Seismic fragility analysis of building structures using equivalent SDOF systems

Gen Hayakawa[1,2], Yazhou (Tim) Xie[3], Reginald DesRoches[3]

[1]Department of Civil Engineering, the University of Tokyo, Japan

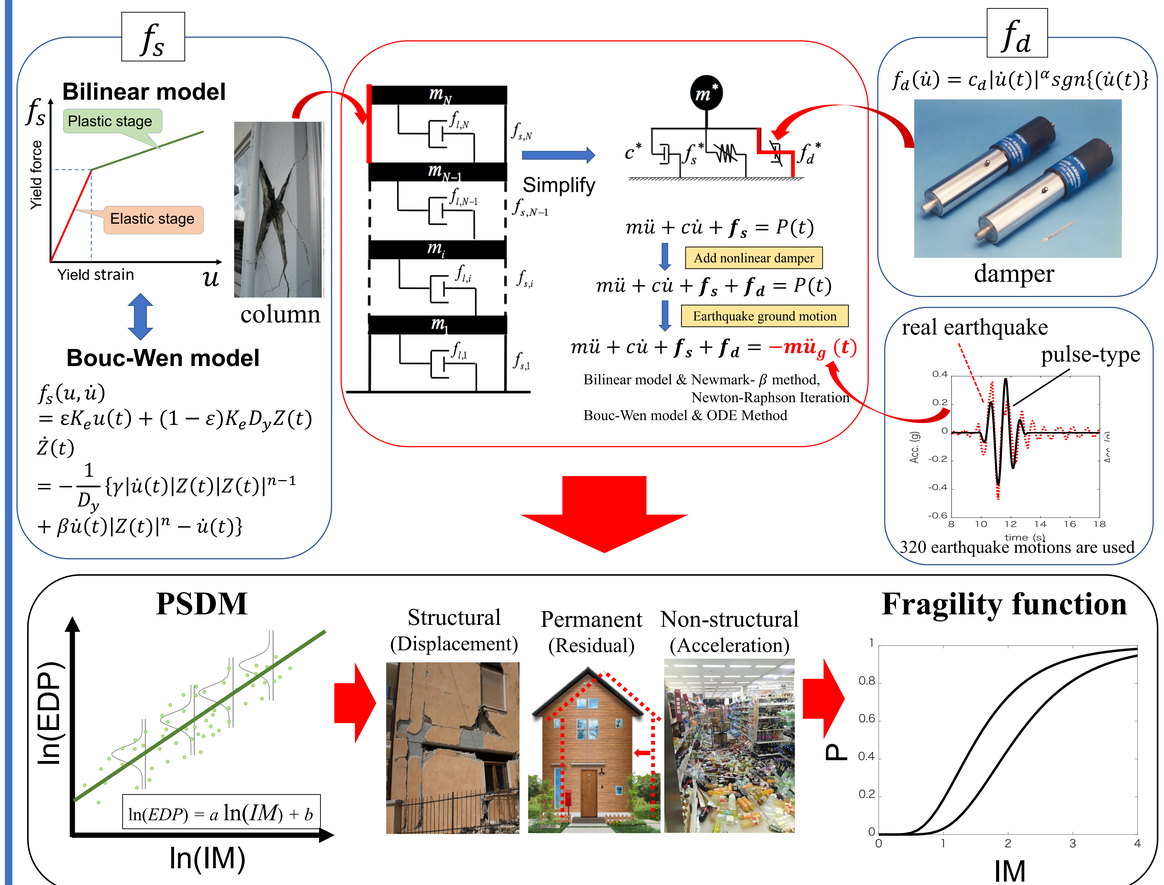
[2]Nakatani RIES: Research and International Experiences for Student, Nakatani Foundation, Japan

[3]Department of Civil and Environmental Engineering, Rice University, U.S.A.

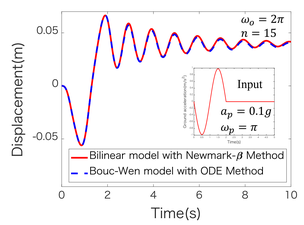
Motivation

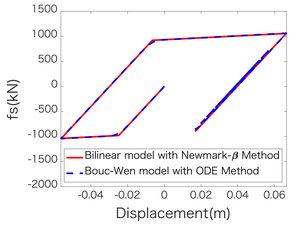
- Significant **earthquake damage** on buildings (e.g. cause 9,000 casualties in 2015 Nepal earthquake).
- Innovative protective devices like **viscous dampers** can improve the seismic performance of civil structures.
- Probabilistic methods such as **fragility functions** can be used to account for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

Analysis Framework



Results & Discussion

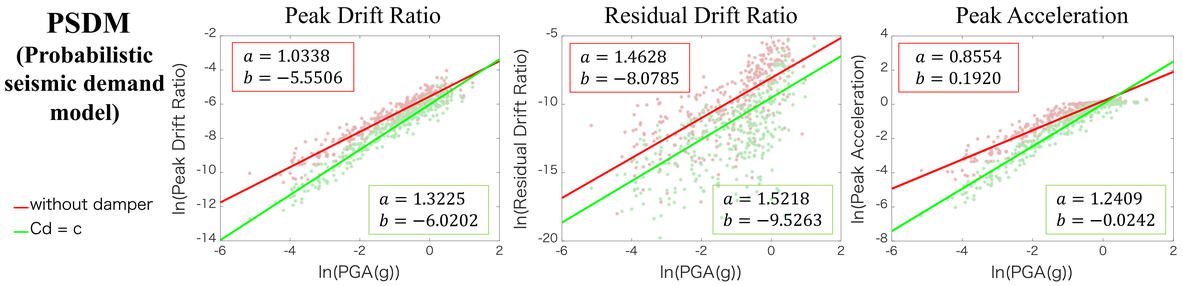




Deterministic time history analysis

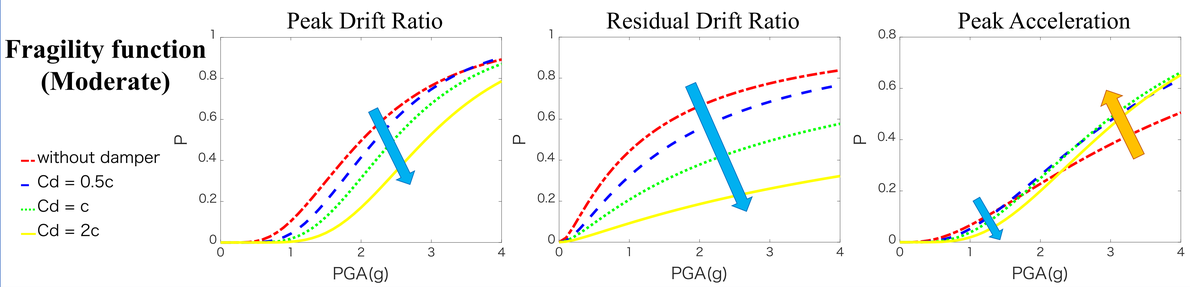
- **Consistent results** by Newmark-β method with bilinear model and ODE method with Bouc-Wen model.
- Considerable **permanent deformation** under pulse motions.

PSDM (Probabilistic seismic demand model)



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

Fragility function (Moderate)



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.

References

1. Yazhou, X., Jian, Z., & Wang, X. (2018). Effectiveness evaluation and optimal design of nonlinear viscous dampers for inelastic structures under pulse-type ground motions. *Earthquake Engineering and Structural Dynamics*.
2. Chopra, A. K., & Chopra, A. K. (2007). *Dynamics of structures: theory and applications to earthquake engineering* (Vol. 3). Upper Saddle River, NJ: Pearson/Prentice Hall.
3. Simo, J. C., & Hughes, T. J. R. (1998). Computational Inelasticity (Interdisciplinary Applied Mathematics)(Volume 7).

Acknowledgement

This research project was conducted as a part of the Nakatani Foundation's 2018 Nakatani RIES Fellowship for Japanese Students. For more information, visit http://nakatani-ries.rice.edu/. Special thanks to the Natural Hazards Mitigation Research Group at Rice University for their research mentorship and to Prof. Junichiro Kono, Sarah Phillips, Aki Shimada, and Kennji Ogawa for their support.