# PROBABILISTIC SDOF MODELS FOR PERFORMANCE ASSESSMENT OF BUILDINGS

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This paper proposes a methodology for generating equivalent single-degree-of-freedom (eqSDOF) models that can mimic the response of multistory buildings from the linear-elastic range through collapse in a probabilistic context. The probabilistic assessment of building response with a comprehensive treatment of epistemic and aleatory uncertainties in the context of performance-based earthquake engineering (PBEE) is computationally intensive. This issue is exacerbated in quantifying the collapse capacity of building structures considering both model uncertainty and record-to-record variability given the high nonlinearity in structural components and scarcity of real high-intensity ground motion records. Accordingly, it is highly desired to devise solutions to alleviate this computational cost (Fragiadakis and Vamvatsikos, 2010; Kosič et al., 2014), particularly in regional risk and resilience analyses. Meanwhile, the use of eqSDOF models as a surrogate for multi-degree-of-freedom (MDOF) systems in seismic response assessment is an accepted and proven approach in structural and earthquake engineering (Fajfar and Dolšek, 2012).

The collapse of SDOF systems was extensively studied using simple bilinear spring models with negative post-elastic stiffness representing P-$\Delta$ effects, such as Adam et al. (2004) among others, to more advanced hysteretic models proposed by Ibarra and Krawinkler (2005). In most studies on the collapse of SDOF systems, record-to-record variability was the only source of uncertainty in the analysis (Ruiz-García and Miranda, 2003; Dolšek and Fajfar, 2004). However, studies on the combined effect of model uncertainty and record-to-record variability on the collapse capacity of building structures indicate that incorporating model uncertainty can significantly alter estimates of the collapse capacity (Ibarra and Krawinkler, 2011). Recently, several simplified procedures are proposed for incorporating model uncertainty in the collapse assessment of MDOF buildings (Fragiadakis and Vamvatsikos, 2010; Kosič et al., 2014) that mainly use pushover-based simplification to predict the collapse capacity.

The proposed methodology is applied to develop probabilistic eqSDOF models with multilinear backbone curves that represent a slew of MDOF models in which prevailing sources of model uncertainty are incorporated. The methodology accounts for two types of uncertainties: first, it propagates in the eqSDOF models the uncertainties inherent in the original MDOF models; second, it accounts for the model uncertainty that arises as a result of approximating an MDOF structure with an SDOF model. To this end, multiple archetypes are designed based on the suggested seismic design codes to account for the uncertainty in design specifications. These archetypes may cover a wide range of practical designs representing buildings with a specific lateral load resisting system. In order to propagate the uncertainty, the Monte Carlo sampling method is employed. For this purpose, multiple random realizations for each building archetype are randomly generated from the underlying random variables that represent gravity loads, material properties, and plastic hinge properties. These randomly generated buildings are then subjected to pushover analysis to produce a host of pushover curve realizations. Thereafter, an idealization method is introduced and employed to transform each pushover curve into one realization of the multilinear backbone curve of the eqSDOF model. Next, the resulting backbone realizations are used to create Bayesian linear regression (Box and Tiao, 1992) equations that predict the key parameters of the backbone curves given the fundamental period of the MDOF structure. The proposed models can be used in a wide range of probabilistic parametric studies. Once the proposed probabilistic eqSDOF model is developed for a lateral load resisting system, no further nonlinear analyses at the level of MDOF structure is needed, and users can solely rely on the eqSDOF model for seismic performance assessment. To showcase the proposed methodology, the eqSDOF model is developed for special steel moment frame (SMF) buildings. The proposed model is validated by comparing the nonlinear dynamic response of MDOF models with their eqSDOF models. The comparison shows that the behavior of the proposed eqSDOF model closely concurs with the nonlinear behavior of the MDOF structures up to collapse. In addition, the IDA curves of an MDOF frame from the literature are compared against those obtained from the proposed model. The comparison proves that the proposed model well captures the behavior of the MDOF frame even though the studied structure is not from the test structures used to develop the eqSDOF model.

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