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ADVANCED INTENSITY MEASURES FOR PREDICTING THE SEISMIC COLLAPSE CAPACITY OF SMRFS

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Intensity measure (IM) can quantify the intensity of a ground motion and serves as a link between the outputs of ground motion hazard analysis and the seismic response of structure to facilitate risk-based calculations. The IM-based approach for collapse risk assessment can involve combination of the probability of collapse conditioned on ground motion properties with observing those ground motion properties. Therefore, the IMs describes with desirable features known as efficiency and sufficiency. Efficiency is a measure of the level of variability in the response or capacity of the structure obtained using different ground motions. While the sufficiency describes as ability of an IM to estimate the response or capacity of the structure independently from ground motion properties such as the average shear-wave velocity at the upper 30 m of soil (Vs_{30}), source-to-site distance (R) and earthquake magnitude (M). Thus, the optimal IM uses the small number of ground motions in the seismic analyses to estimate the structural response having a level of confidence, and it can reduce the complexity of record selection (Baker and Cornell, 2008). Recently, advanced scalar-valued and vector-valued IMs have been used to predict the collapse capacity of SMRFs equipped with viscous dampers compared with other well-known IMs (Jamshidiha et al., 2018; Jamshidiha and Yakhchalian, 2019). These IMs include information about the spectral shape and ground motion duration, and have better performance.

Incremental dynamic analysis (IDA) is a technique to assess the seismic collapse capacity of structures utilizing a series of nonlinear dynamic analyses. Seismic collapse of a structure is displayed by the flat part of each IDA curves. Recently, some researchers used IDAs to achieve the seismic collapse capacity of Special Moment-Resisting Frames (SMRFs) using the Modified Ibarra–Krawinkler bilinear-hysteretic model as a nonlinear rotational spring at both ends of each elements representing nonlinear behavior of the structures (Kazemi et al., 2018 and 2019). In this research, the 2-, 4- and 8-Story Reinforced Concrete (RC) SMRFs designed by Haselton and Deierlein (2007) were used (2-, 4- and 8-Story SMRFs design ID are 2064, 1003 and 1011, respectively). To capture seismic capacity of the RC SMRFs, three-dimensional effects and contribution of modeling uncertainty were used. In addition, the 3- and 6-Story steel SMRFs designed by Kitayama and Constantinou (2016), and the 9-Story steel SMRF using their design procedures was considered. The site of interest for both RC and steel SMRFs was considered in California, with soil class D. It is worth to mention that to consider the P-Delta effect, all columns except those in the SMRFs are considered as gravity columns and were modeled as leaning column. IDAs were performed to assess the seismic collapse capacities of SMRFs using OpenSees software. The records were used to perform IDAs were a set of 67 high-amplitude ground motion records, and the five scalar- and their corresponding vector-valued IMs considered in this study were introduced by Jamshidiha et al. (2018).

To compare the efficiency of a scalar IM with that of corresponding vector-valued IM, the values of $\sigma_{\ln IM_{col}}$ (the logarithmic standard deviation of IM_{col} values obtained from IDAs) and $\sigma_{\ln Sa_{col}|IM_2}$ (the conditional standard deviation of $\ln IM_{1col}$ given IM_2) can be compared and the IM with a lower dispersion is more efficient than the other one. Figure 1 shows the values of $\sigma_{\ln IM_{col}}$ and $\sigma_{\ln Sa_{col}|IM_2}$ for 2-, 4- and 8-Story RC SMRFs in sections of a, b and c, respectively. According to results, the proposed advanced Sa_{avg} and $Sa_{avg\ M-D}$ scalar-valued IMs that includes the spectral shape and ground motion duration achieve values lower than 0.3, and are more efficient than the other considered IMs. In addition, their corresponding vector-valued IMs have highest efficiency among all other IMs, with $\sigma_{\ln Sa_{col}|IM_2}$ values lower than 0.3. Moreover, the results of 3-, 6- and 9-Story steel SMRFs show that the proposed advanced $Sa_{avg\ M-D}$ scalar-valued IM and its corresponding vector-valued IM achieve values lower than 0.3, and is the efficient IM. To specify the sufficiency or insufficiency of the IM, the *p-value* was calculated, which the *p-value* greater than 0.05 implies the sufficiency of the IM. The sufficiency of IMs with respect to *M*, *R*, Vs_{30} and Scale Factor (SF) was compared, and the results show that the proposed advanced Sa_{avg} and $Sa_{avg\ M-D}$ scalar- and vector-valued IMs satisfy the sufficiency parameters for the RC and steel SMRFs. Therefore, the proposed Sa_{avg} and $Sa_{avg\ M-D}$ scalar- and vector-valued IMs can be used for predicting the seismic collapse capacity of the RC and steel SMRFs with better efficiency and sufficiency criteria.

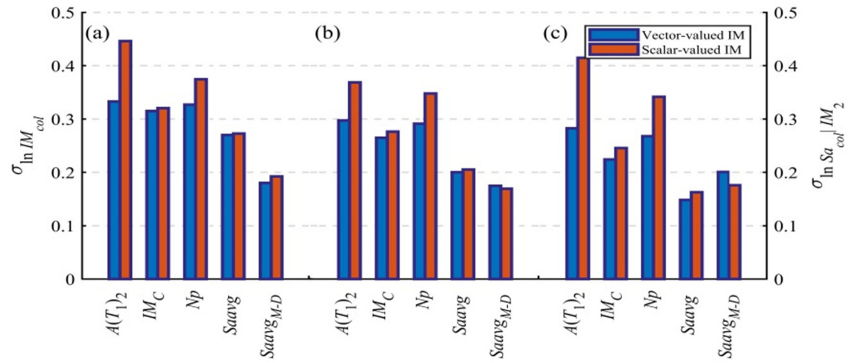

Figure 1. Comparison of the $\sigma_{\ln IM_{col}}$ and $\sigma_{\ln Sa_{col}|IM_2}$ values for the 2-, 4- and 8-Story RC SMRFs.

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