Collapse Analysis of Torsional Moment Frame Structures Against Earthquake

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Abstract

In the present study, the effect of torsion on the collapse behavior of steel moment frame structures is investigated. For this purpose, 4, 7 and 10-story steel buildings with two types of soil, C and D, which are irregular in plan, were designed by common softwares and it was observed that the eccentricity values in previous studies were higher than possible in the reality and the maximum eccentricity in single moment frame systems, if the members are optimally designed considering the torsion, is usually less than 10%. Then, the structures designed with logic eccentricity values were nonlinearly modeled and their collapse behavior under 11 consistent earthquake records was evaluated by incremental dynamic analysis (IDA) and spectral acceleration against the maximum floor drift curves were calculated for each earthquakes. Nonlinear modeling of members is done in OpenSees software and for this purpose, beams are modeled with nonlinear hinge elements concentrated on both ends and elastic element between the two hinges and columns with BWH fiber element model. The advantage of this type of modeling is the involvement of the phenomenon of deterioration in beams and the interaction of two-axis bending and axial force in columns in the analysis. Finally, assuming the distribution of the log-norm, the fragility curve of each structure was plotted for different eccentricity values. Using the results of analyzes, the torsional irregularity effects on the safety margin of collapse and the fragility curve of the structures were studied.

It was observed that this phenomenon can reduce the safety in the performance of the collapse of the structures. With increasing torsion in buildings, the collapse fragility curve retreats and, as a result, the acceleration of the collapse as the probability of 50% decreases. In addition, as the torsion of the structure increases, its marginal safety margin decreases. It should be noted that most of the changes occurred at the 15% eccentricity and there are no drastic changes at the lower eccentricities, so that the maximum reduction of the CMR values compared to the non-torsional one, for eccentricities of 5%, 10% and 15%, are 11.1%, 22.8% and 45.6%, respectively, which all occur in the 10-story building on soil C. The slope rate of this declining of safety margin is more remarkable in taller structures and the most reduction values in 4, 7 and 10-story building are 8.7%, 23.7% and 45.6%, respectively. The results obtained in both types of C and D structures are similar and in the maximum eccentricity and the 10-story structure, the most critical behavioral state always occurs. The difference is that as the soil under structure becomes weaker, the sections of members become heavier and the fragility curves are placed in front. It seems that as the stiffness of the structure decreases, the torsional effect increases. In the worst case, the safety margin of 10-story building suffering from 15% eccentricity ratio on the type C soil decreases up to 45.6% compared to the non-torsional state, while the reduction value in the same structure on soil D is 25.1%. Note that the eccentricity of all floors of each structure was assumed to be same. Therefore, the significant effect of torsion on 7 and 10 story structures is somewhat exaggerated because the possibility of simultaneous occurrence of the same eccenticity in all floors is low. It should be noted that in this study, soil-structure interaction have been neglected.

Keywords

Collapse analysis, Torsional structure, Incremental dynamic analysis, Fragility curve, Steel moment frame, Probabilistic.