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CHRISTCHURCH NEW ZEALAND

NHRP
Natural Hazards Research Platform

UC QUAKE CENTRE

Improving Post-tensioned Rocking Bridge Columns for Large and Multiple Earthquake Events

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Co-authors: Brandon McHaffie
Prof. Alessandro Palermo

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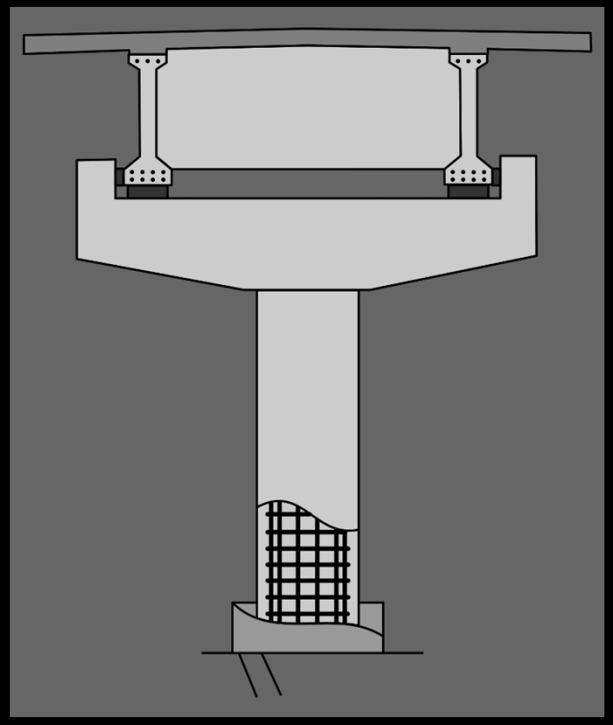

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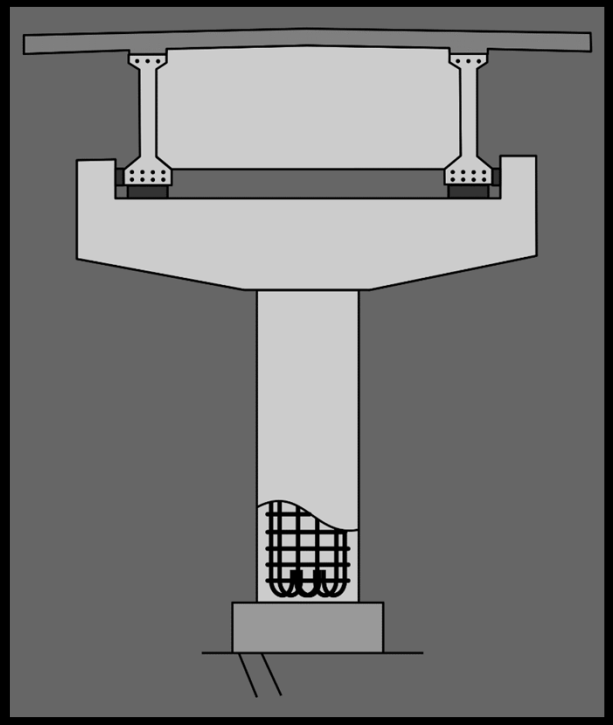

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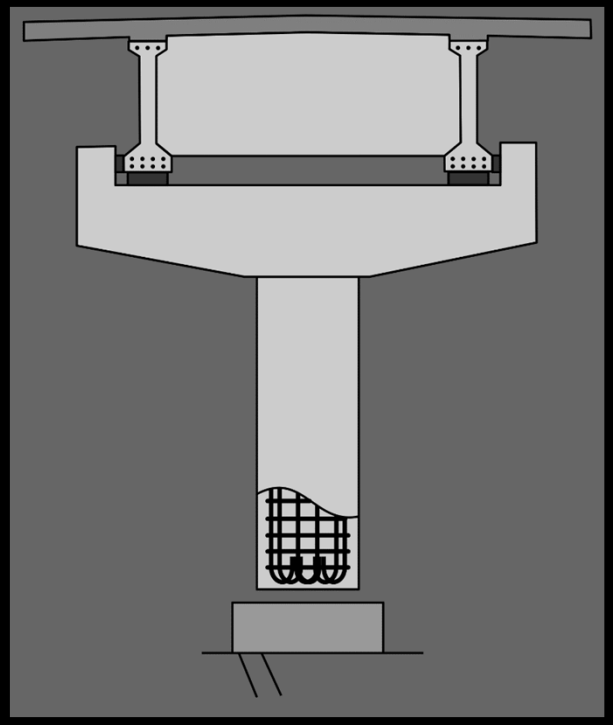

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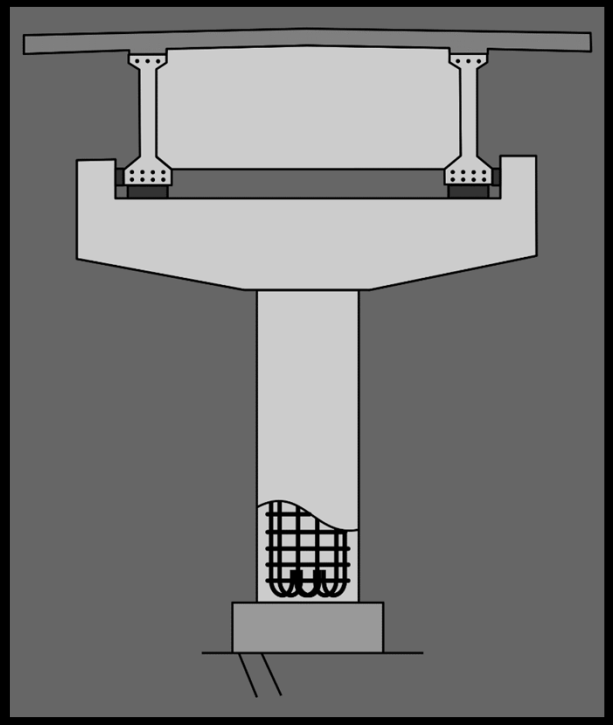

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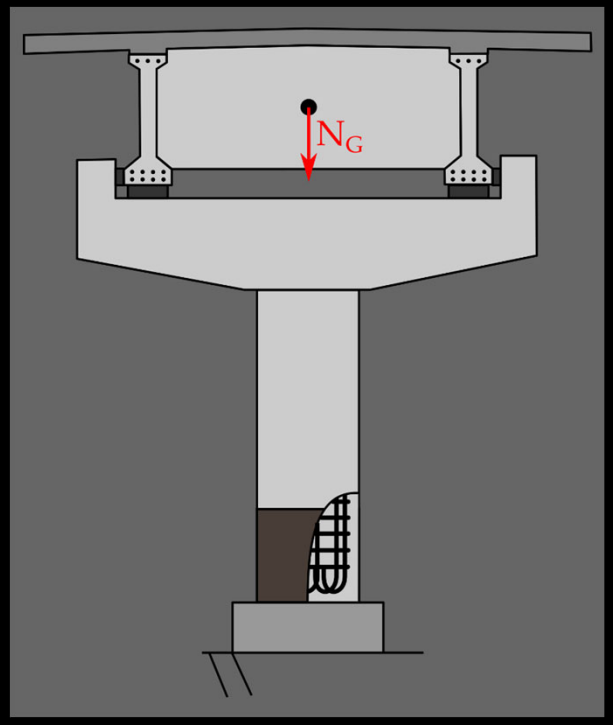

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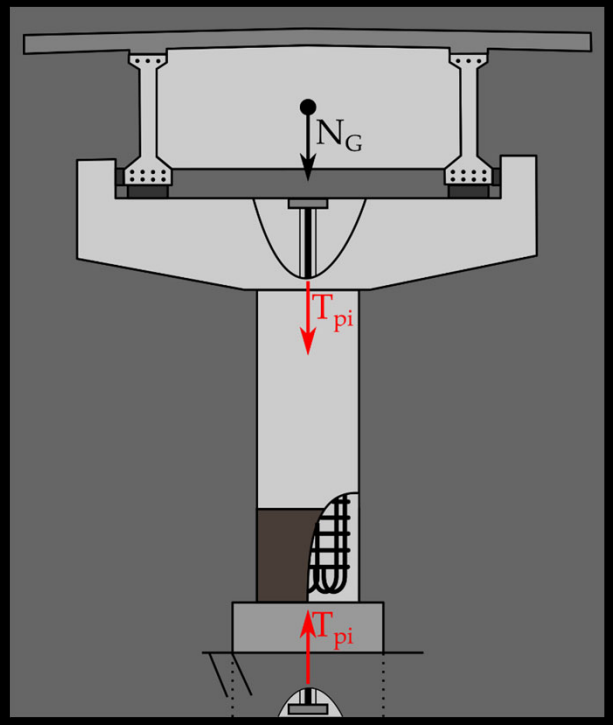

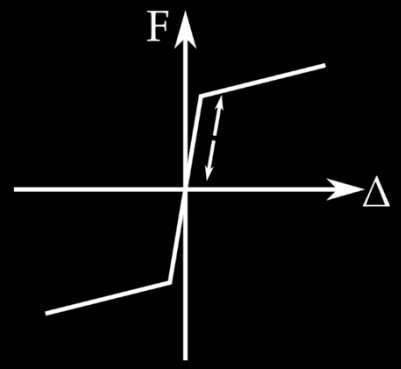

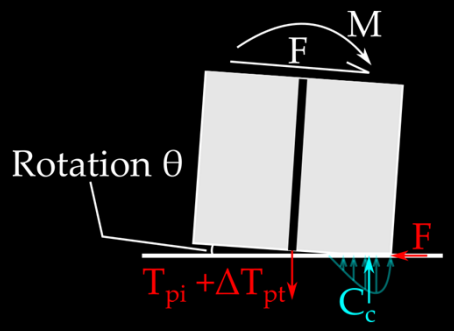

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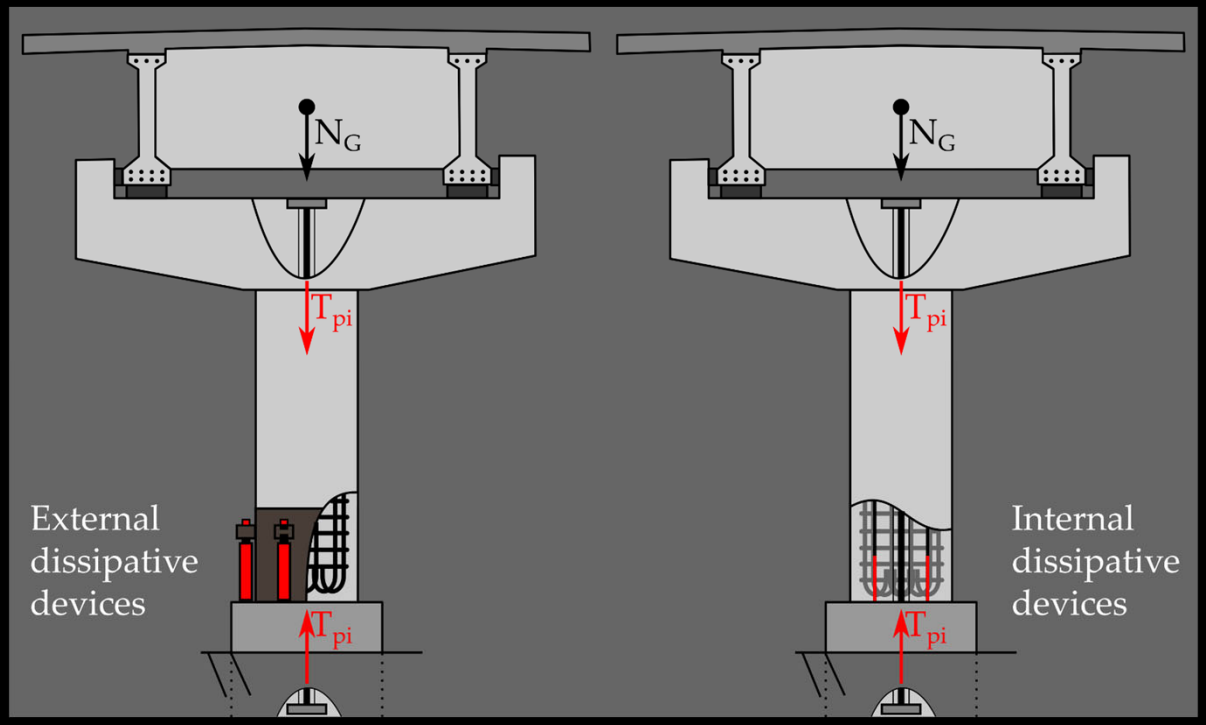

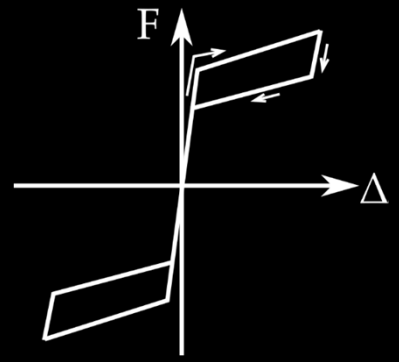

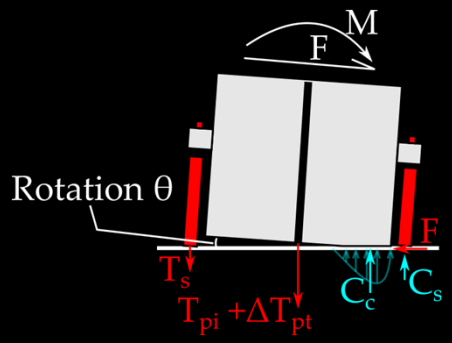

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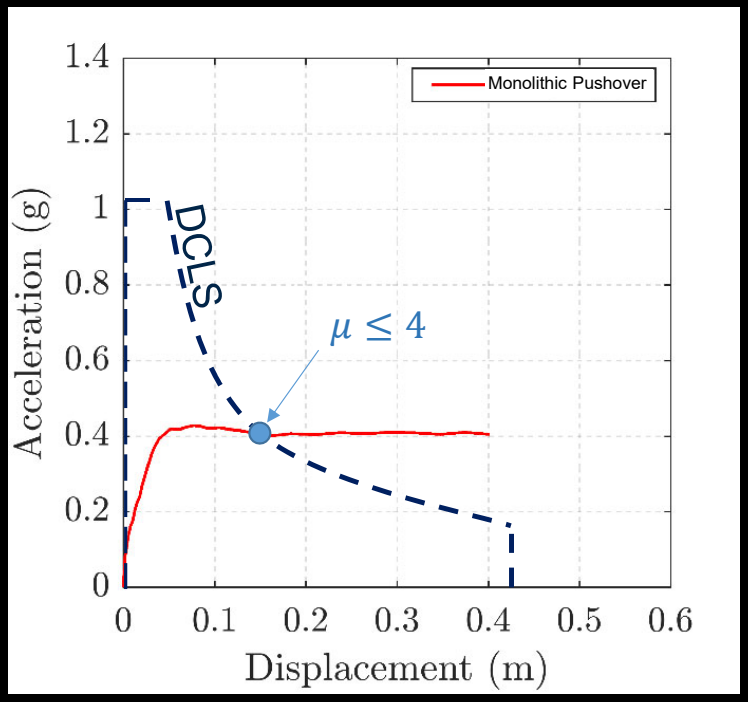

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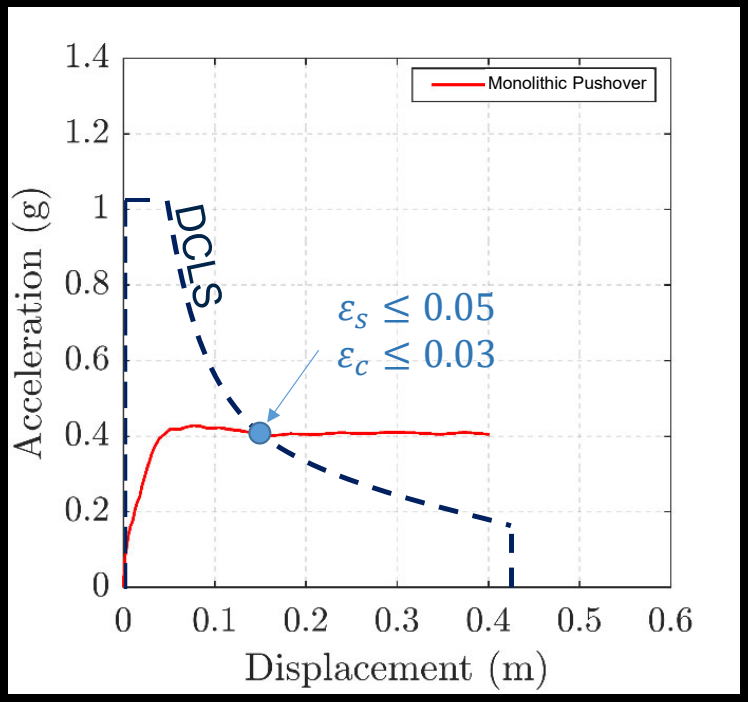

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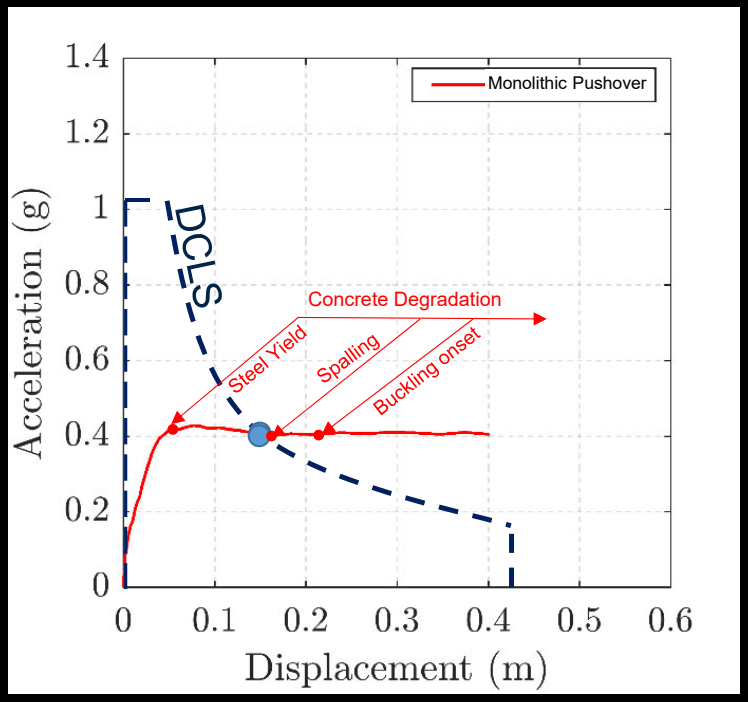

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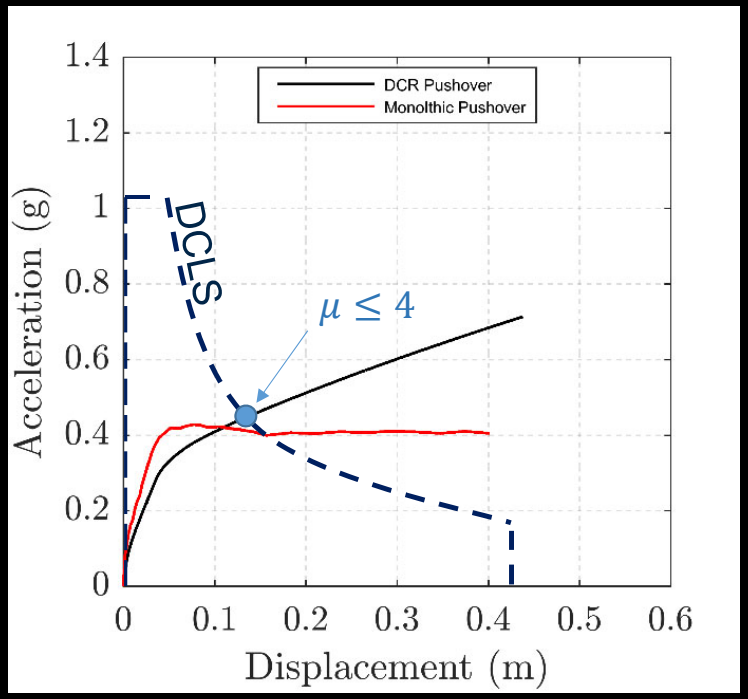

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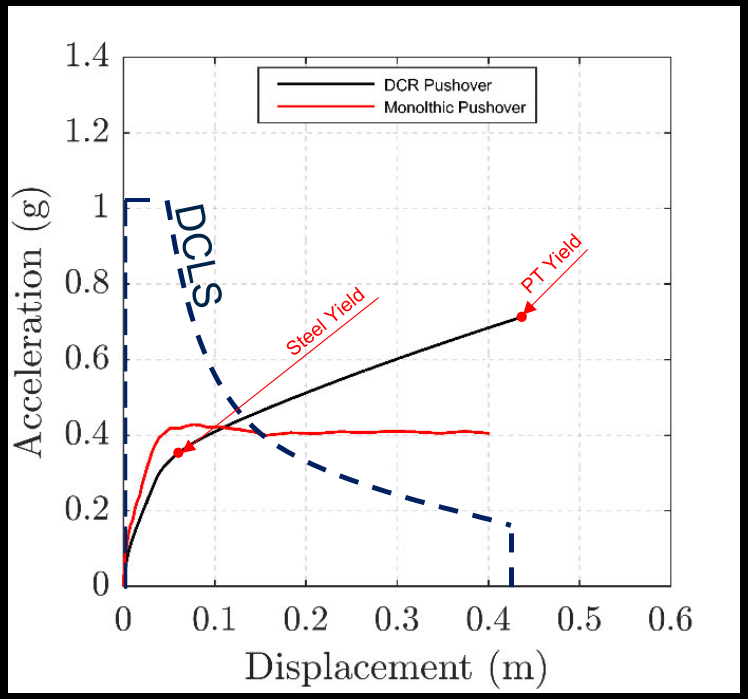

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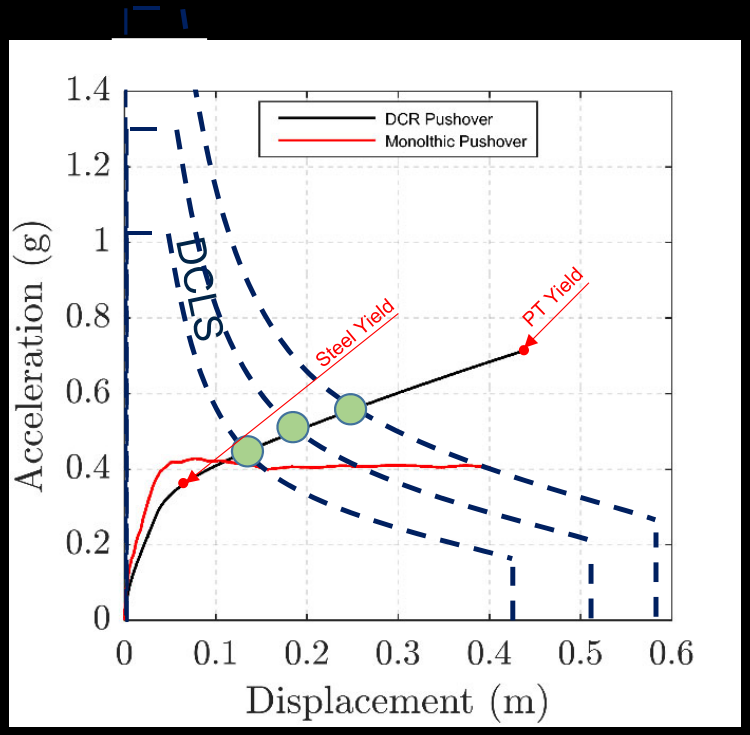
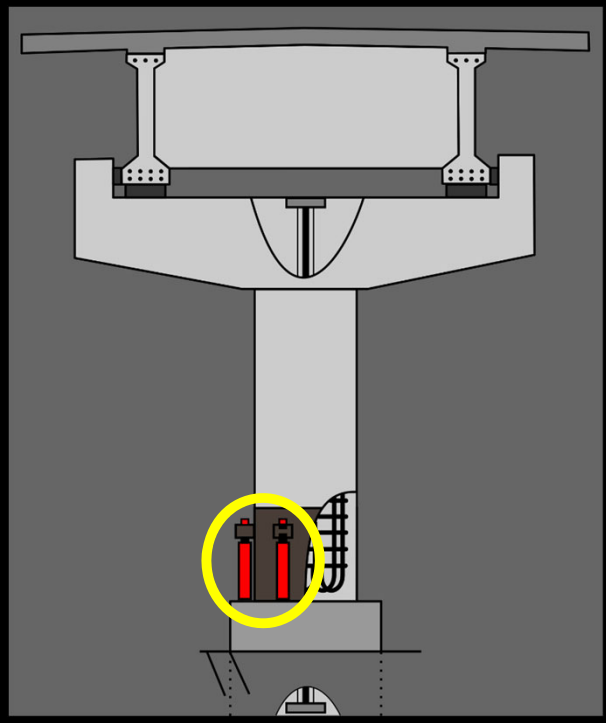


Replace Dissipaters



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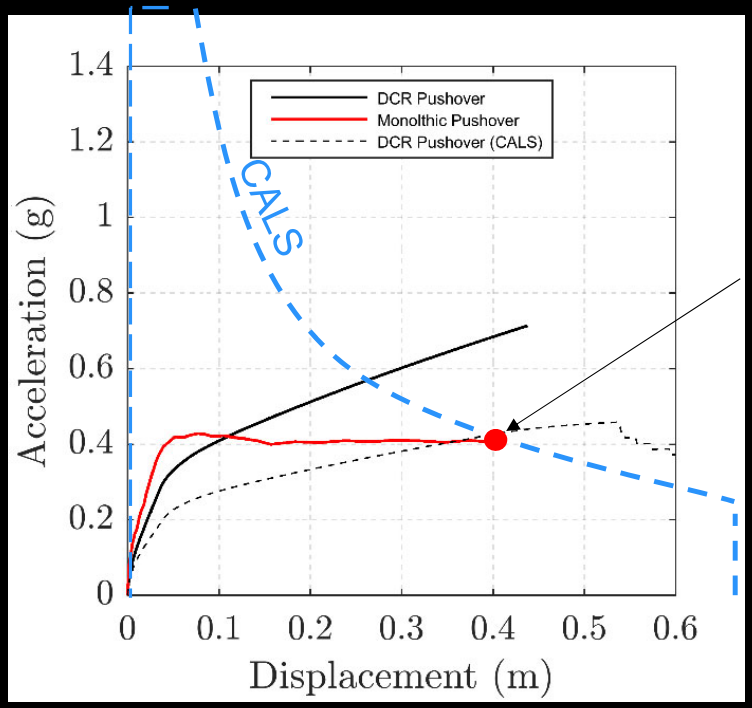

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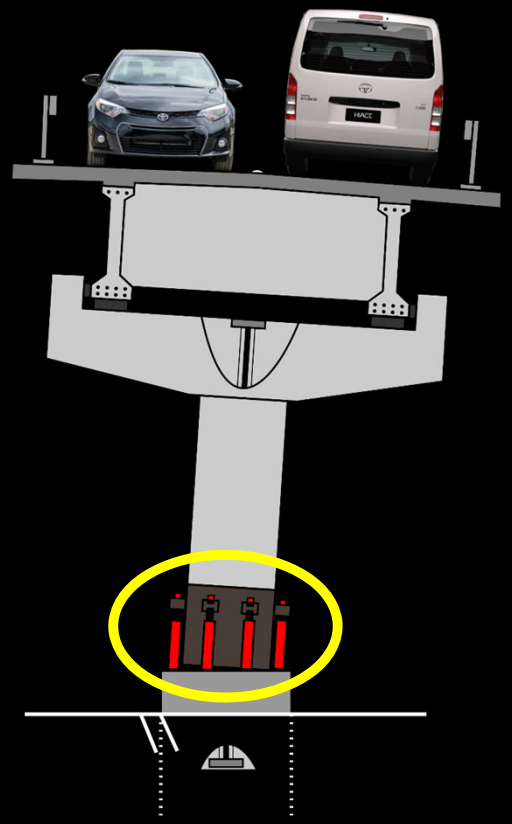

What to choose as the design strain?

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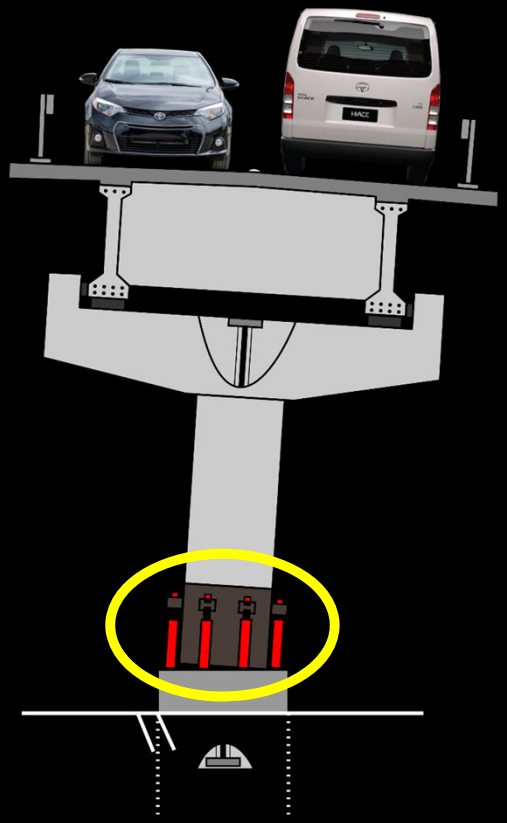

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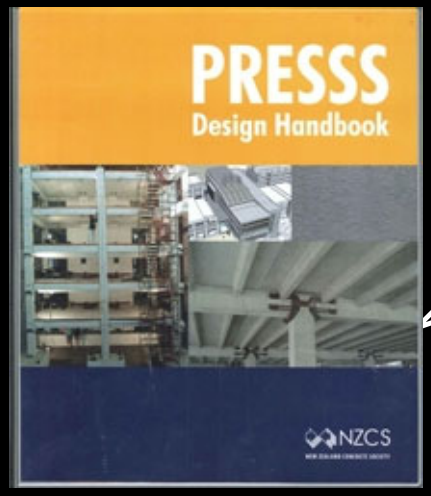

5% @ DCLS

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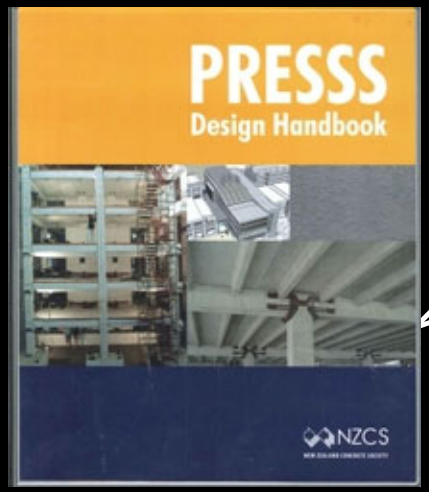
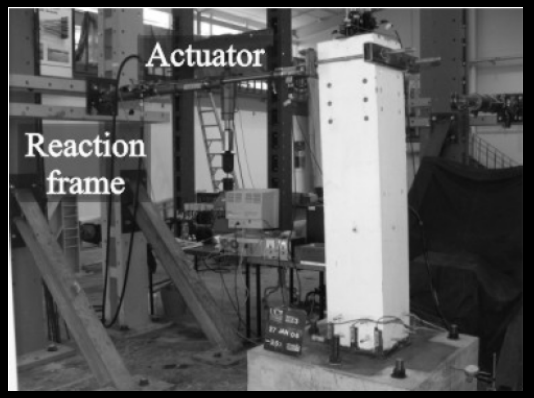
based on



5% @ DCLS



rather than

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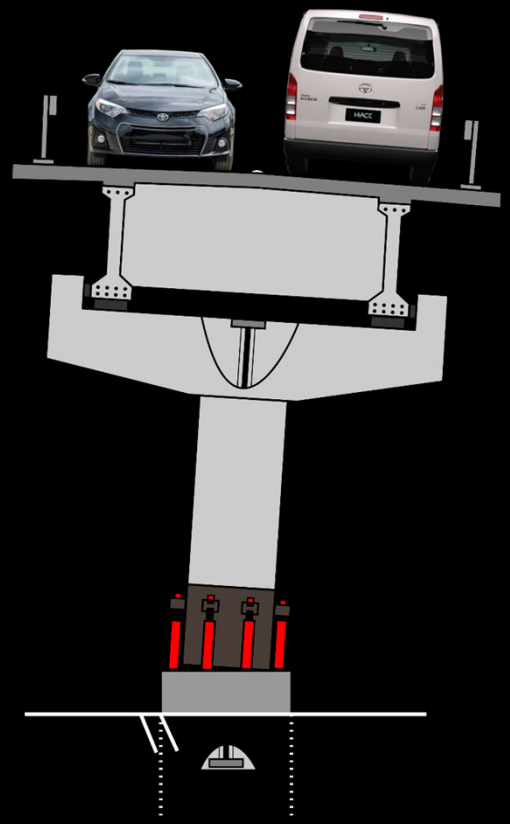

What to choose as the design strain?

Does designing directly for CALS have a negative impact on seismic performance?

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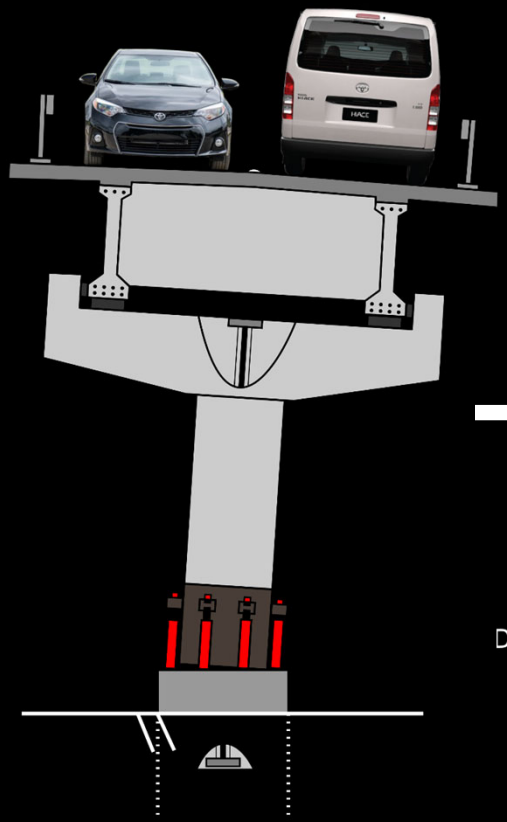

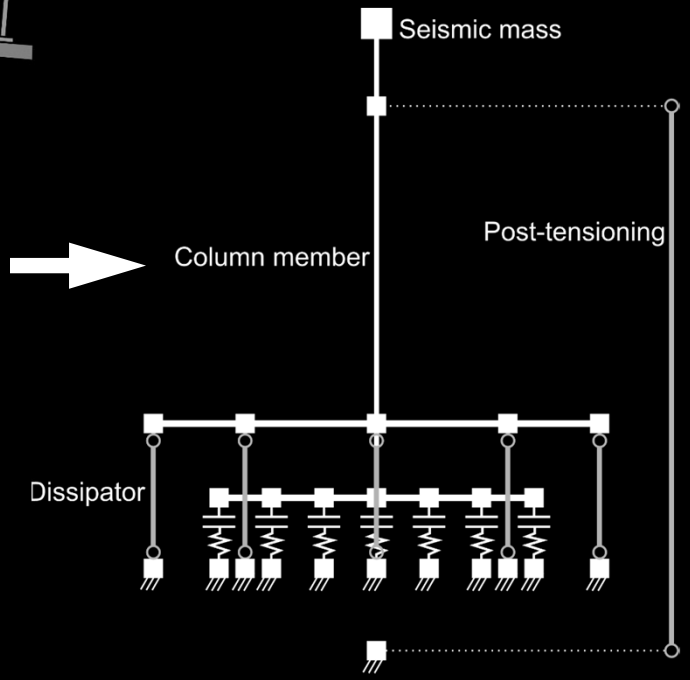

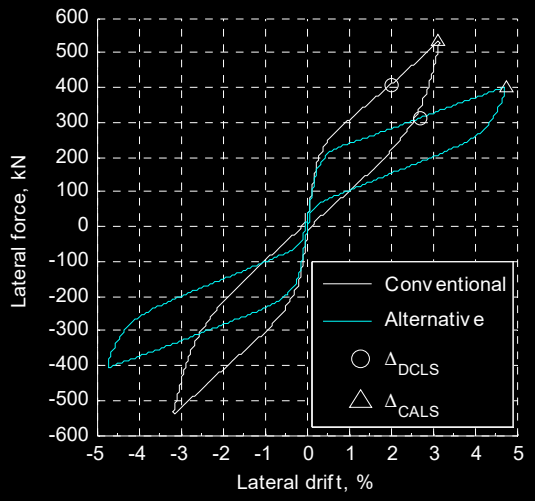

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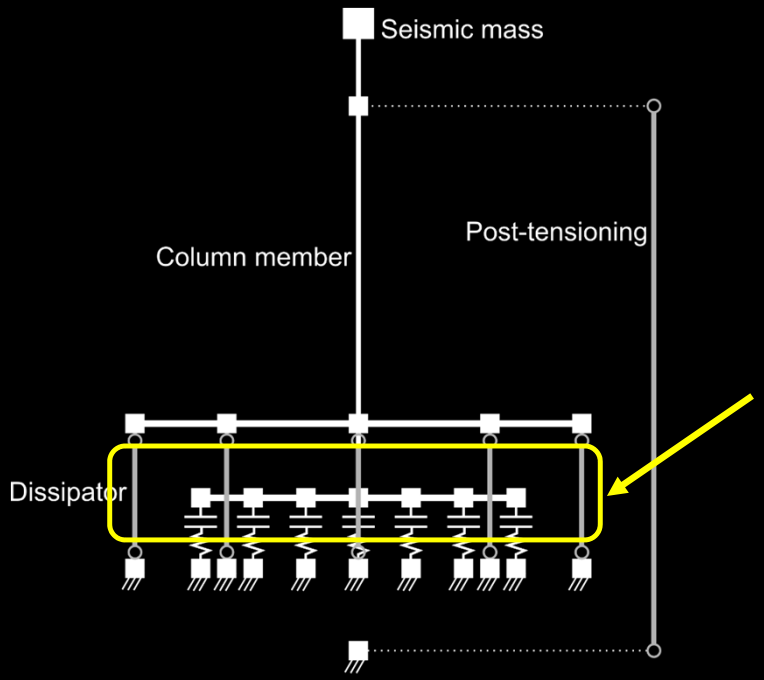

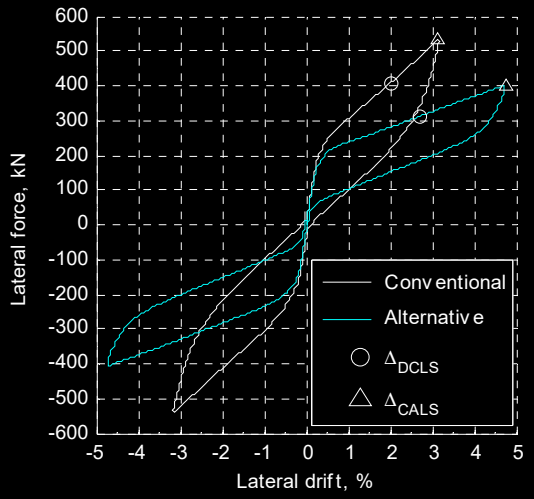

Structure	Dissipator strain at DCLS, %			
Conventional (DCLS first)	3 (5)	5 (9)	7 (15)	9 (15)
Alternative	4 (8)	6 (10)	7 (13)	9 (17)

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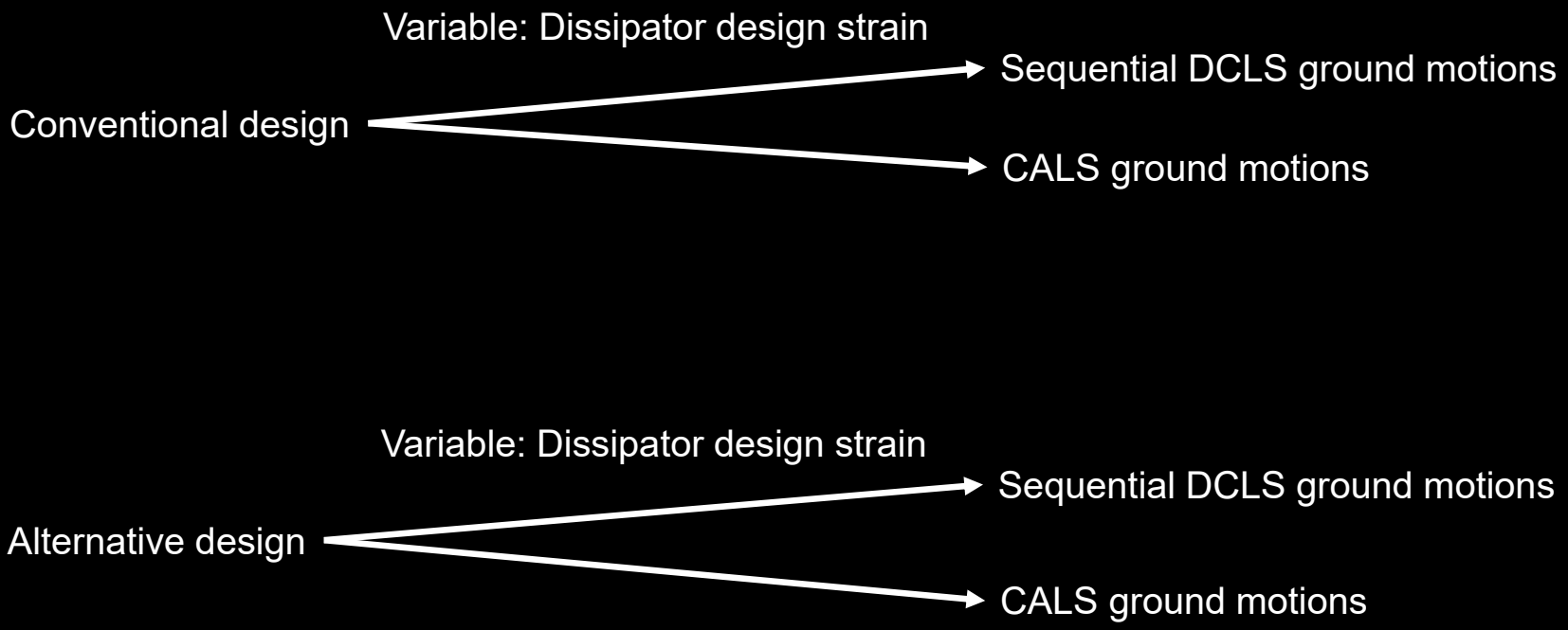

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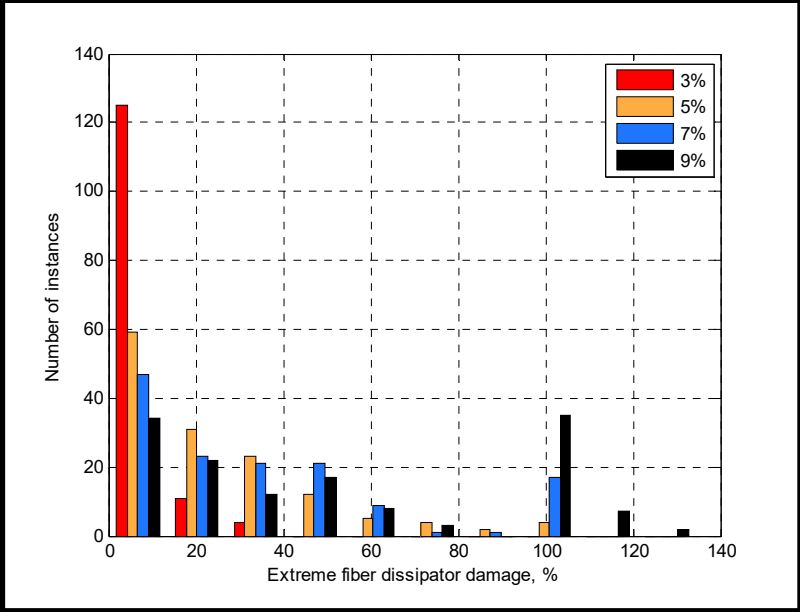
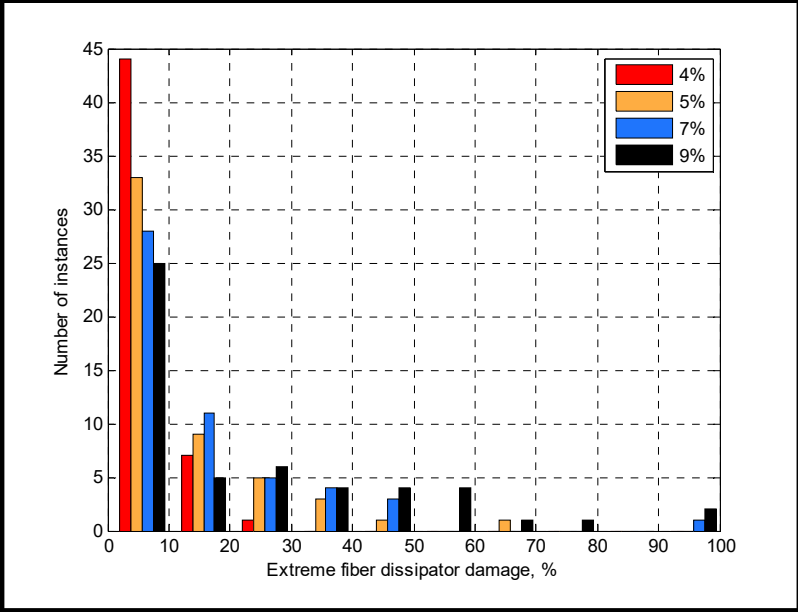
Results: CALS Ground motions

- Design strains did not significantly affect other engineering parameters: peak drift, residual drift, and peak PT force



Conventional



Alternative

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Results: CALS Ground motions

- Recommend a DCLS strain limit of 6% and CALS limit of 10%

DCLS design strain	3% Strain	5% Strain	7% Strain	9% Strain
CALS design strain	5% Strain	9% Strain	12% Strain	15% Strain
Number of GM's that caused rupture*	0	3	10	25
Average no. of dissipator layers which ruptured	0	1.3	1.7	2.2

Conventional

72 ground motions

DCLS design strain	4% Strain	6% Strain	7% Strain	9% Strain
CALS design strain	8% Strain	10% Strain	13% Strain	17% Strain
Number of GM's that caused rupture*	0	0	1	1
Average no. of dissipator layers which ruptured	0	0	1	3

Alternative

36 ground motions

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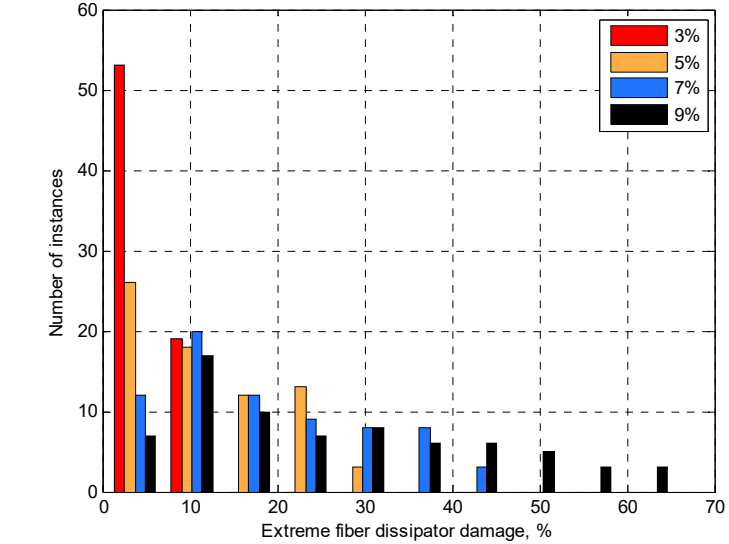
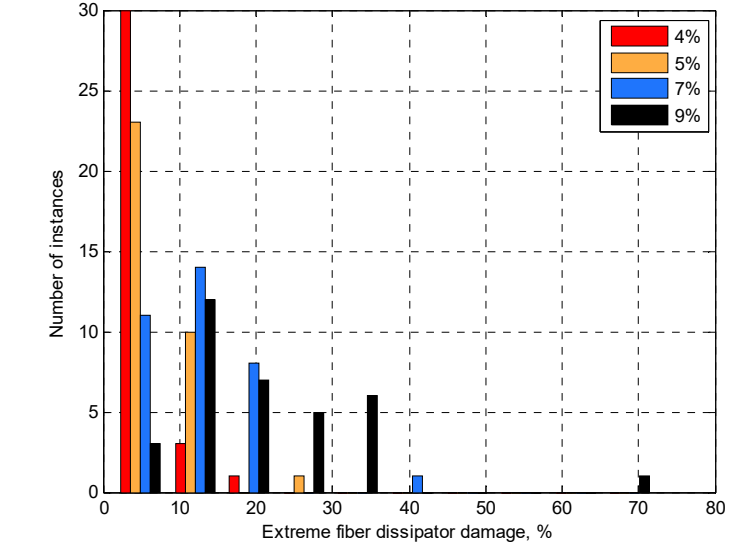
Results: Sequential DCLS Ground motions

- Cyclic demands from sequential events do not appear to be critical



Conventional



Alternative

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Vulnerability: Seismic Structural Redundancy

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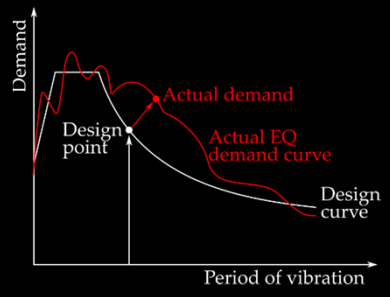
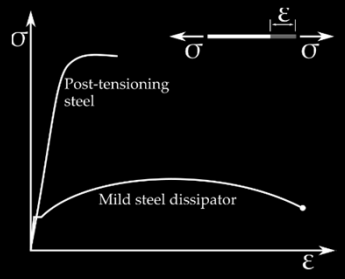
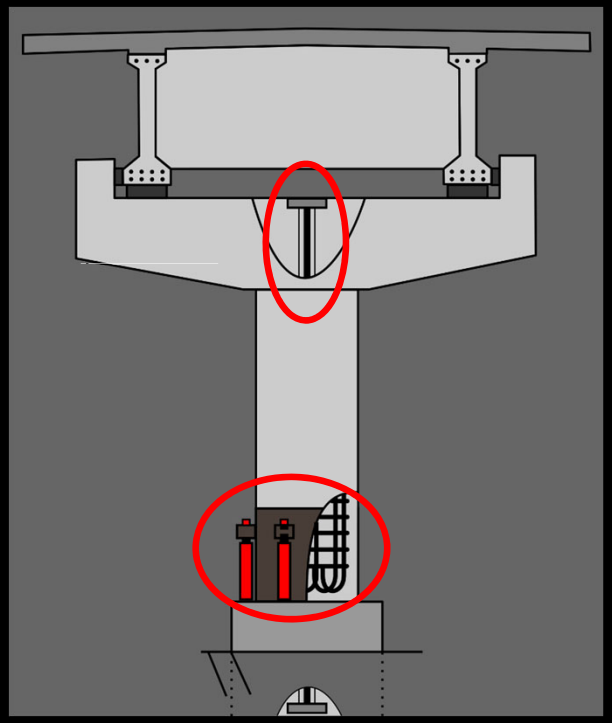
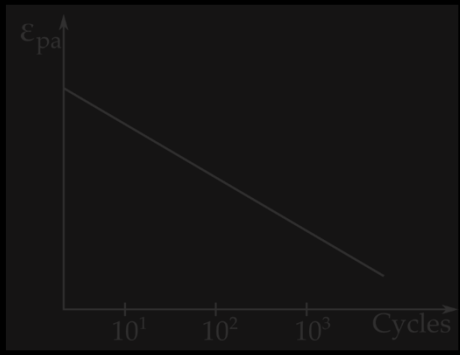
Design level exceedance







Sequential & long duration EQ's



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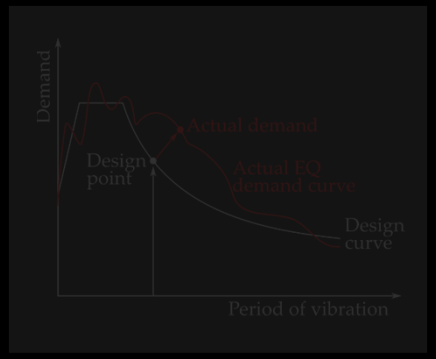
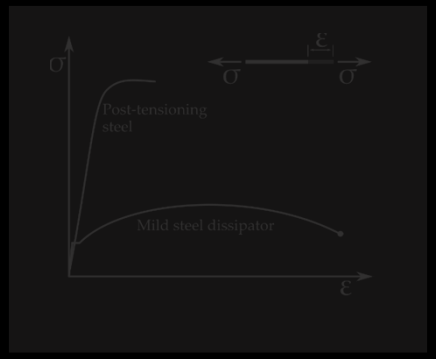
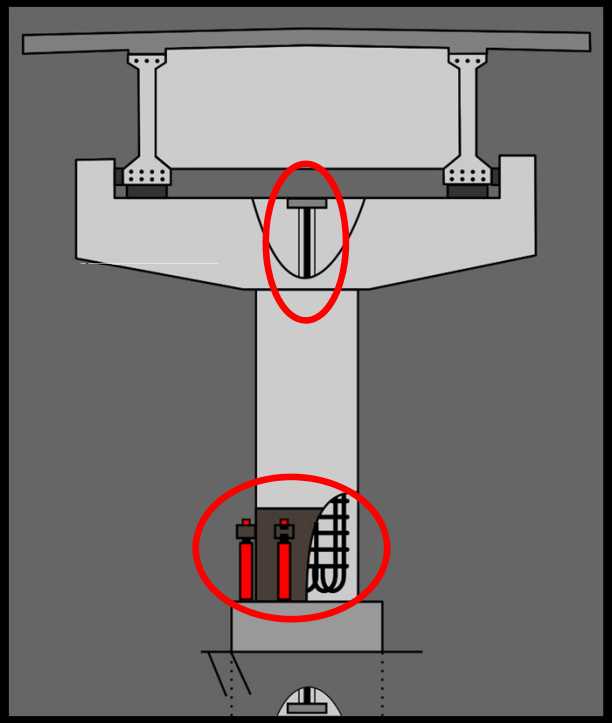
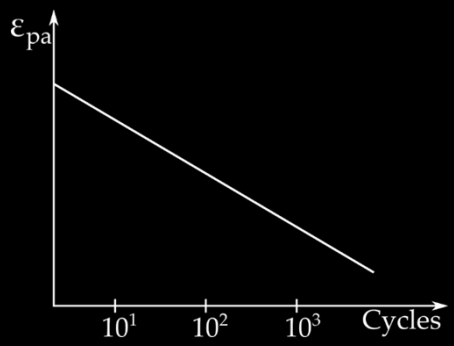






Sequential & long duration EQ's



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Background

Default limit state for Low Damage Design

Design strain specification for dissipators

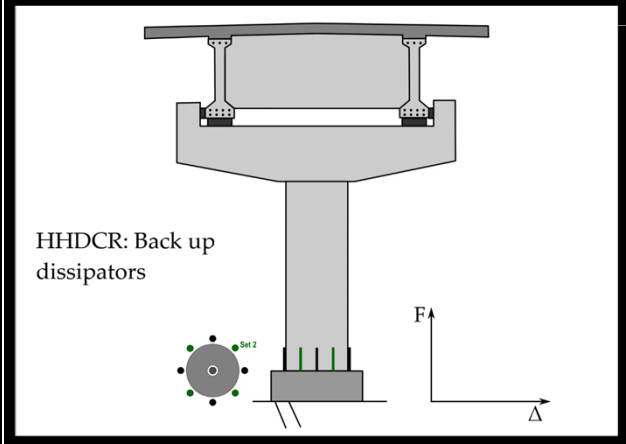
Modifying DCR for extreme earthquakes

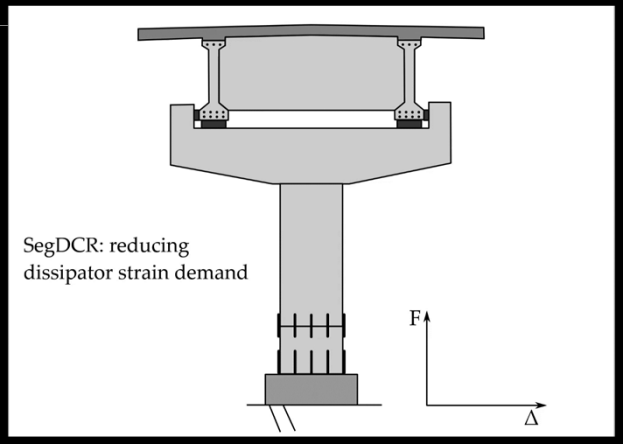
Conclusion

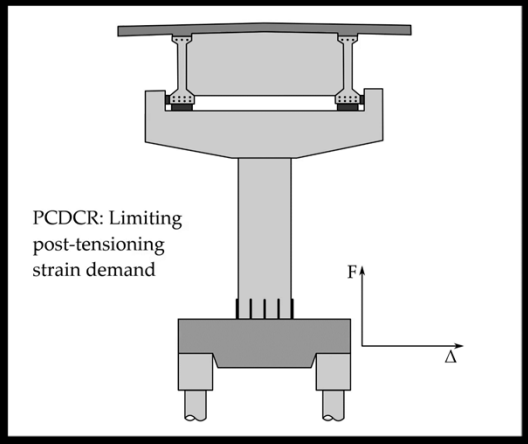
Improving Seismic Structural Redundancy

Modify the structural system

- Back up set of dissipative devices
- Reduce demand on dissipative devices
- Limit the amount the post-tensioning bar can be stretched







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Outcomes

- Direct design for Collapse Avoidance Limit State
  - DCR is repairable
  - There is only one damage state between DCLS and CALS
- Recommend DCLS strain limit of 6% and CALS limit of 10%
- CALS events govern over sequential DCLS in terms of LCF demand
- Presented methods to modify DCR for improving seismic structural redundancy