# Development and Spectral Analysis of an Advanced Control Law for Semi-Active Resetable Devices

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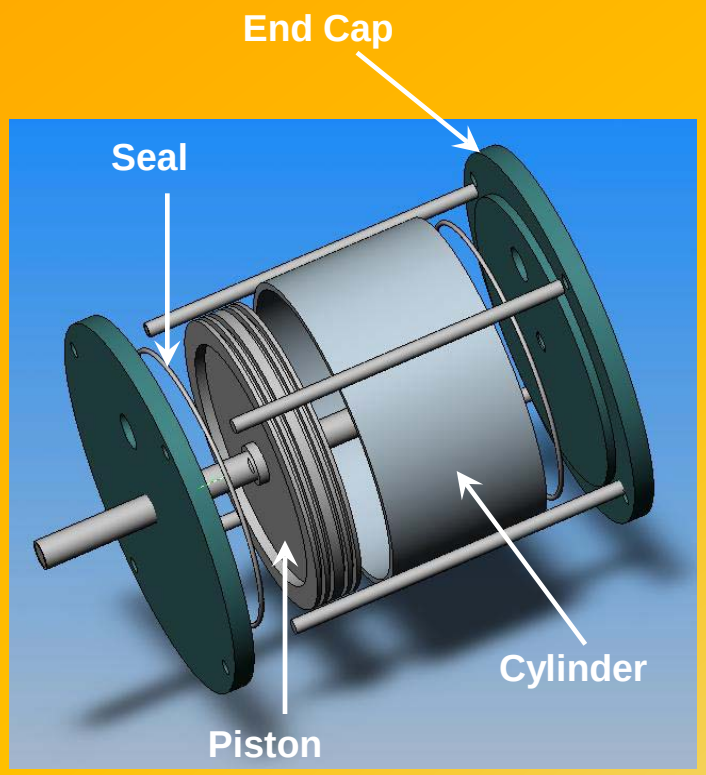
# Motivation

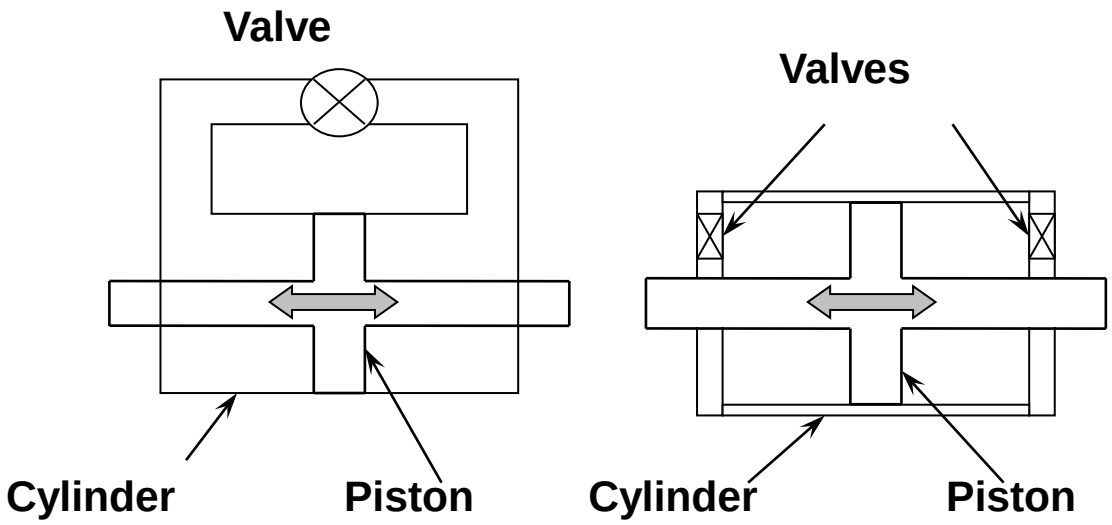
- *A main goal of a structure in a seismic event is to dissipate energy in a repeatable fashion*
- *Preferably in large amounts*
- *Existing research has investigated the use of emerging devices adn technologies to accomplish this goal*
  - *Resetable devices are one answer presented at this conference for certain application areas where a more complex device and behaviour are warranted.*
- *Resetable devices are semi-active, but more importantly they offer the ability to customise the overall structural response behaviour to maximise energy dissipation*
- *This presentation presents a novel structure and hysteresis loop that is enabled only by semi-active technology*
  - *A further talk shows how to achieve it within the devices*

# Re-Shaping Hysteretic Behaviour Using Semi-Active Resetable Devices

## *Double-acting piston with controlled dissipation enables customisation of structural hysteresis*




# Device Design




Independent two chamber design allows broader range of control laws

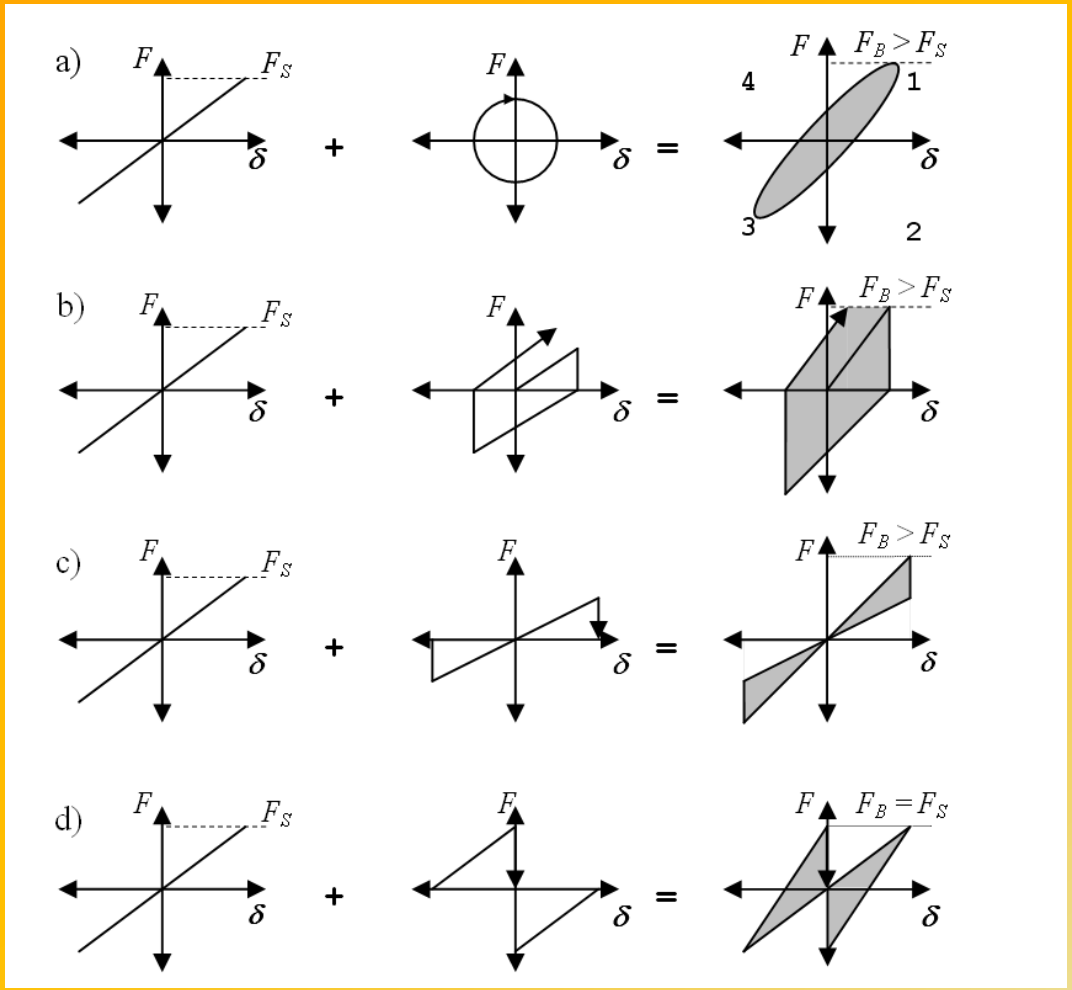
# Overall Customised Hysteresis

Resist all velocity

Resist **all** motion

Resist motion **away** from 0

Resist motion **toward** 0




Viscous Damper

1-4 Resetable

1-3 Resetable

2-4 Resetable

**Only the 2-4 control law does not increase base-shear**

# The Problem

- You get a choice with these devices:
  - **Reduced** base shear and displacement response, but **reduced** energy dissipation
  - **Reduced** displacement with increased energy dissipation, but with **increased** base shear

- <u>Neither choice is optimal</u>

- Goal: **Reduce** base shear (or dont increase it), **reduce** base shear, and **increase** energy dissipation

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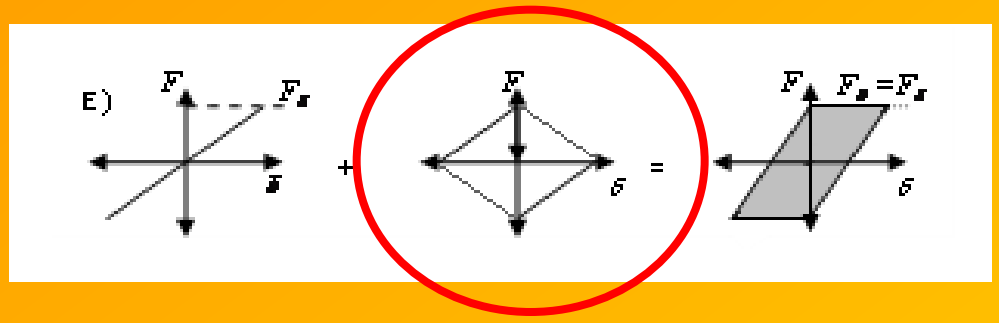
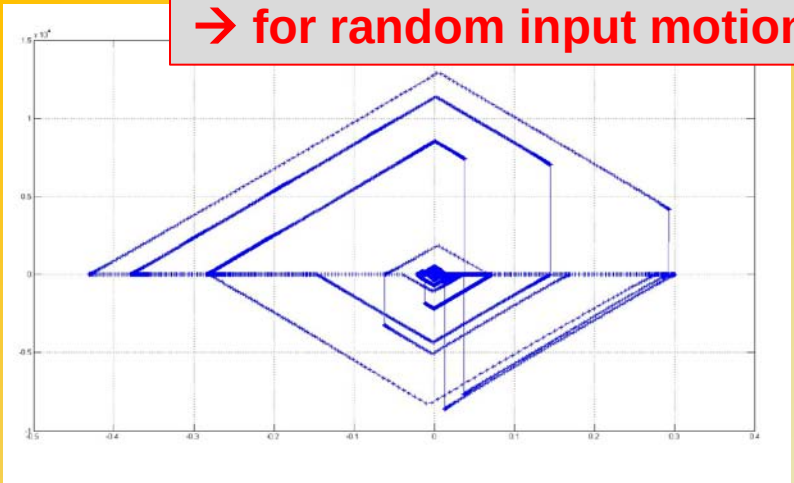
# A Diamond-Shaped Solution




- **Increased** energy dissipation
- **No increase** to base shear
- **Reduced** displacement

**Ideal Device Model Loop**
**→ for random input motion**



- Meets all goals

- **Requires active control release of working fluid = Difficult to achieve with potentially nonlinear devices**
  - See next talk!

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# Analysis

- Create design spectra and reduction factors (RFs)
- Ground motions = 60 EQ's from SAC suites (Sommerville et al)
- Examine RFs for structural force (displacement)and base shear
- Compare to 2-4 and 1-4 devices that define the compromise
  - Note these devices do not require active valve control of release rate of working fluid

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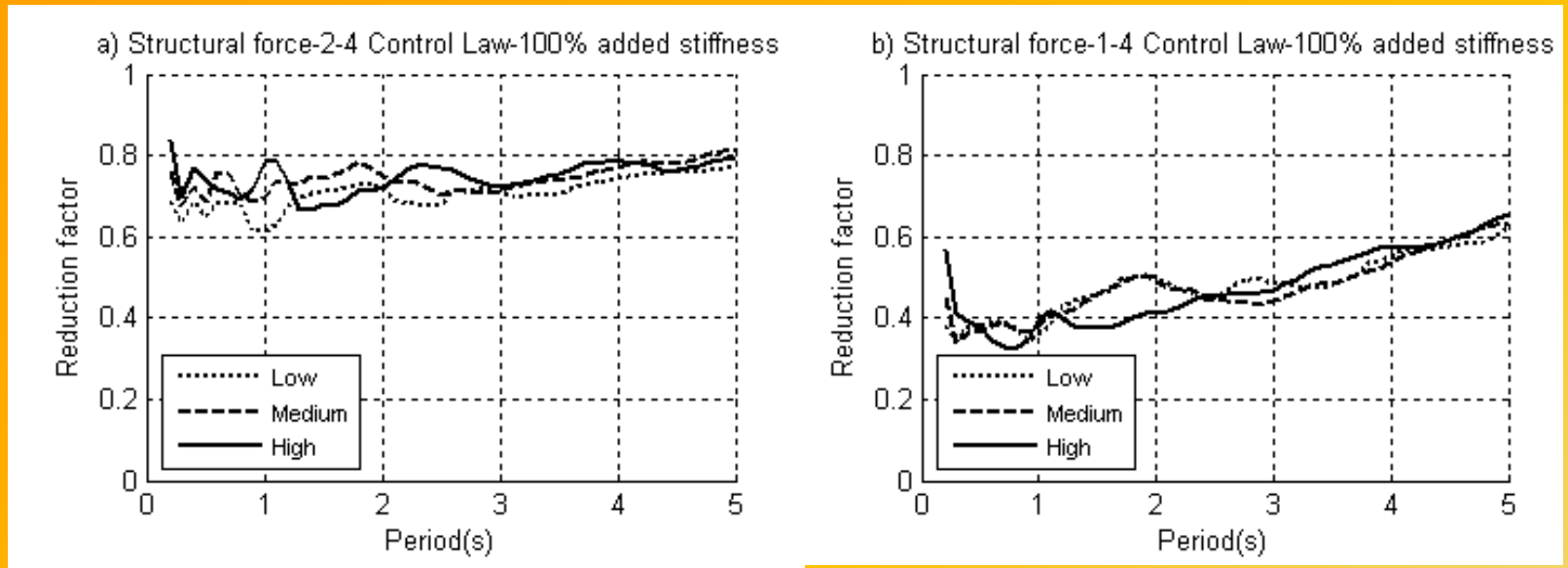
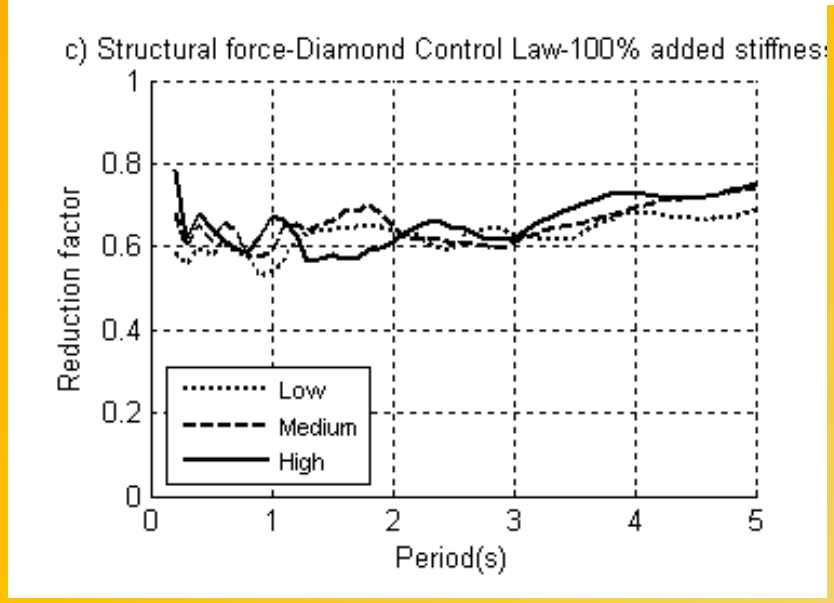
# Results – Structural Force




- Results are suite invariant
- 1-4 > Diamond > 2-4 as might be expected

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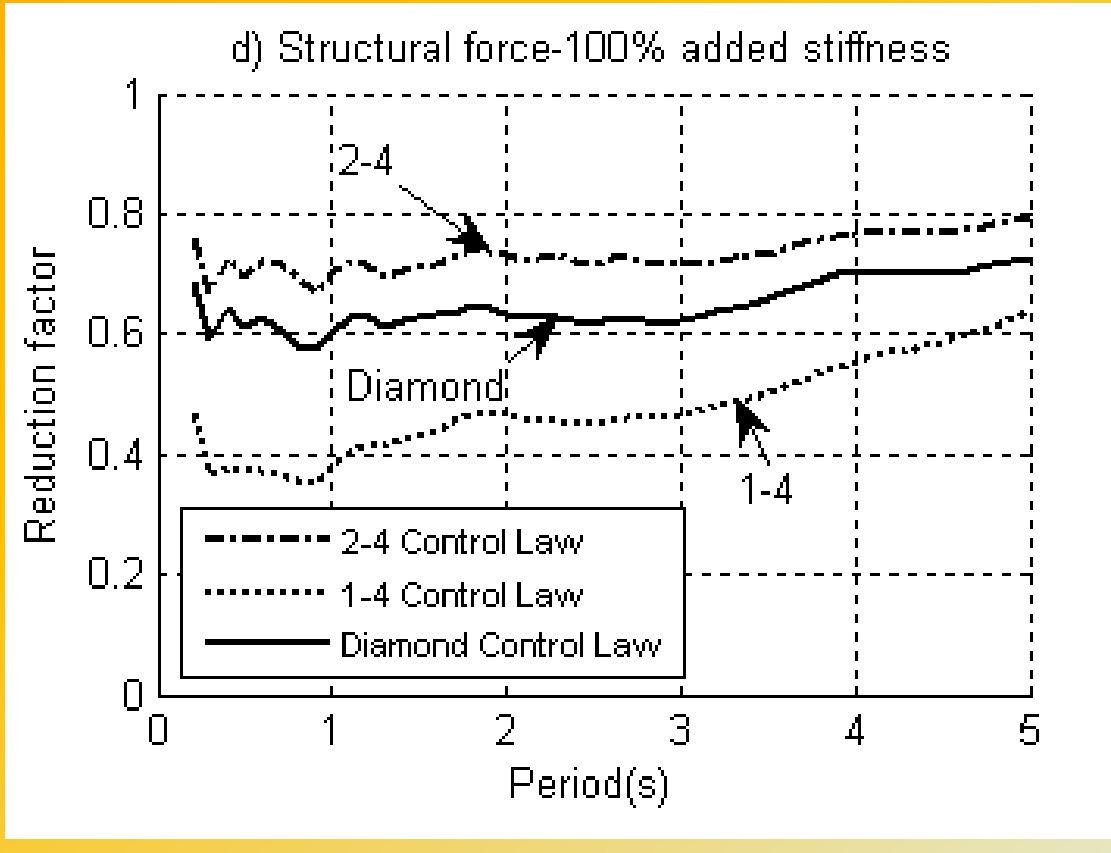
# Results – Structural Force

- Diamond shape offers a reasonable tradeoff between the two passive semi-active device control laws
- Difference shrinks at longer periods

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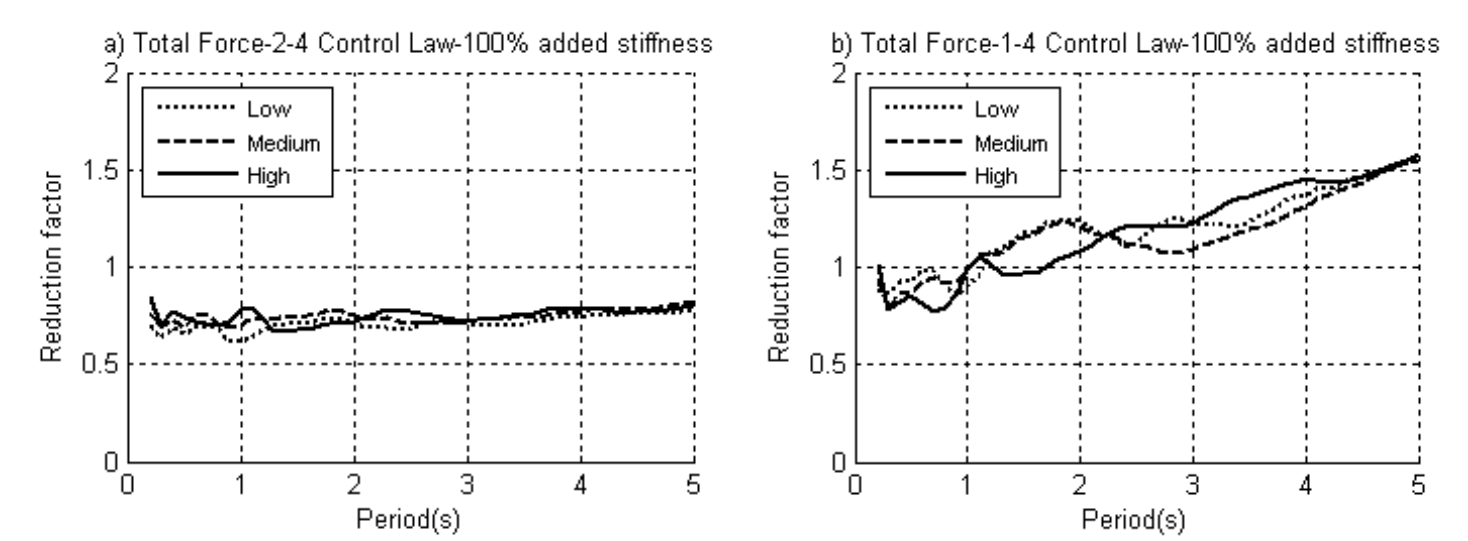
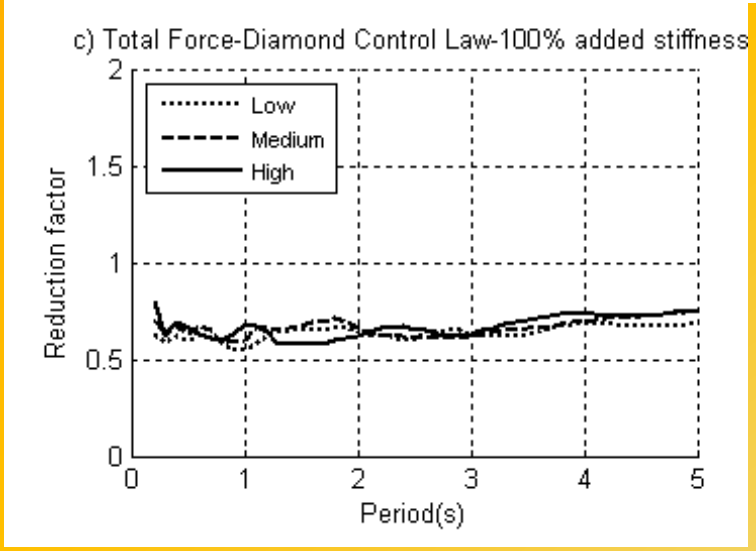
# Results – Base Shear




- 1-4 and 2-4 as expected
- Diamond shaped offers equivalent or better than 2-4
- Extra displacement reduction due to greater energy dissipation is the key

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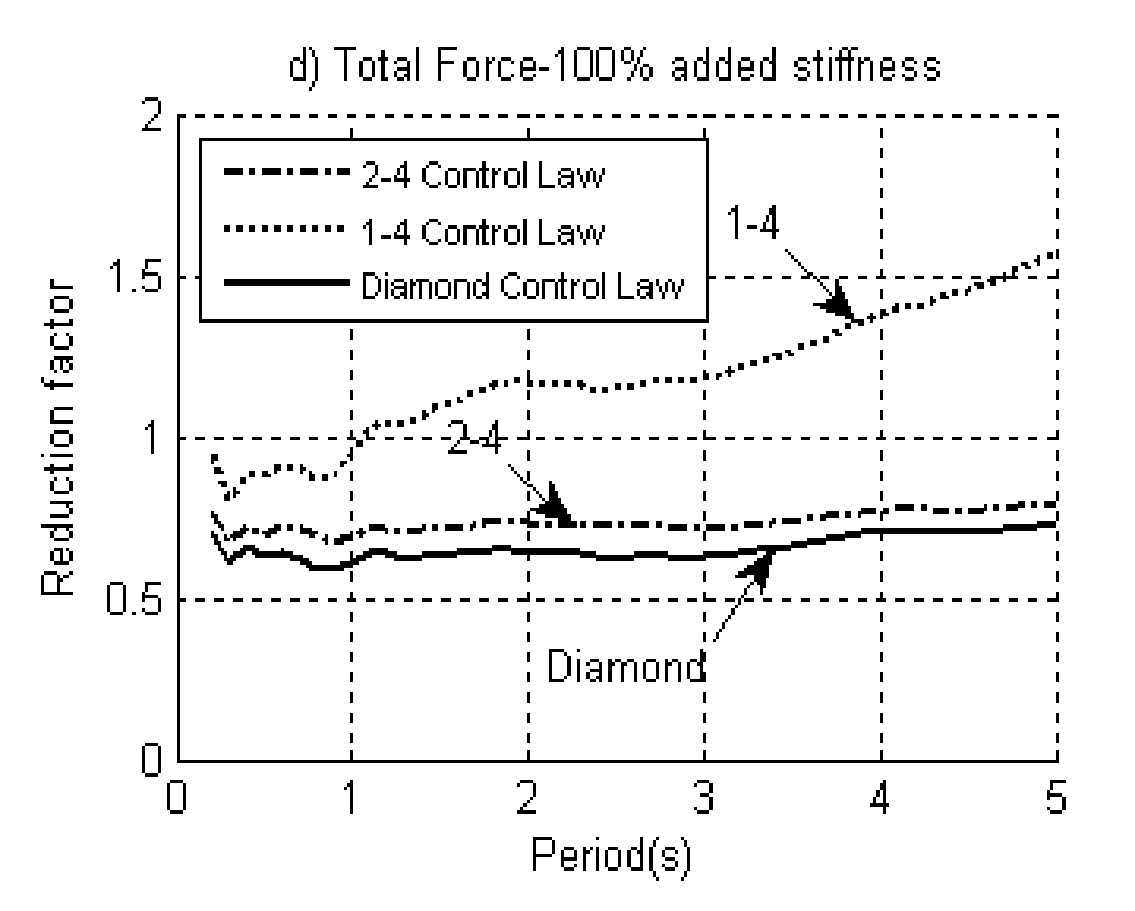
# Results – Base Shear




- Extra energy dissipation yields greater reduction in displacement
- Diamond shape thus out performs 2-4 on base shear reduction
- Overall a relatively optimal tradeoff for this device

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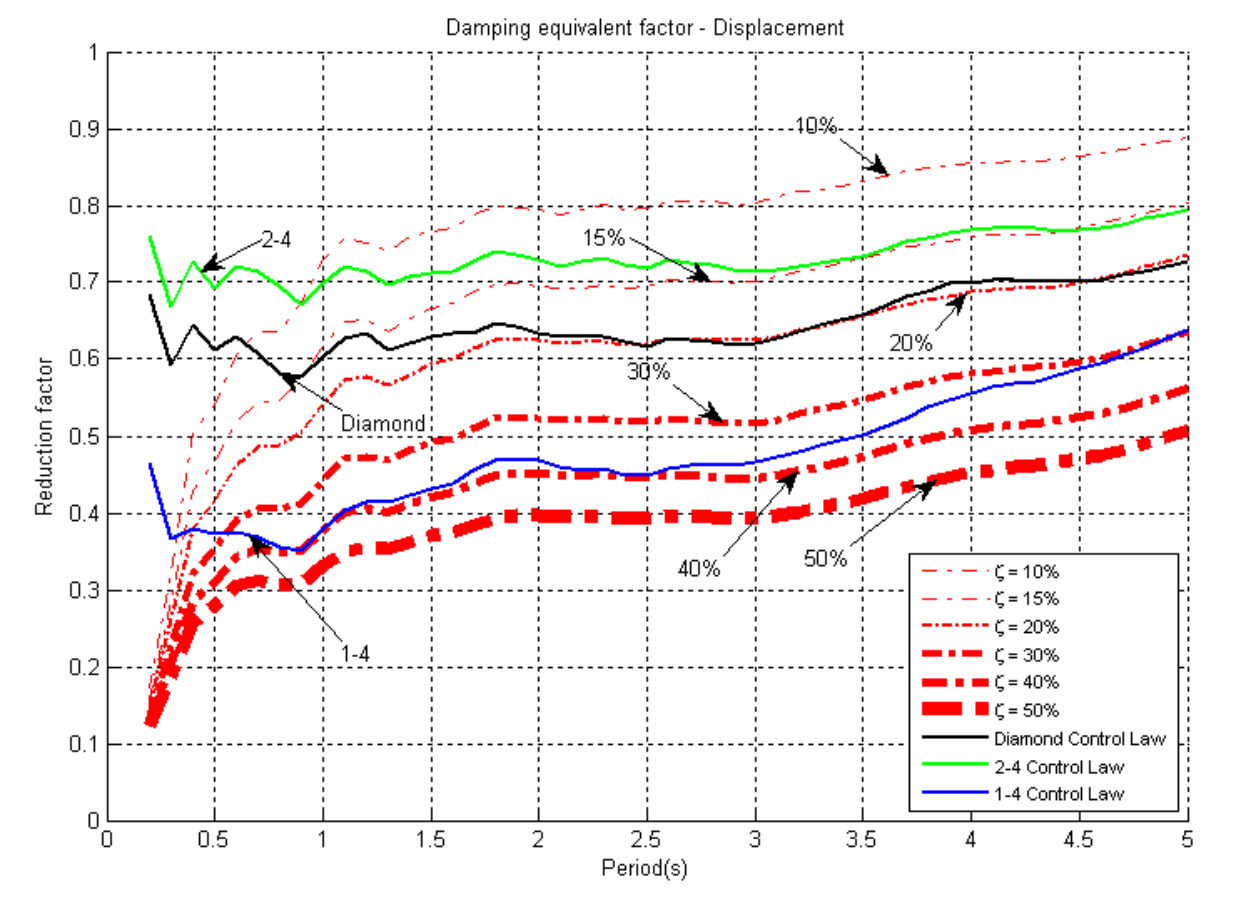
# Equivalent Viscous Damping




- Increase viscous damping and compare displacement RFs
- No devices
- 2-4 → 10-15%
- 1-4 → 40-30%
- Diamond → 15-20%

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# Conclusions

- Semi-active control enables customisation of overall structural hysteresis in novel ways not available with passive systems
- Active valve control expands these unique tradeoffs to maximise performance
- A diamond shaped device control law and hysteresis loop can reduce base shear while adding significant extra energy dissipation versus strictly passive valve control on these devices
- Extra complexity of such a semi-active device may be readily justified in certain structures, sub-systems or high-value equipment/plant
- **BIG QUESTION**: Can we control the valves to get this unique shape and relatively ideal, **linear** device hysteresis loop?

# ACKNOWLEDGMENTS

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