Energy Based Comparisons of Linear and Non-Linear Modeling of Seismic Isolators

Alex Wightman, Civil Engineering

Mentor: Dr. Giuseppe Lomiento

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Introduction

The use of base isolation systems to decouple a building from the ground has risen in recent years. By disconnecting a building from the surrounding earth, the building does not experience intense vibration during a strong seismic event (Fig. 1), avoiding potential damage from the shaking induced by an earthquake.

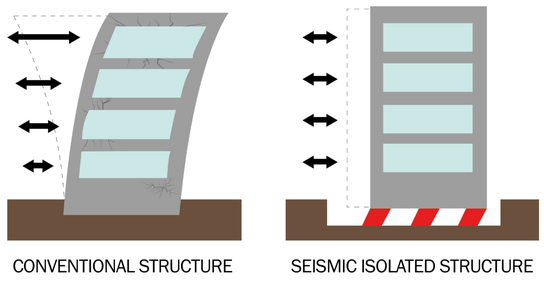


Figure 1. Seismic Isolation

Traditional methods for the design of seismic isolation systems have been based on linear, force- and displacement-based approaches. However, in reality, isolators undergo nonlinear behavior during strong ground motion events. This causes predictions made by force- and displacement-based methods to be inaccurate when determining the response of base isolators during an earthquake. Strain energy is suggested as a possible alternative control parameter that can be used to reduce this inaccuracy.

Objective

Compare the accuracy of linear modeling of base isolated structures with the true, nonlinear response of the structure. Additionally, compare the amount of energy absorbed by an isolation system between friction pendulum and lead rubber bearing isolators.

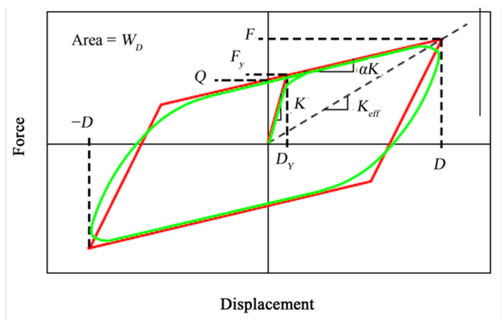


Figure 2. Hysteresis Loop

Numerical Dynamic Non-Linear Analysis

- Modeled as a Multiple Degree of Freedom (MDOF) system with an isolator (Fig. 3)
- Acceleration data is taken from a record of 22 actual earthquakes (Fig. 4)
- Modeling is done in SAP2000, a structural analysis program (Fig. 5)
- Data on energy absorption is taken from analysis and compared in results

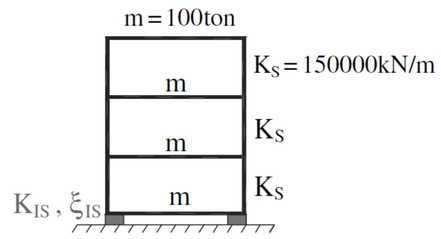


Figure 3. Design parameters

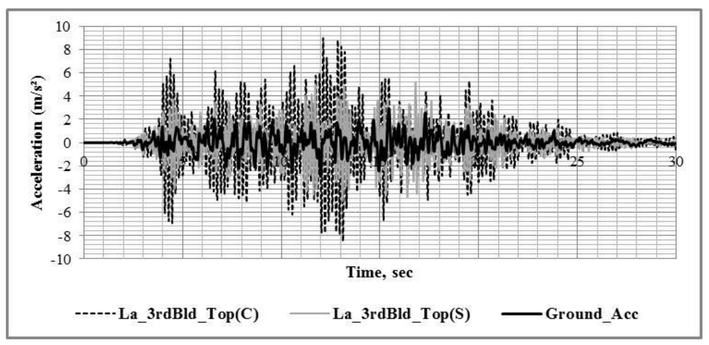


Figure 4. Time History Response

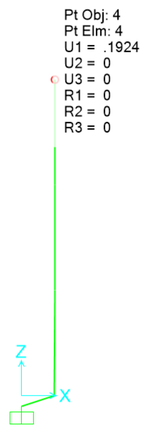
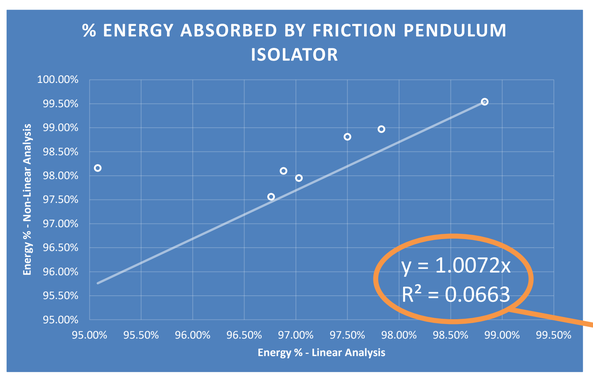
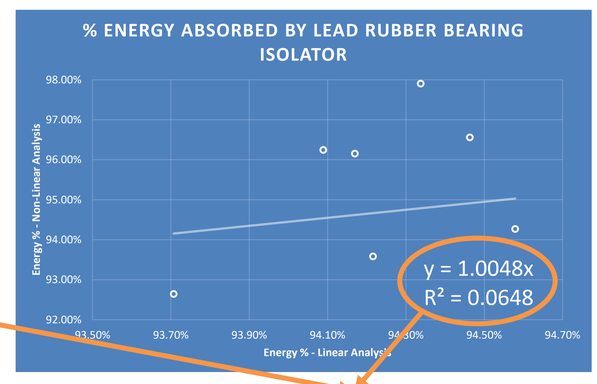


Figure 5. SAP2000 Model

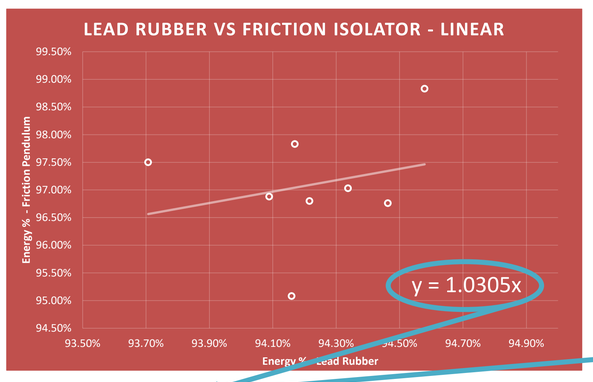
Results

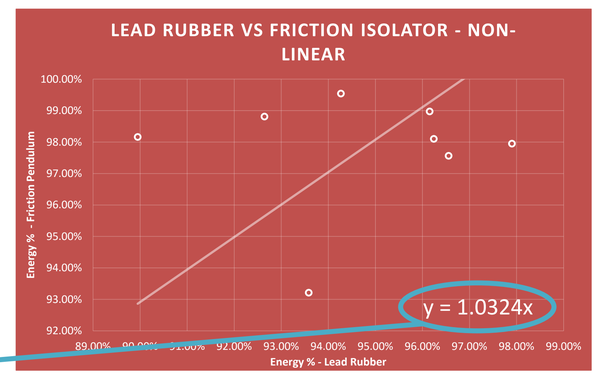




Figures 6 & 7. Linear vs Non-Linear Energy Absorption

Weak correlation between linear and non-linear response

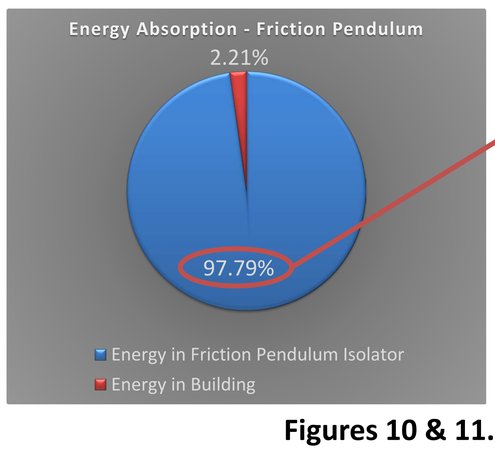


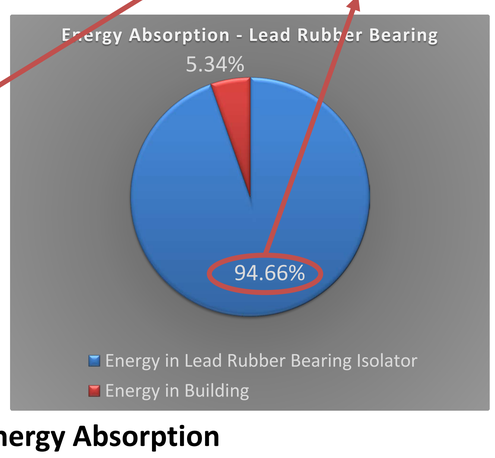


Figures 8 & 9. Lead Rubber vs Friction Isolators

LRB isolators absorb less energy than friction pendulum

Majority of energy absorbed by isolation system





Figures 10 & 11. Total Energy Absorption

Conclusion

From the results generated above, we can make some conclusions about the data:

- There is a weak correlation between linear and non-linear predictions of energy with R^2 values less than 0.1 (Figs. 6 &7)
- Linear predictions consistently under predict the amount of energy absorbed by isolators
- Friction pendulum isolators outperform lead rubber bearing isolators in energy absorption by about 3% (Figs. 8-11)

Acknowledgements

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❖ References

[1] Priestley, M. J. N. (2000). Performance based seismic design. 325-346.

[2] Fajfar, P. (2000). A nonlinear analysis method for performance-based seismic design. 573-592.

[3] Buchanan, A. H., (2011). Base isolation and damage-resistant technologies for improved seismic performance of buildings.

[4] Patil, S. J., & Reddy, G. R. (2012). State of art review-base isolation systems for structures