DAD Post-Tensioned Concrete Connections with Lead Dampers: Analytical Models and Experimental Validation

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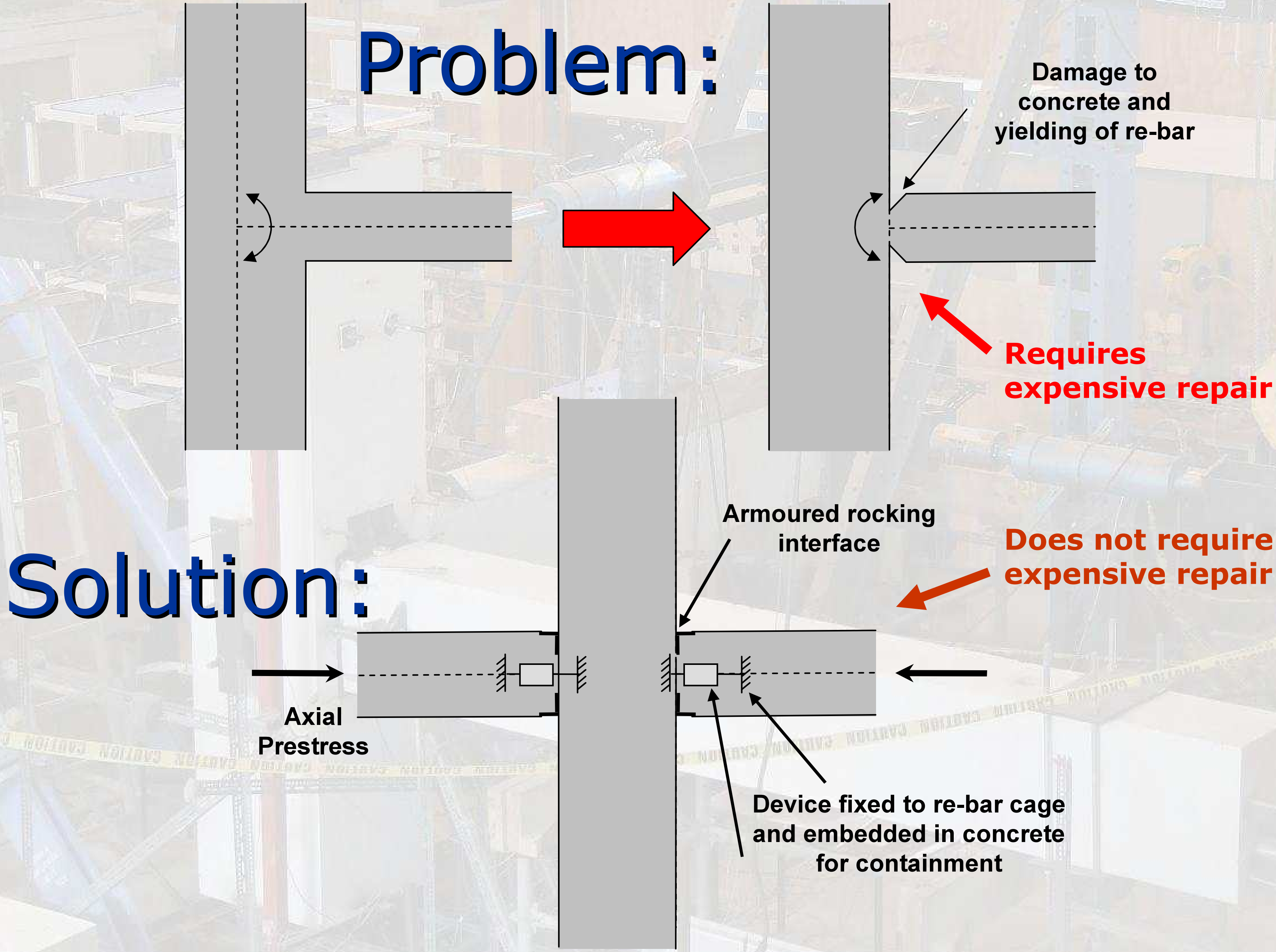
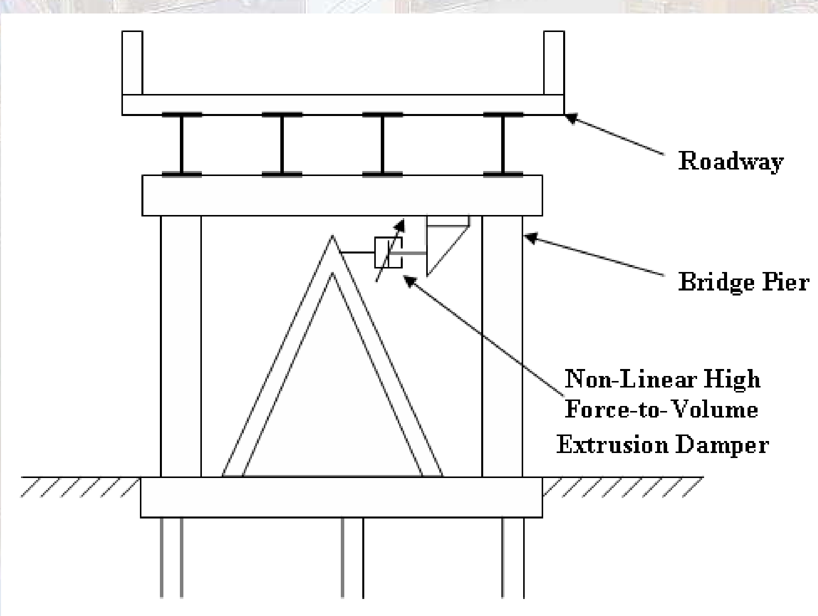


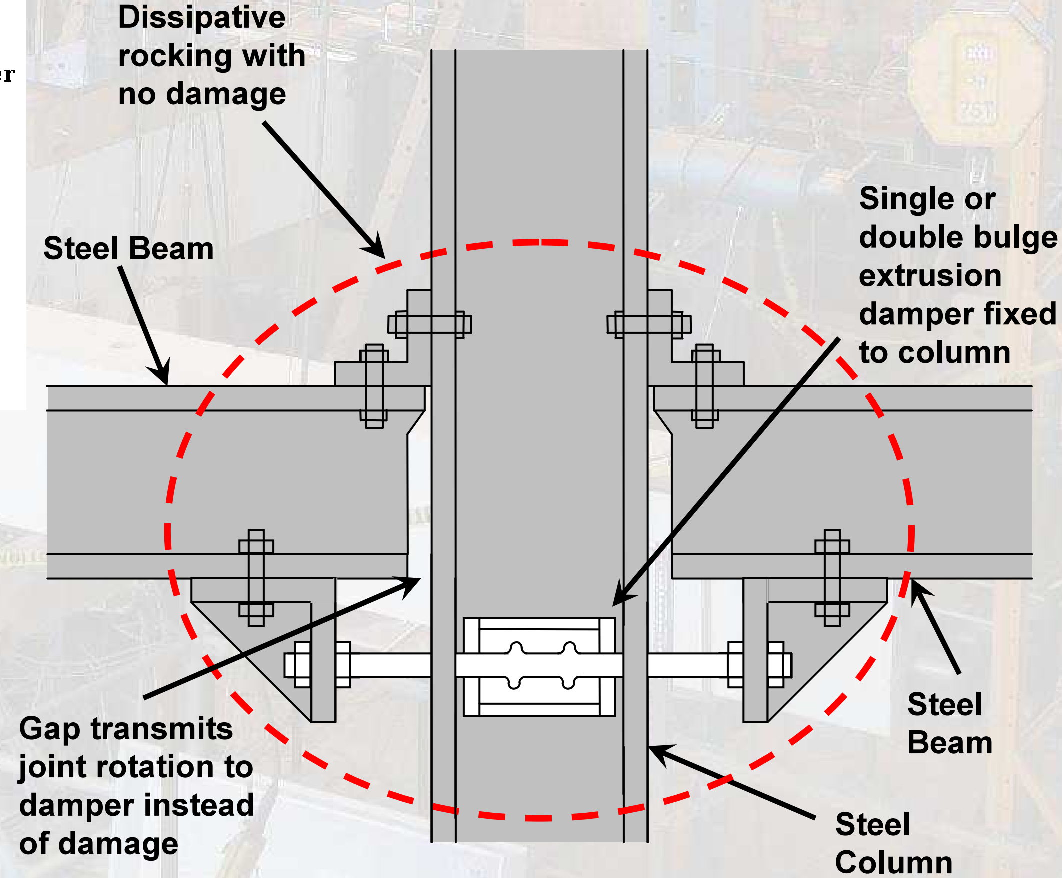
Significantly reduce yielding of the critical reinforcing bar.
This will also absorb more energy– particularly after 1-2 cycles.

Possible Applications

Seismically Vulnerable Bridge Piers



Direct Placement into Steel Joints



- Steel joints
- Reinforced concrete joints
- Bridge decks
- Tuned mass dampers
- Base isolation

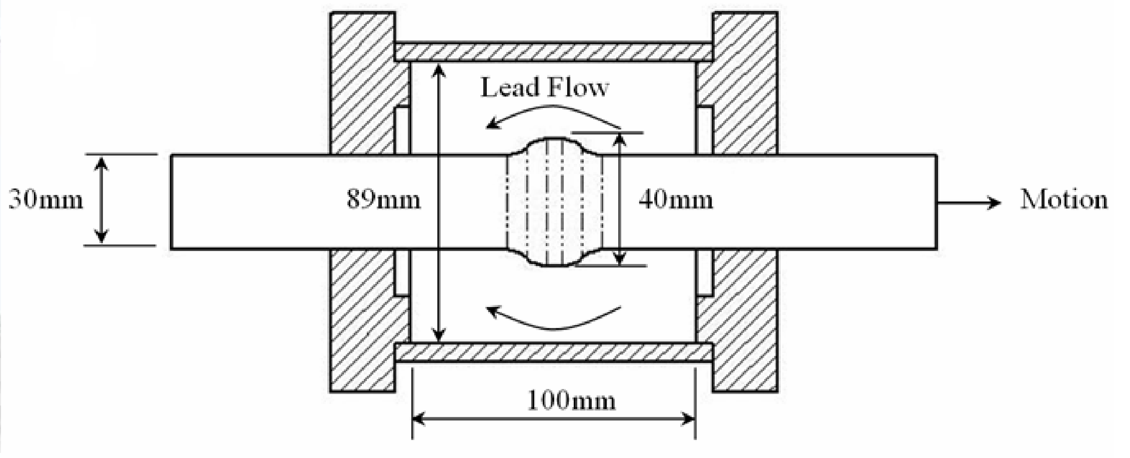
Main Goals

- **High force capacity** = High dissipation
  - Only 3-10 large response cycles per big earthquake
- **Small device volume**
  - Tight constraints for typical structural connections - Universal column sections nominally 350mm deep – W14 in American Codes
- **Maximum energy dissipation per cycle**
  - “Square” hysteresis loop
- **Goal:** Dissipate energy in the device every cycle rather than by damage to structural connections

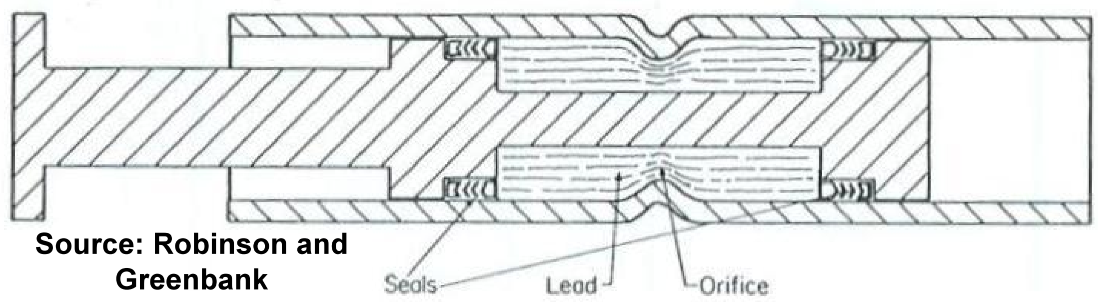
Device Mechanics

Plastic extrusion of working material through an annular restriction

Bulged-shaft type extrusion damper



Constricted-tube type extrusion damper

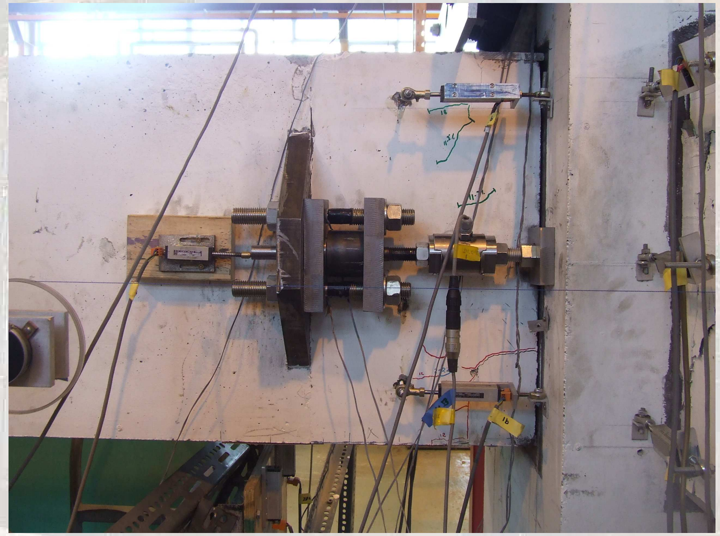


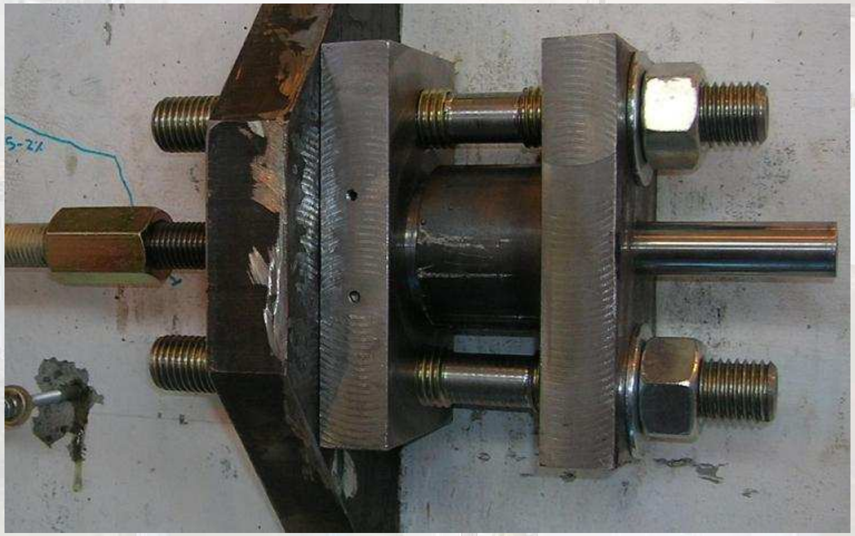
Source: Robinson and Greenbank

Bulged-shaft design chosen for low manufacturing cost and repeatable results

Structural Implementation

Placement of lead extrusion dampers into the rocking interface of a reinforced concrete joint.

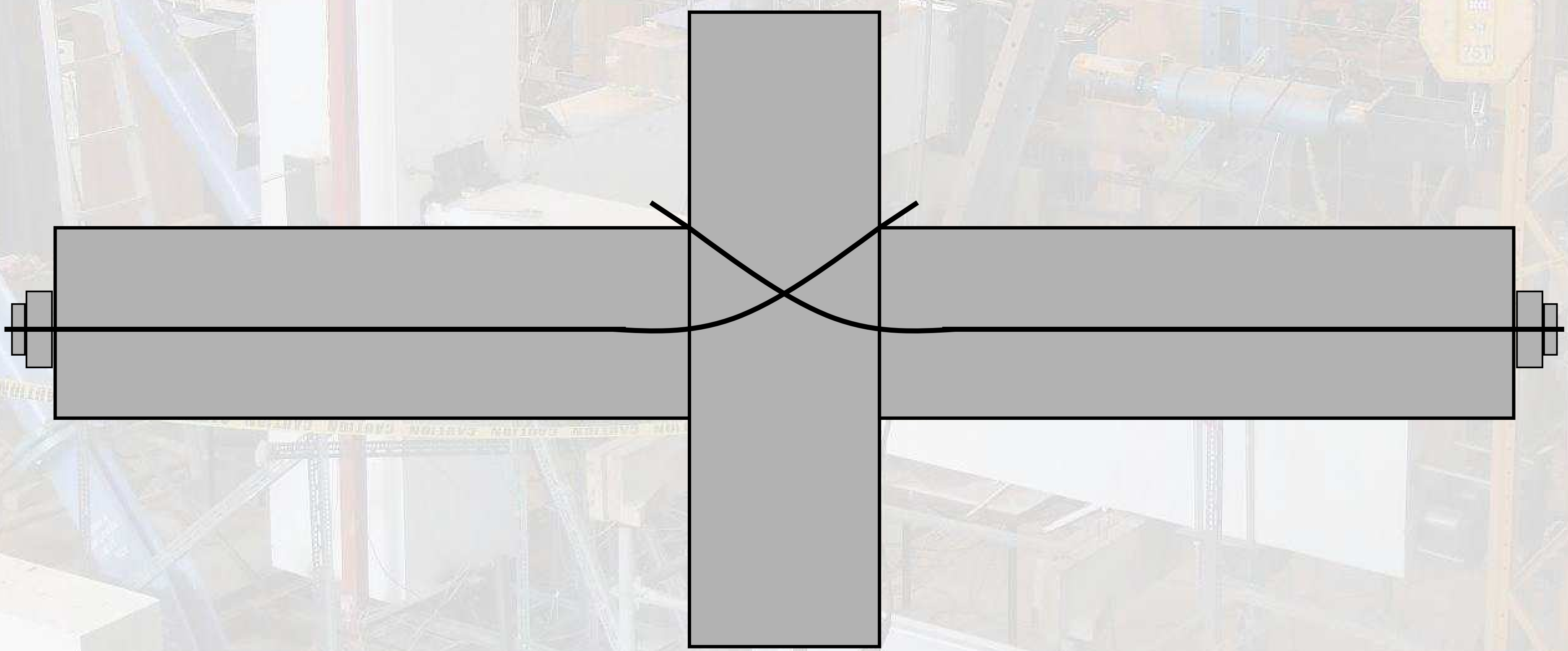




Structural Implementation

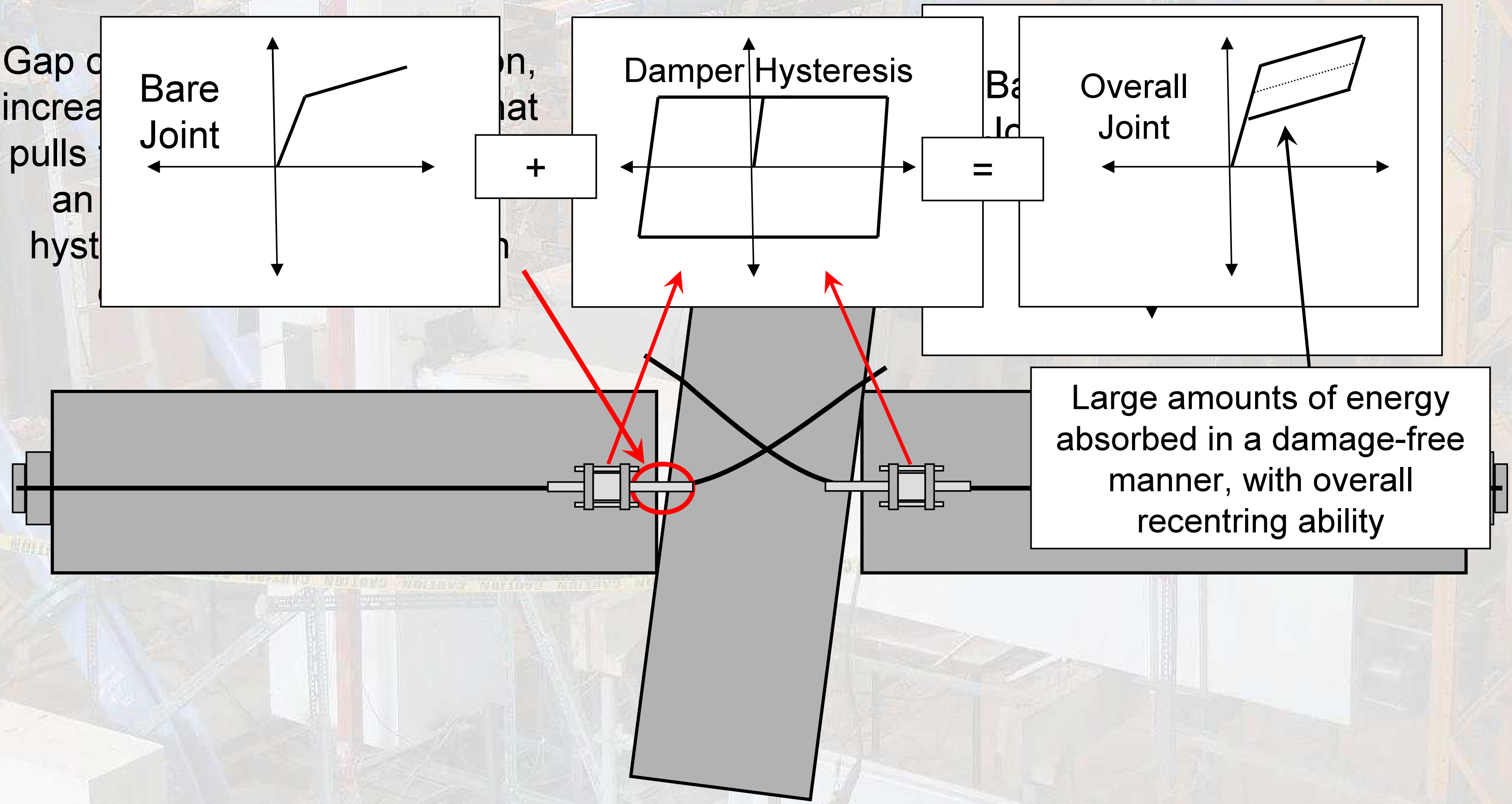
Recent research has focused on damage-free jointed pre-cast connections

Beams and columns are completely separate entities, held together by post-tensioned tendons running through the joint region



Structural Implementation

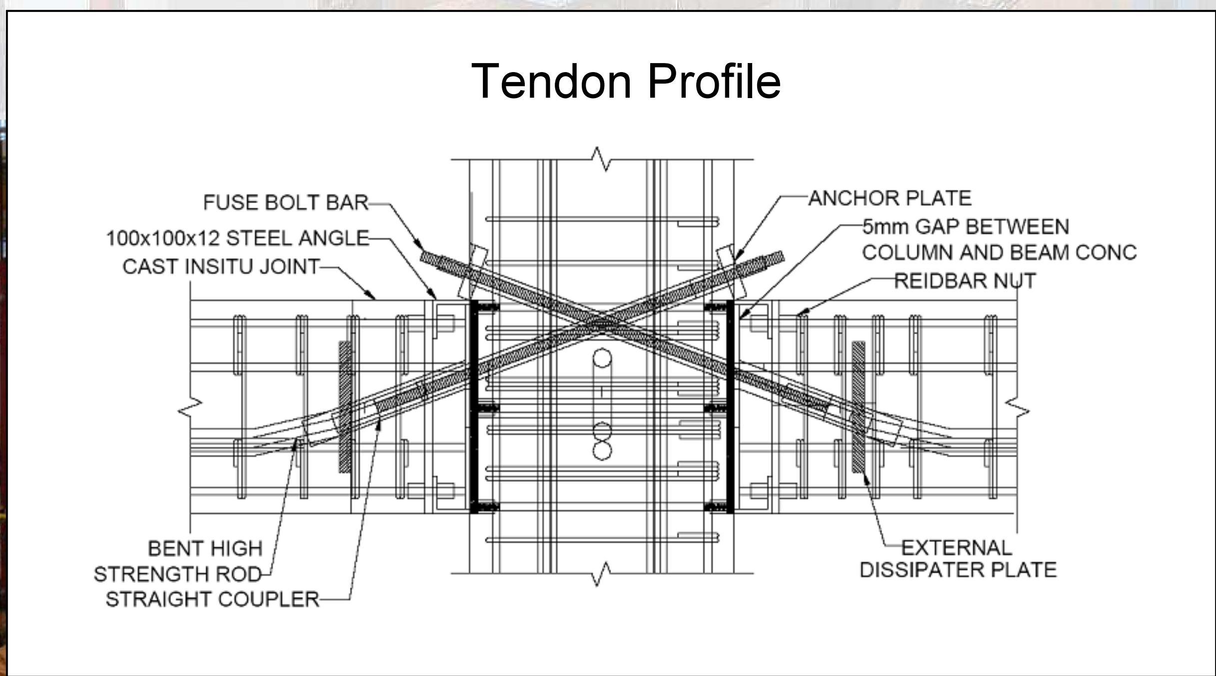
Non-linear response is achieved by joint-opening at the connection in place of structural damage and the formation of a plastic hinge

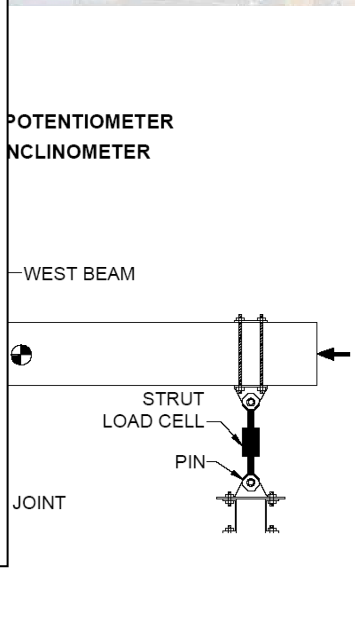


Experimental Joint Testing

A near full-scale 3D joint configuration was constructed using Damage-Avoidance Design principles.

This joint utilised a bend tendon profile

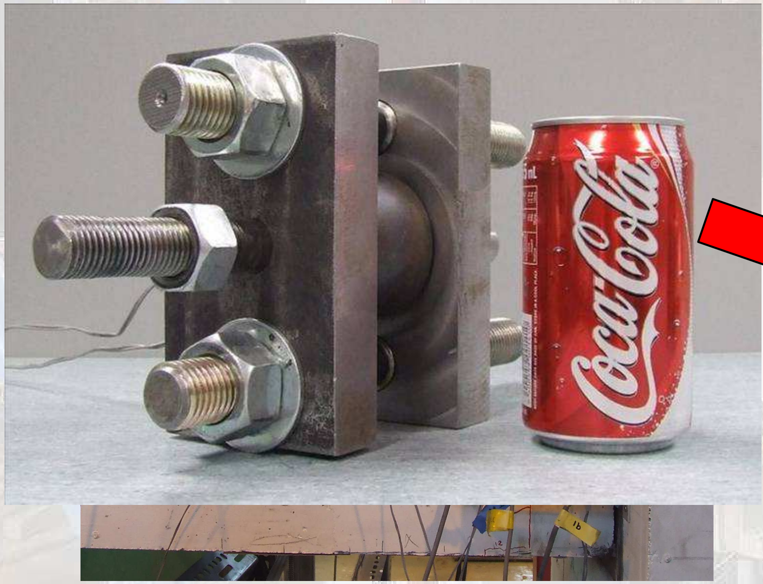


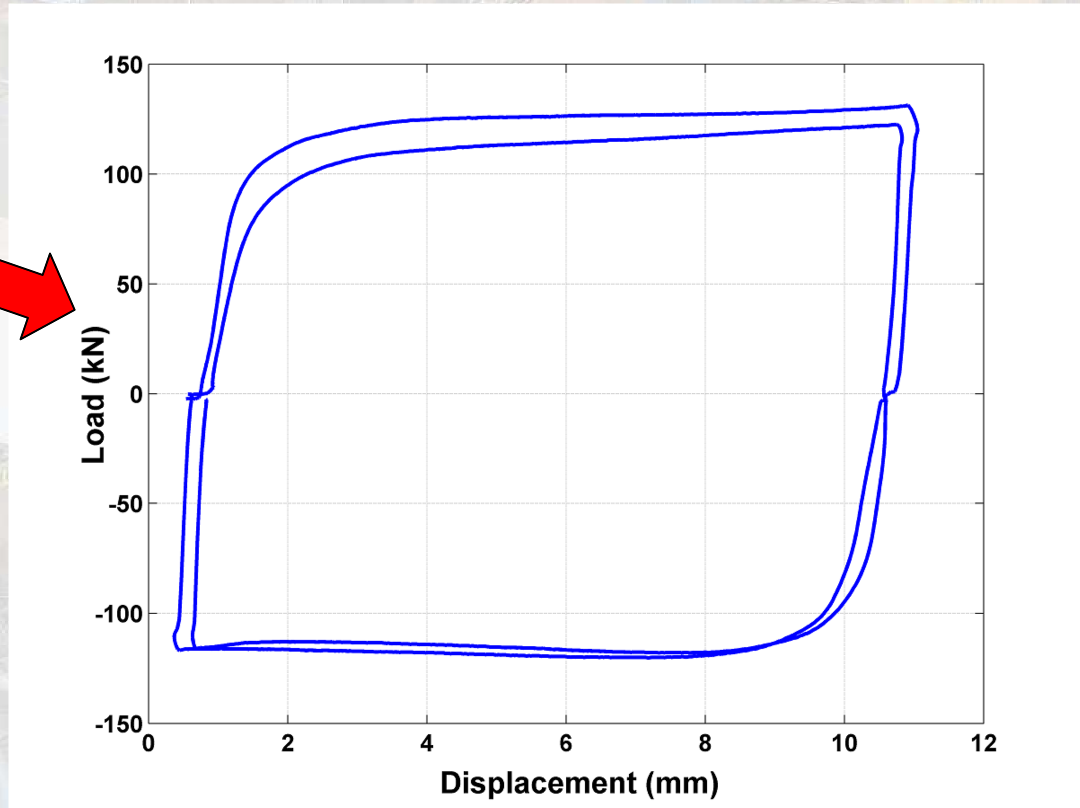


Externally Mounted Dampers

Damage-Avoidance-Design (DAD) joint have very low inherent damping, so another form of energy dissipation is provided.

By mounting lead extrusion dampers across the joint region, joint opening leads to large amounts of energy being absorbed directly in the joint.

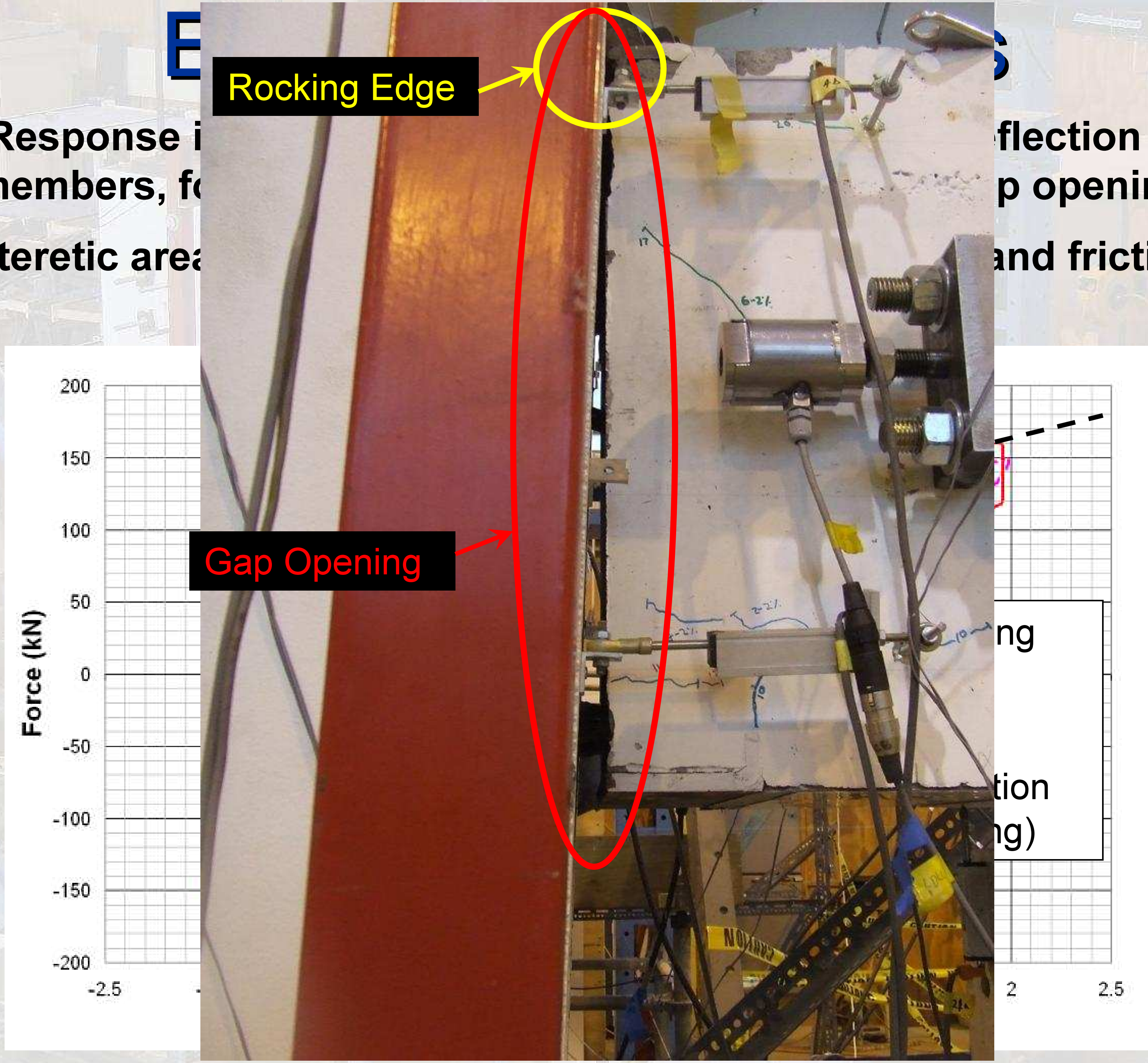




E… s

Response i… flection of members, f… p opening.

Hysteretic are… and friction of

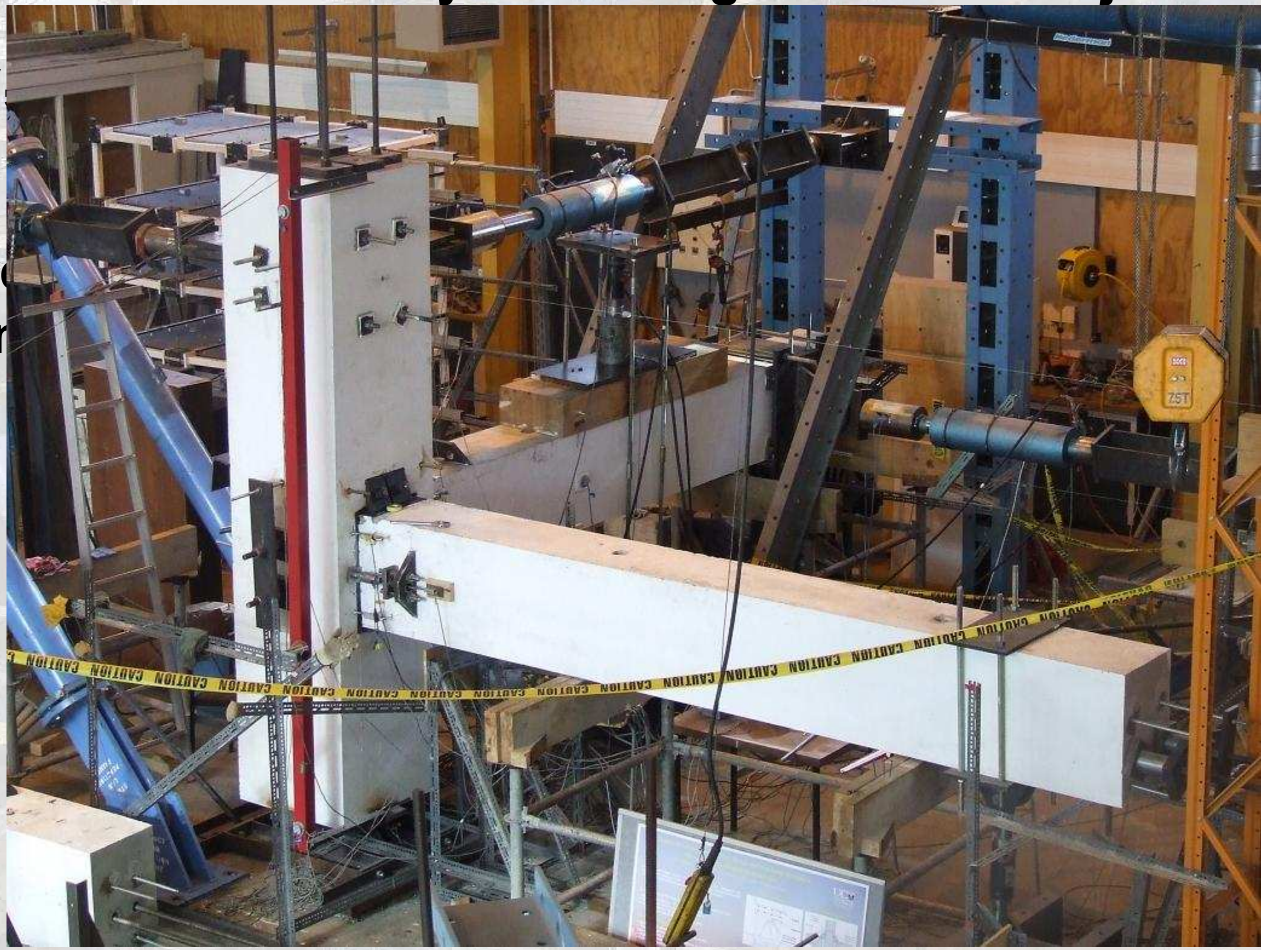


Corner Joint

The original joint has only most amounts of added damping, kept low to ensure ready recentring of the overall joint.

In reality, … the loss of

There… d both extrusion… amount of

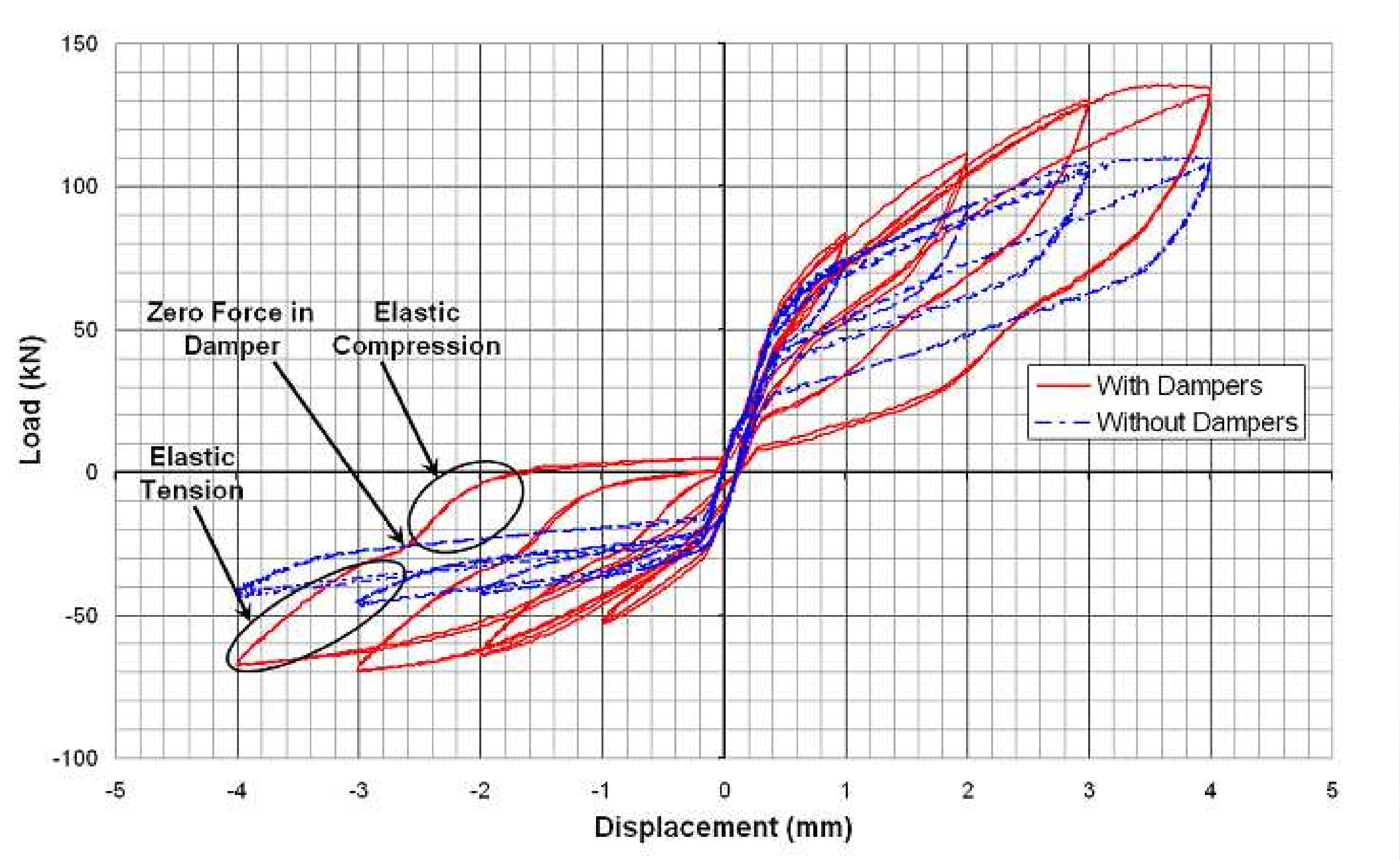


Corner Joint Results

Much larger hysteretic area – much larger dissipation

Asymmetry of force due to eccentric tendon profile

Asymmetry of inherent hysteresis due also to tendon profile



High Force-to-Volume Experiment and Overall Summary

- Significant added force capacity
- “Weak” joint with device can outperform sacrificial designs in first and every cycle – by design!
  - Easily fit inside of existing typical structural connections
- Large amounts of energy dissipated, without damage, and ready joint recentring
- Design equations derived for devices and for application (spectral analysis) – we can make any “size” for any application

Conclusions

- Novel devices can enable significant new applications
  - Open several new design avenues not previously available
- Large amounts of energy can be absorbed reliably and repeatably
- Damage can be significantly reduced or eliminated
- Full or large scale validation of all concepts
  - Several further applications show promise in analysis (using validated models) and/or hybrid experimental testing