Seismic Energy and Friction Dampers

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Background and Objective

This study focuses on mitigation of earthquake induced pounding effects between adjacent buildings. Pounding is the event of two structures colliding with each other due to excessive horizontal sway.

It can occur between adjacent buildings with significantly different dynamic characteristics, and when the distance between the two structures is less than the seismic separation set by design specifications. This is a concern as pounding can cause serious damage to the building, or even bring about complete failure and collapse. For example, in the Mexico earthquake of 1985, pounding was found in 40% of the 330 buildings that experienced structural failure [1]. An example of pounding damages is shown in Fig. 1.

Fig. 1 - A case of structural failure due to pounding in Greece Earthquake of 1978

The objective of our experiment we investigate the ability of friction dampers to mitigate pounding effects between two model frames while being tested on a shake table to simulate earthquakes. Friction dampers utilize the Law of Conservation of Energy by translating the kinetic energy of the earthquake, into heat energy via friction in the damper.

Concept

Friction dampers have been used in buildings to dissipate energy as seen in Fig. 2. This same energy mechanics are applied to our experiments. However, instead of in the building, we are also designing friction dampers on the exterior that join the two structures as seen in Fig. 3.

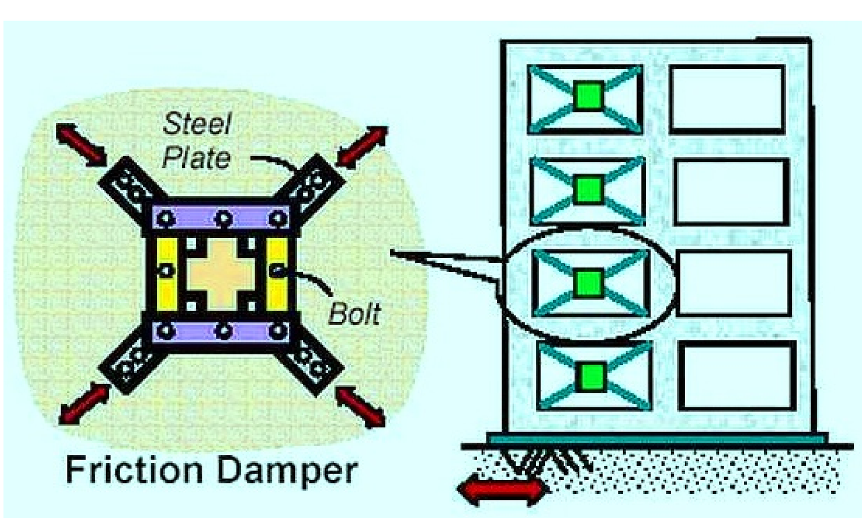


Fig. 2 – Fundamental mechanics of a friction damper [4]

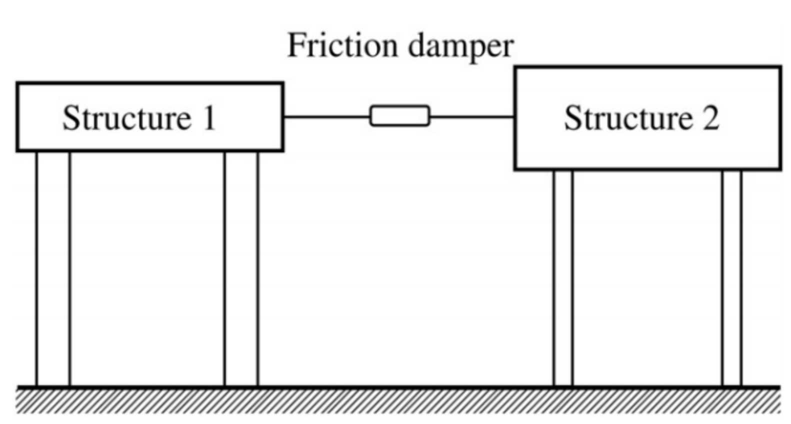
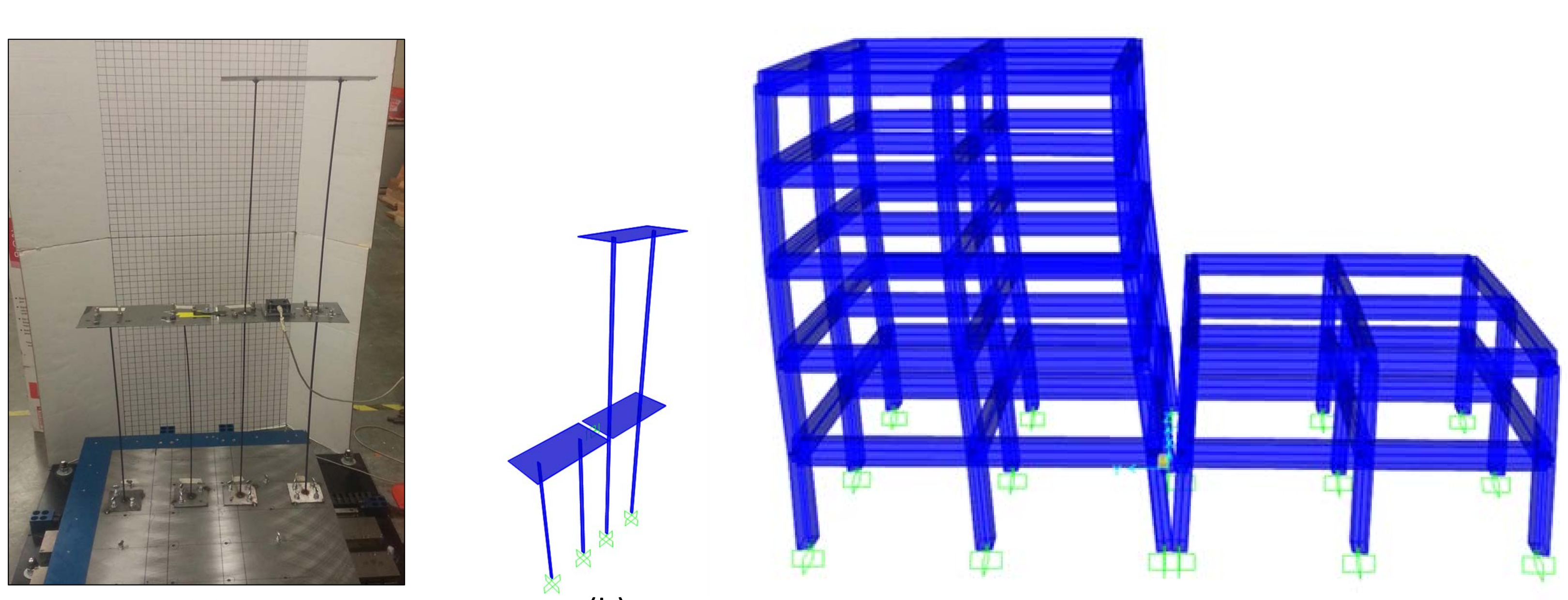


Fig. 3 – Exterior friction damper to mitigate pounding [5]

Physical and Numerical Tests

Two test specimens (namely Test 1 specimen and Test 2 specimen) were considered in this study. The Test 1 specimen consists of a set of two structural portal frames, one-story and two-story tall respectively, and was subjected to physical (Fig. 4a) and numerical (Fig. 4b) analyses with the structural analysis software SAP2000. The test 2 specimen consists of a set of two buildings, two-story and five-story tall respectively, and was subjected to numerical analysis in SAP2000 (Fig. 4c).



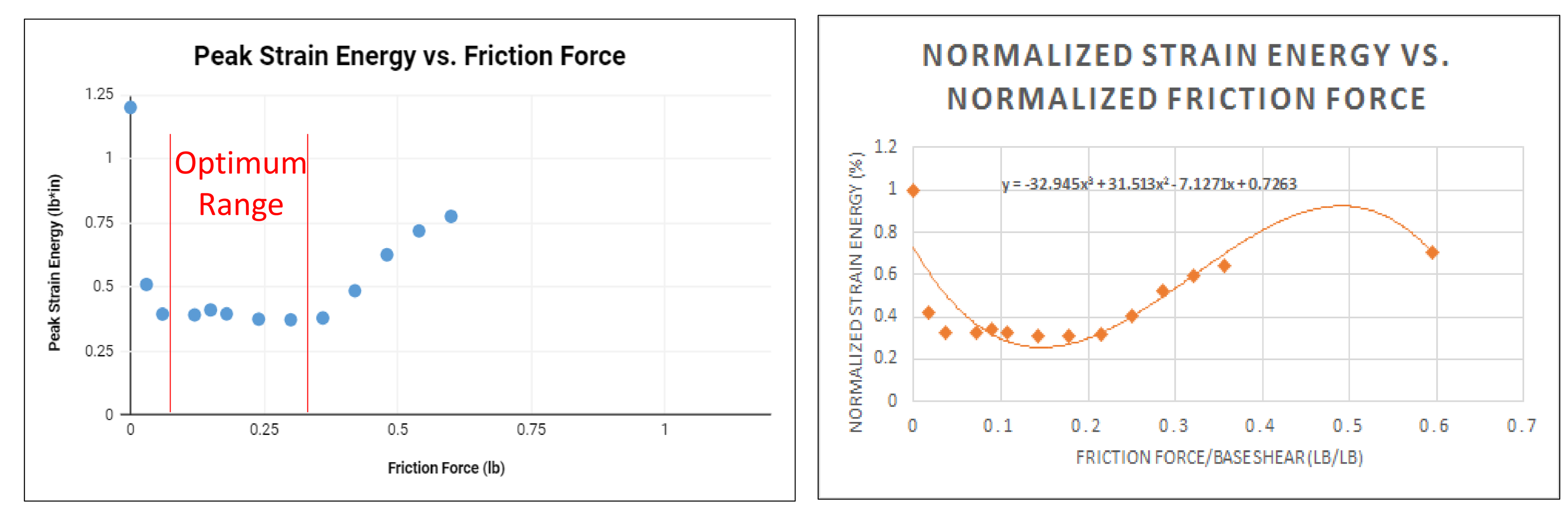
(a) (b) (c)

Fig. 4 – a) Test 1 specimen on Cal Poly Pomona Shake Table, **b) Test 1 specimen in SAP2000, c) Test 2 specimen in SAP2000**

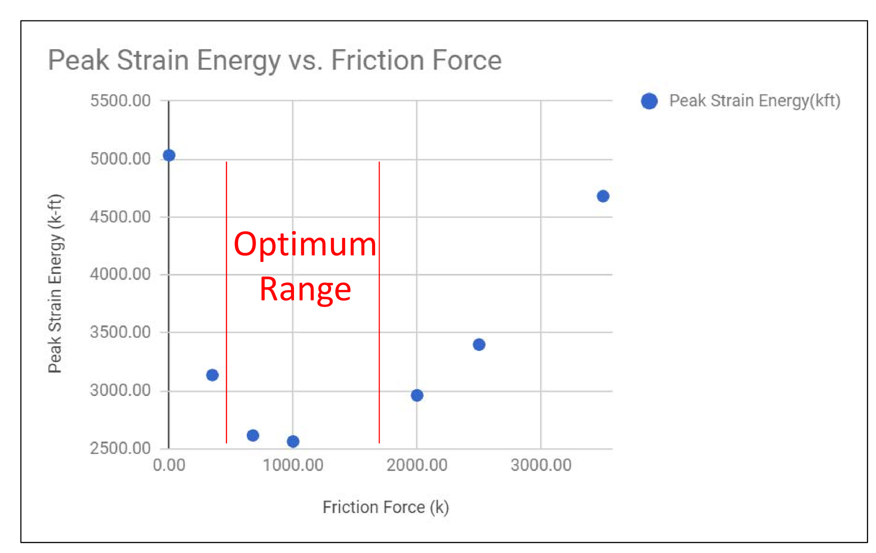
The specimens were analyzed with and without friction damper, in order to evaluate the effectiveness of the energy dissipation mechanism. I used different device settings (in terms of friction force) to compare and contrast changes in energy dissipation throughout the structure. Numerical analysis was performed to extend experimental results to a wider range of excitation levels.

Results

Physical and numerical tests show the ability of friction dampers to decrease the likelihood of pounding. Also, maximum energy is dissipated from the structures if the friction damper is tuned to peak efficiency. We found a relationship between the cumulative base shear and applied friction, through which we were able to determine a local minima . This local minima correlated to maximum reduction of peak strain energy. Peak strain energy is associated with deflection and deformation. Therefore, using this method we can significantly reduce the possibility of pounding and reduce strain energy in both structures.
Utilizing real seismic acceleration data from Northridge Earthquake of 1994, I performed Test 1. From there a relationship was found between friction force and total strain energy in the system. We normalized this data using the base shear from the structures, and then applied it to full scale model in Test 2. Refer to Fig. 5



(a) (b)



(c)

Percent of Base Shear	Friction Force (k)	Combined 2nd Story Deflection (in)	Percent Reduction in Peak Strain Energy
0%	0	12.3	0
18%	349	8.1	38%
34%	676	7.9	48%
50%	1000	8.1	49%
100%	2000	8.7	41%
125%	2500	9.0	32%
175%	3500	9.8	7%

(d)

Fig. 5 – a) Test 1 specimen in SAP 2000, **b)** Numerical analysis to extend data to larger model , **c)** Test 2 specimen in SAP 2000 , **d)** Test 2 specimen in SAP 2000 raw data

Conclusion and Future Work

For the structural configurations considered in this study, it appears that the ideal range of friction force in the damper is between 18% and 34% of the total base shear in the structures.

Test 2 confirmed the relationship. Furthermore, peak strain energy was reduced by 49%

Future works involve…
-Collecting more data to find a precise range of optimum friction for design applications
-Designing and drawing technical details of the friction damper for a full sized structure
-Exploring different applications for this tribological phenomena

Acknowledgments

Francisco Garrido led design, fabrication, and construction of Test 1 specimen seen in Fig. 4-a. His craftsmanship and ingenuity will help progress seismic pounding research. This model will serve as a devise for learning for future aspiring Civil Engineers at Cal Poly Pomona. Also, a special thank you to my advisors, **Dr. Felipe Perez** and **Dr. Giuseppe Lomiento**. Their expert knowledge on the subject pushed me to excel in my undergraduate research. It is my hope that this research continues and gets published so that friction dampers for seismic pounding can become commonplace in engineering. Therefore, seismic pounding may hopefully be eliminated completely as a source of structural failure in the near future.

References

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