A procedure for damage-based seismic design of steel moment frame structures with torsional irregularity

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Seismic design of structures encompasses various methodologies, one of which is force-based design. In this method, an earthquake is modeled as equivalent static horizontal forces that serve as the design basis. Typically, similar members of the structure are designed to have the same deformation capacity. However, in reality, only a limited number of these members enter the nonlinear region during an earthquake and utilize their plastic capacity. In many earthquakes, the lower stories of structures are more susceptible to damage than the other stories. Performance-based seismic design is another approach that introduces a general framework for seismic design of structures by defining performance levels. This includes displacement-based design and damage-control design methods. This research presents a novel approach to seismic design of structures. The primary objective is to utilize displacement-based design to design torsionally irregular structures based on a specific damage level. The proposed method involves subjecting the studied structures to dynamic analysis using 11 ground motions, each scaled 10 to 15 times. For each scale, the Park-Ang damage index is calculated for the story with the maximum maximum drift ratio among the earthquakes. Subsequently, the damage index and the maximum drift ratio of the story are transformed into a point on the drift ratio-damage index diagram for each amount of eccentricity. Next, a linear regression is performed on the obtained point diagram, and the resulting function is determined, with the dependent variable being the drift ratio. After this step, by selecting the base damage index and substituting it into the specified regression function, the design drift value of the structure is calculated. Using the design drift value and the displacement-based design code, the corresponding base shear for the structure is determined, and the structure is designed. To evaluate the performance of the damage-control designed structures, they are subjected to nonlinear dynamic analysis, and the damage index values for the stories are determined. By examining the results, it can be determined whether the damage index of the stories exceeds the predetermined limit (base damage index) or remains within the desired range. This design method is presented for steel structures with special moment frames and plan irregularities with eccentricities of 0, 5, and 10% with 5 and 10 stories in a region with high seismicity and soil type C.By examining the drift ratio-damage index diagram of the studied structures, it was observed that the scatter of the points relative to the regression line is small, and the obtained function is an appropriate one. Nonlinear dynamic analysis of the damage-control designed structures showed that the average damage index of the stories for the 5-story structure without torsional irregularity, the 5-story structure with 5% torsional eccentricity, the 5-story structure with 10% torsional eccentricity, the 10-story structure without torsional irregularity, the 10-story structure with 5% torsional eccentricity, and the 10-story structure with 10% torsional eccentricity are 0.233, 0.226, 0.214, 0.255, 0.234, and 0.212, respectively. These values are sufficiently lower than the base damage index (damage index 0.4), indicating that this method is appropriate and safe. Furthermore, the maximum damage index of the stories for the mentioned structures is 0.389, 0.375, 0.360, 0.392, 0.377, and 0.365, respectively. These values indicate that the maximum damage index of the stories (critical state) in the damage-control designed structures is slightly equal to the predetermined damage (damage index 0.4). The proposed damage-control design method provides a reliable approach for seismic design of torsionally irregular steel structures, ensuring that the damage level of the structures remains within the acceptable range under various earthquake excitations.

Keywords: Seismic design, Damage-based design, Displacement-based design, Torsional irregularity, Steel structures.