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EVALUATING COLLAPSE MARGIN RATIO OF STEEL MOMENT FRAMES WITH VERTICAL MASS IRREGULARITY

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Preventing the collapse of structures under severe earthquakes has become one of the main objectives of seismic codes and design standards (e.g., ASCE 7, 2016), and Iranian seismic code (Standard No. 2800, 2014). While seismic codes imply there to be a low chance of collapse, their use for seismic design typically does not lead to a certain collapse risk. In fact, the margin of collapse safety for structures designed based on the recent seismic codes is not clearly determined. FEMA P695 (2009) has proposed methods for structural collapse capacity assessments and determining collapse safety margin. In accordance with FEMA P695 (2009), a quantity is defined as the collapse margin ratio (*CMR*) to determine the seismic safety of structures against collapse. In addition, different research studies have been conducted to reliably compute seismic collapse capacity of structures (e.g., Yakhchalian et al., 2014, 2019).

In the present study, the seismic collapse capacity and CMR for steel special moment-resisting frames (SMRFs) with vertical mass irregularity are investigated. To create the structures with vertical mass irregularity, the mass of the bottom, mid-height or top story of 5- and 10-story structures is multiplied by a factor of 2.0 or 3.0. Therefore, 12 structures with vertical mass irregularity and two regular structures were designed according to Iranian seismic code (Standard No. 2800, 2014). The identifiers (IDs) of the structures are as follows. The first part represents the number of stories, the second part represents regularity (reg) or irregularity (irr) of the structure. The third part for irregular structures represents the location of the heavier story and the mass ratio of 2.0 or 3.0. Incremental dynamic analysis (IDA) approach (Vamvatsikos and Cornell, 2002) was applied to obtain the seismic collapse capacity values of the structures using 67 ground motion records. IDA curves for the 5s-reg and the 5s-irr-B2 structures in terms of 5%-damped spectral acceleration at the fundamental period of the structure, Sa(T1), as ground motion intensity measure, are illustrated in Figure 1.

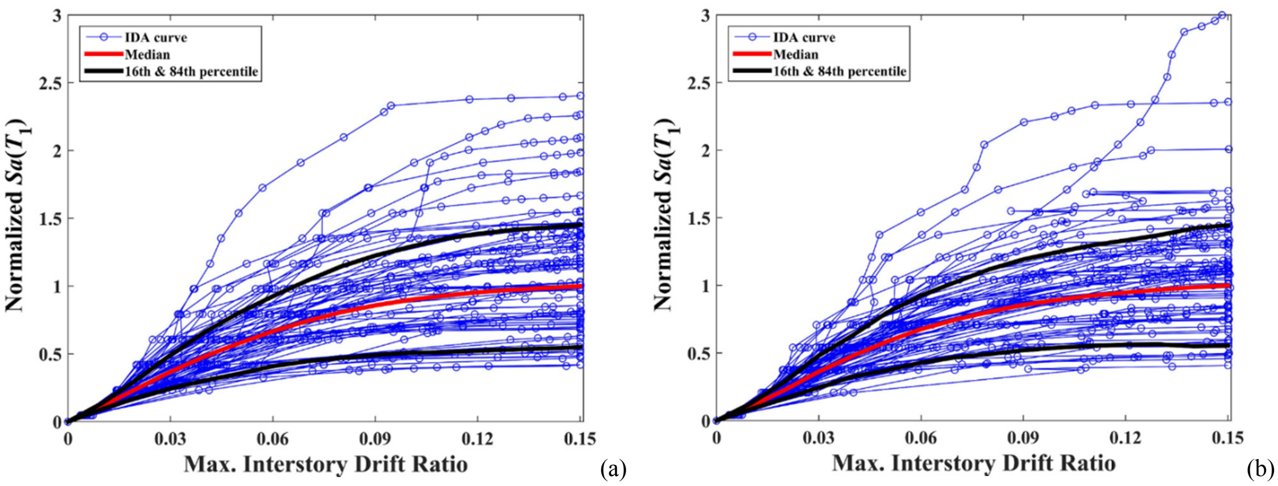

Figure 1. IDA curves for (a) 5s-reg and (b) 5s-irr-B2 structures obtained using $Sa(T_1)$.

After determining the structural collapse capacity values for each structure, its *CMR* is defined as:

$$CMR = \frac{S_{CT}}{S_{MT}} \tag{1}$$

where S_{CT} is the median of structural collapse capacity values in terms of $Sa(T_1)$, and S_{MT} is the 5%-damped spectral acceleration of the maximum considered earthquake (MCE) at the fundamental period of the structure. Table 1 presents the obtained S_{CT}, logarithmic standard deviation of the collapse capacity values (STD) and *CMR* for the structures. It can be seen that increasing the number of stories results in a significant reduction in *CMR*. In other words, the structures designed based on Iranian seismic code (Standard No. 2800, 2014) do not have a uniform safety margin against collapse. Investigating the effects of vertical mass irregularity shows that the highest *CMR* is obtained when the heavier story is located at the mid-height of the structure with the mass ratio of 3.0. However, the lowest *CMR* is obtained when the heavier story is located at the top of the structure with the mass ratio of 3.0. It can be concluded that when the heavier story is located at the bottom or mid-height of the structure, the stiffness and strength of the lower stories increase (because larger beams and columns are demanded in order to carry the heavier mass), where the nonlinear response of the structure is more concentrated. Therefore, the obtained *CMR* values of the structures increase. On the other hand, when the heavier story is located at the top of the structure, the stiffness and strength of the lower stories are less increased, while the mass of the structure is increased similar to the cases of the heavier story located at the bottom or mid-height of the structure.

Table 1. S_{CT}, STD and CMR values obtained for the structures.

Structure	S_{CT}	STD	*CMR*
5s-reg	2.1459	0.4210	3.5610
5s-irr-B2	2.4014	0.3951	3.7318
5s-irr-B3	2.4017	0.3907	3.5970
5s-irr-M2	2.2560	0.4070	3.5828
5s-irr-M3	3.1934	0.3754	4.4959
5s-irr-T2	1.7548	0.4605	3.1116
5s-irr-T3	1.5721	0.4379	2.8484
10s-reg	0.7870	0.4073	1.9864
10s-irr-B2	0.8515	0.3976	2.1086
10s-irr-B3	0.8418	0.4176	2.0455
10s-irr-M2	1.0800	0.4608	2.4993
10s-irr-M3	1.2623	0.4537	2.8117
10s-irr-T2	0.8643	0.4128	2.1741
10s-irr-T3	0.7361	0.4190	1.9240

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