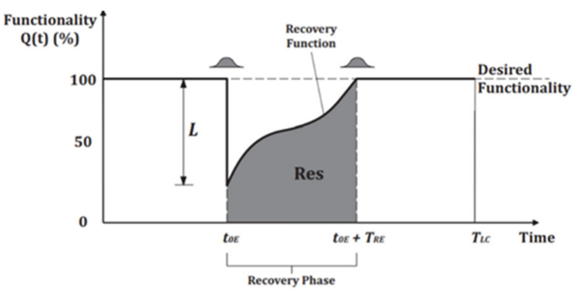

Figure 1. The resilience calculation Bruneau et al (2007).

In the present study, comparing two seismic resistant systems (Special Concentrically and Eccentrically Braced Frame) in the steel structure designed in the region with high seismicity, based on performance criteria such as economic damage, downtime, and resilience in two seismic hazard levels of service and design is considered. In order to quantify seismic resilience in the studied buildings, a suitable criterion for the performance of buildings is defined based on their use and a method for calculating the amount of function loss during earthquake event in two seismic risk levels by considering direct and indirect damages. Also, unlike most previous studies, where simple recovery functions are used, a method is presented to compute a more accurate recovery function based on the reconstruction process after the earthquake, and to calculate the modified disability duration based on REDi.

After the design and analysis of the structures, the economic damages of structural and non- structural components were calculated using FEMA-P58 instruction and the results obtained from the analysis of the structures. In order to calculate the indirect economic losses due to the displacement of the damaged building and stopping economic activities, the instructions of HAZUS have been used. Downtime of buildings to reach three performance levels are also achieved using the REDi method. Finally, the resilience of the studied buildings using the proposed method to calculate the functionality and downtime modified based on REDi is evaluated. In the following, the mentioned steps are elaborated in detail.

The investigated structures in this study represent low- and mid-rise structures designed based on modern codes in the regions with high seismicity. Buildings are located in San Francisco. The use of buildings is assumed to be administrative. The number of stories is considered 4 and 8. The structures are designed based on IBC codes and its reference standards. The structures were evaluated for two seismic hazard levels of 10 percent in 50 years and 50 percent in 50 years. Seven pairs of earthquake records were used. Agreement with design spectrum, the type of soil and fault mechanism are considered in the selection of records. The records pairs are scaled based on FEMA-P58 instruction. Non-linear time history analyses are performed using OpenSEES software. The accuracy of the special concentric brace and the shear linked-beam modeling is verified by the presented experimental data.

The results of show that making decision in relation to the destruction and construction of the new structure or repair of existing structures after the earthquake cannot be based solely on the evaluation of the engineering demand parameters or total damage to the building. Other factors such as the contribution of structural and non-structural components in the total damage and the time required to restore the building to pre-earthquake conditions can be effective in this regard. Thus, resilience, which embraces all items, can be a more appropriate measure of decision-making in this regard. The results of the present study show that the resilience of structures with eccentric bracing has declined by increasing the number of stories, while this trend has been reversed for the structures with concentric bracing. Therefore, application of special concentric braced frame in the medium-rise structures and eccentrically braced frame in the low-rise structures are suggested.

REFERENCES

Almufti, I., and Willford, M. (2013). Resilience-based earthquake design initiative (REDi) for the next generation of buildings.

Bruneau, M. and Reinhorn, A. (2007). Exploring the concept of seismic resilience for acute care facilities. *Earthquake Spectra*, *23*(1), 41–62.

Calvi, G.M., Sullivan, T.J., and Welch, D.P. (2014). A seismic performance classification framework to provide increased seismic resilience, in Perspectives on European Earthquake Engineering and Seismology, ed. A. Ansal, Geotechnical, *Geological and Earthquake Engineering*, 34, Ch. 11.

FEMA (Federal Emergency Management Agency) (2012). *Seismic Performance Assessment of Buildings*. Rep. FEMA P-58, Washington, DC.

FEMA (Federal Emergency Management Agency) (2014). *HAZUS-MH 2.1 Technical Manual: Earthquake Model*. Washington, DC: Federal Emergency Management Agency.

Hutt, C.M., Almufti, I., Willford, M., and Deierlein, G. (2015). Seismic Loss and Downtime Assessment of Existing Tall Steel-Framed Buildings and Strategies for Increased Resilience. *Journal of Structural Engineering*, *142*(8).