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Hyperelastic Structural Fuses for Steel Buildings

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Hyperelastic Structural Fuses for Steel Buildings

DEPARTMENT OF CIVIL ENGINEERING

University of Nebraska Lincoln

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1 Resilient Construction is Needed

Why to upgrade traditional systems?

The FEMA P-58-1 listed some of the limitations in present-generation procedures:

- Questions regarding the accuracy and reliability of available analytical procedures in predicting actual building response.
- “High” level of conservatism underlying the acceptance criteria.
- Inability to reliably and economically apply performance-based procedures to the design of new buildings; and
- Lack of alternative ways of communicating performance to stakeholders that is more meaningful and useful for decision making purposes.

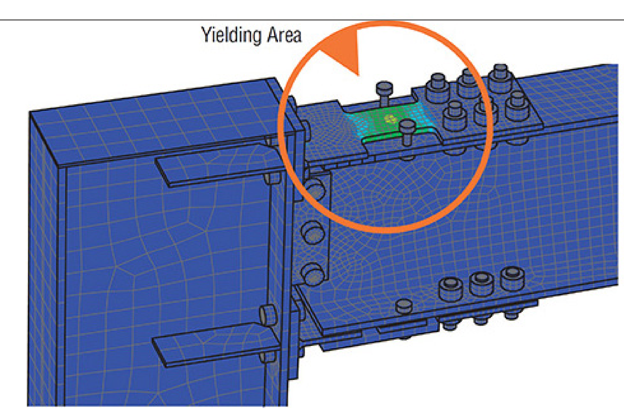
How did we address these issues?

Performance based design (PBD) emerges as the methodology aiming to bridge this gap, raising the design level performance from life safety (traditional systems) to keep structures fully functional after strong EQ.

2 Hyperelastic Fuses

What is a traditional Structural Fuse?

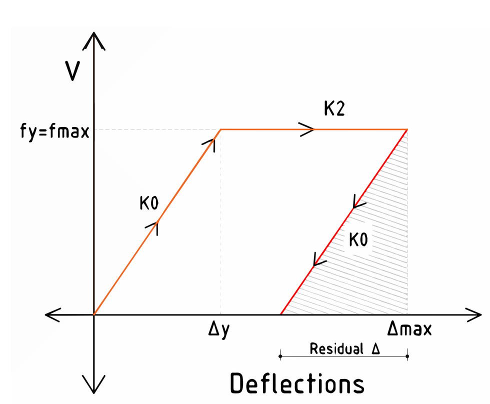
- Structural element where inelastic deformation (damage) is intentionally concentrated.
- Preferably, disposable and easy to repair structural element.



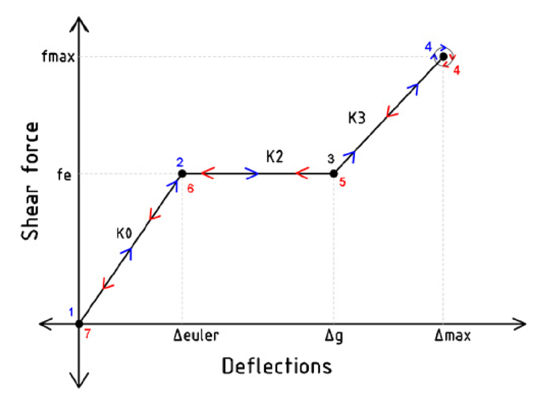
The highlighted green section illustrates the yielding area on the special moment frame connection, which is designed to yield in a seismic or wind event.

What is a Hyperelastic System?

Remain elastic when subjected to considerably large deformations



Hysteresis



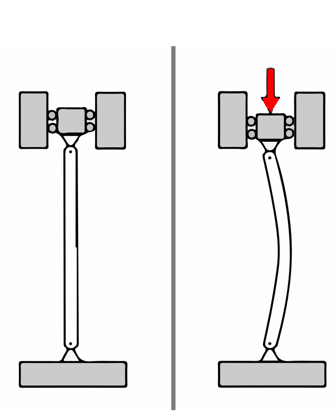
Hyperelastic

Why Hyperelasticity?

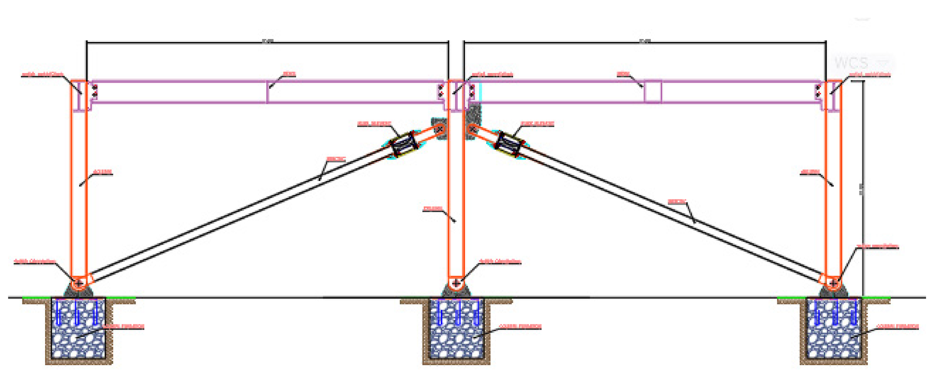
No inelastic deformations, and thus no residual drifts / **Resiliency**

Hyperelastic Fuse

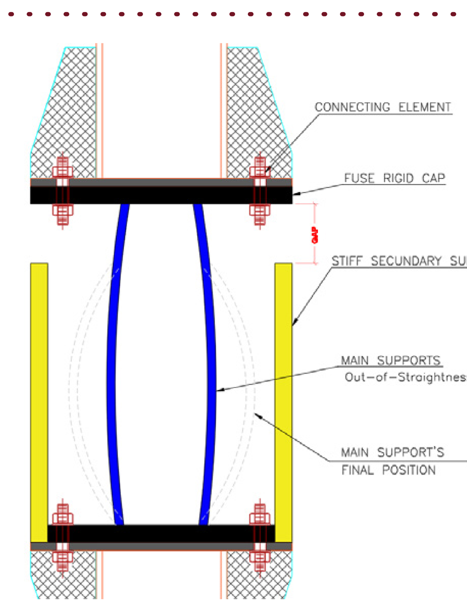
The internal elements have an small initial skew that assures that the elements’ buckling path remains through the cycles.



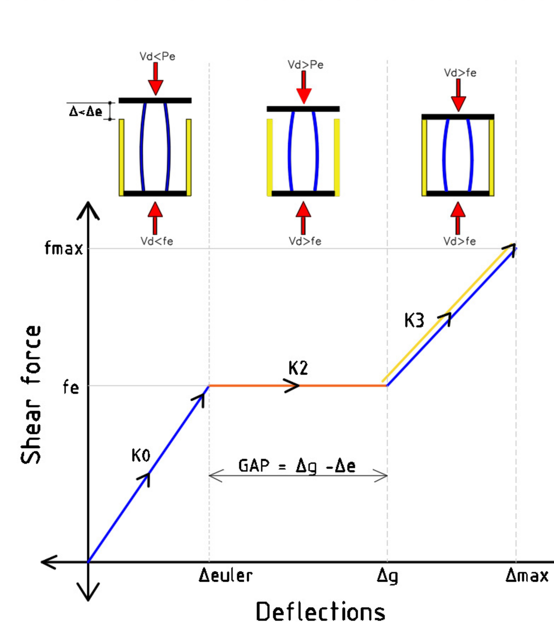
elastic buckling elements



Frame equiped with Hyperelastic Fuses

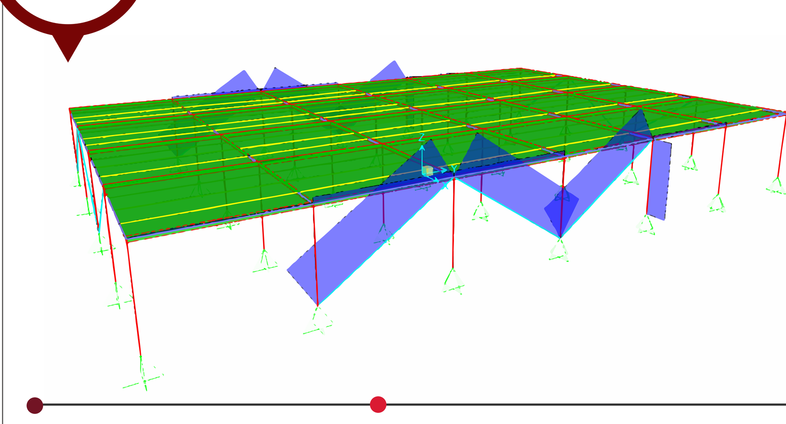


Fuse initial sketch

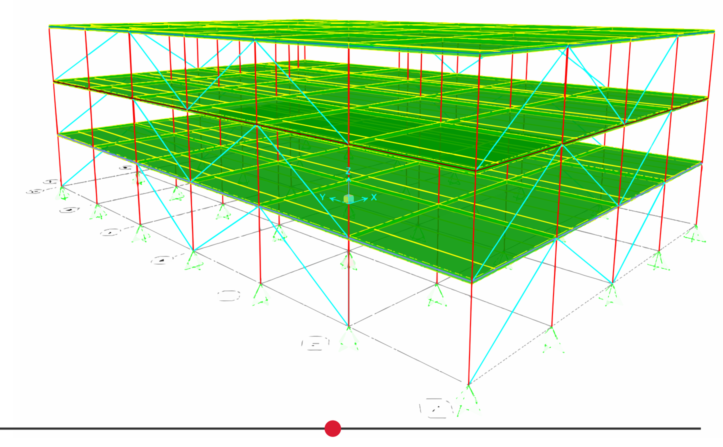


3 Parametric Study

Target Buildings



R\Tn	0.17	0.35
6	A	B
3.5	C	D



The target behavior is represented as follow.

Where:

fe = elastic buckling load

Ductility = ration between the displacement needed to close the fuse’s gap and the buckling displacement

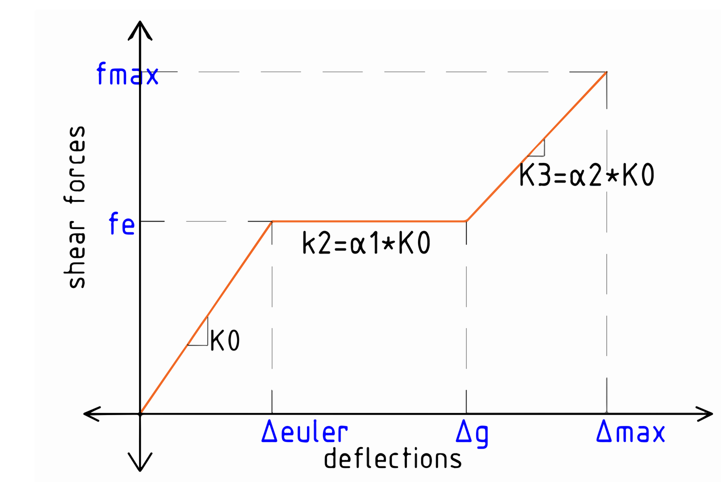
$$duct = \frac{\Delta_g}{\Delta_y}$$

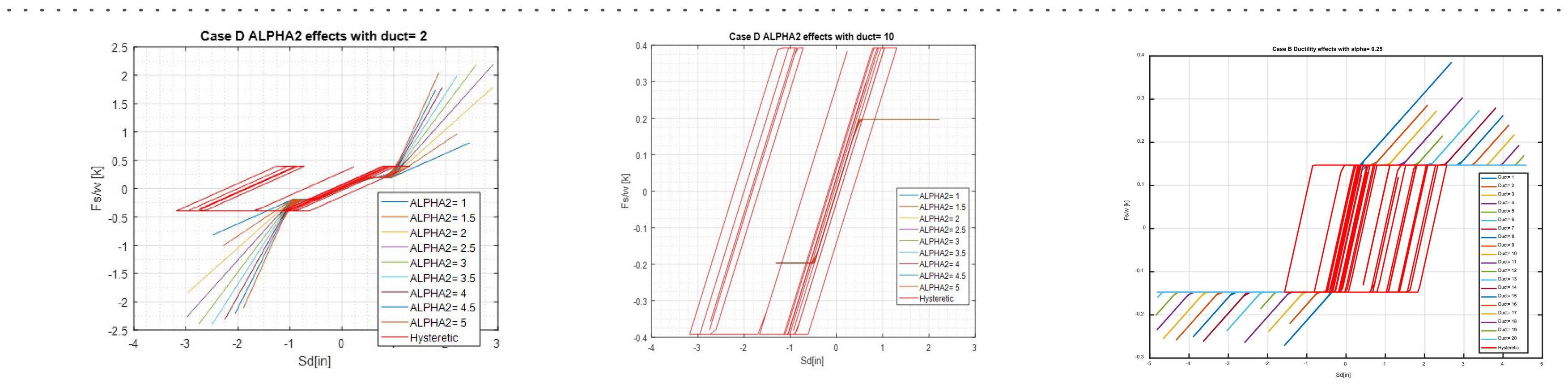
Alpha1 = ratio between the secondary and initial stiffness

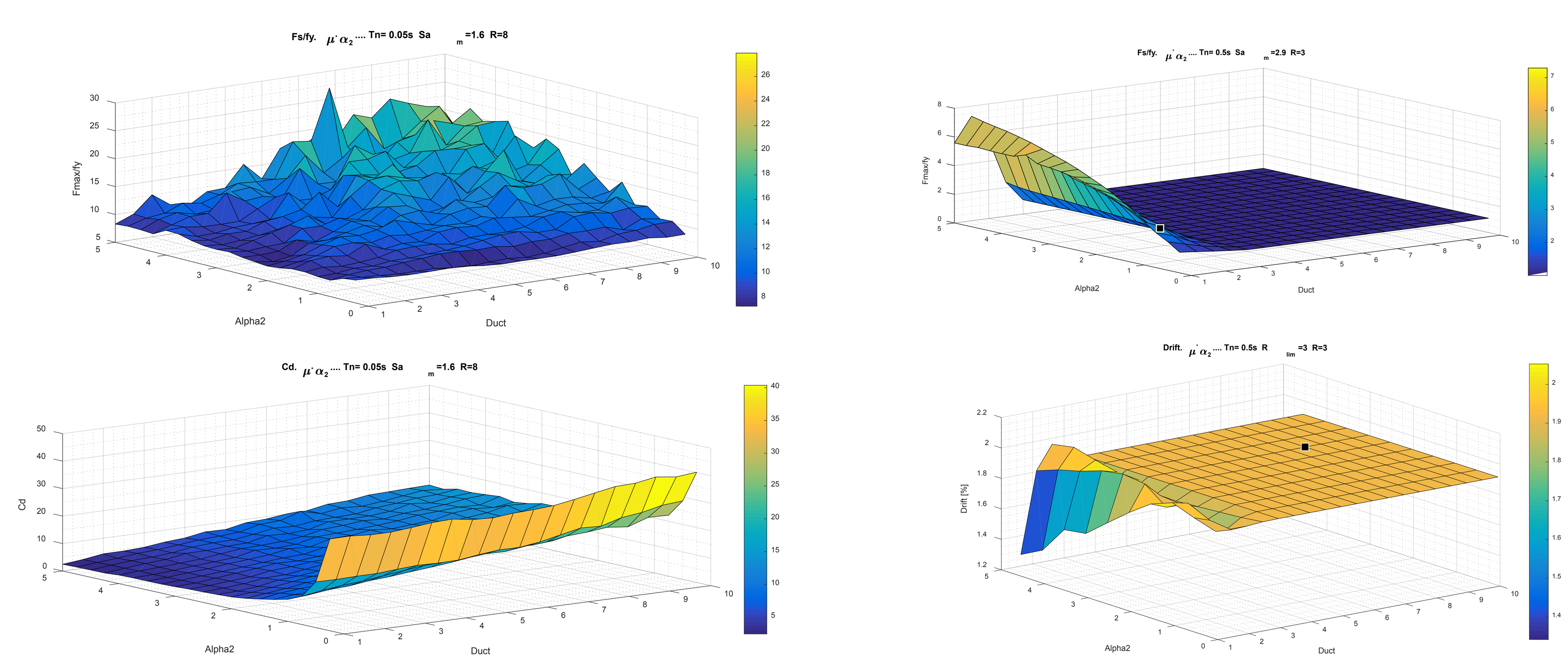
$$\alpha 1 = \frac{k_2}{k_0} = 0$$

Alpha2 = ratio between the third and initial stiffness

$$\alpha 2 = \frac{k_3}{k_0}$$



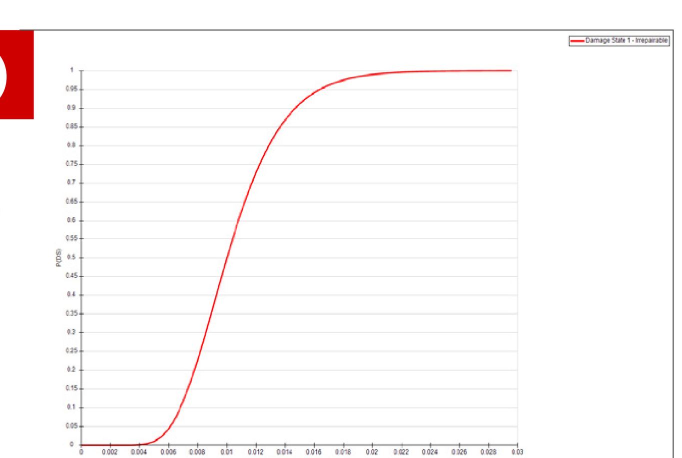




4 Building Performance (Under Evaluation)

How does this response (displacement and acceleration) translate into performance?

Using the FEMA P-58 report the respeonse can be associated with fragility levels, which will be useful to compare performance outcomes between strucrures with traditional and hyperelastic fuses.



5 Conclusions (Under Evaluation)

- For 3-story buildings, a ductility higher than 15 is needed to equal the force level on both systems (Hyst. vs Hyper)
- It is vital to 3D print fuse samples to investigate geometric sensitivities, and define and analyze the elastic buckling mode (internal elements of the fuse).
- Evaluate hyper elastic fuse potential for retrofitting existing structures.

6 References

- FEMA 445 Next Generation Performance- Based Seismic Design Guidelines: Program Plan for New and Existing Buildings. (n.d.). Retrieved February 06, 2017, from https://wbdg.org/ffc/dhs/criteria/fema445
- Goldsworthy, H. (2012). Lessons from the 22 February 2011 Christchurch earthquake. Australian Journal of Structural Engineering, 13(2). doi:10.7158/s11-136.2012.13.2

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