Seismic fragility analysis of building structures using equivalent SDOF systems

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Motivation

- Significant earthquake damage on buildings (e.g. cause 9,000 casualties in 2015 Nepal earthquake).
- Innovative protective devices like viscous dampers can improve the seismic performance of civil structures.
- Probabilistic methods such as fragility functions can be used to account for the earthquake uncertainties to quantify both structural and non-structural damages.

Analysis Framework

\[ f_S(\omega, \ddot{u}) = \varepsilon a_{\text{yield}}(\ddot{u}) + (1 - \varepsilon)K_p\ddot{u}Z(t) + \frac{1}{\beta}\left[\gamma(\ddot{u})Z(t)\ddot{Z}(t)\right]^{p-1} + \beta\ddot{u}(t)Z(t)^p - \ddot{u}(t) \]

\[ f_d(\omega) = c_\text{d}a_{\text{yield}}(\ddot{u})^p \text{sgn}(\ddot{u}) \]

Results & Discussion

Deterministic time history analysis

- Consistent results by Newmark-β method with bilinear model and ODE method with Bouc-Wen model.
- Considerable permanent deformation under pulse motions.

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\text{PSDM (Probabilistic seismic demand model)}
\]

- Viscous dampers alters the PSDMs substantially.
- Residual drift ratio yields large standard deviation when conditioned on PGA.

Conclusions

- Damper can significantly reduce the structural and permanent damage of the building.
- Damper is effective in reducing non-structural damage under small ground motions, but it has adverse effect when subject to large ground motions.
- Optimal design of viscous dampers is required to reduce structural and non-structural damages simultaneously, which would improve the seismic resilience of the built environment.

Future work

- Examine the seismic response with superelastic shape memory alloy (SMA) dampers.
- Validate the equivalent SDOF system by MDOF structures.
- Identify the optimal design parameters of dampers.
- Investigate effective means to reduce non-structural damage induced by floor acceleration.

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References