

SANDFORD FLEMING FORUM

Resilience: Emerging Thinking and Practice

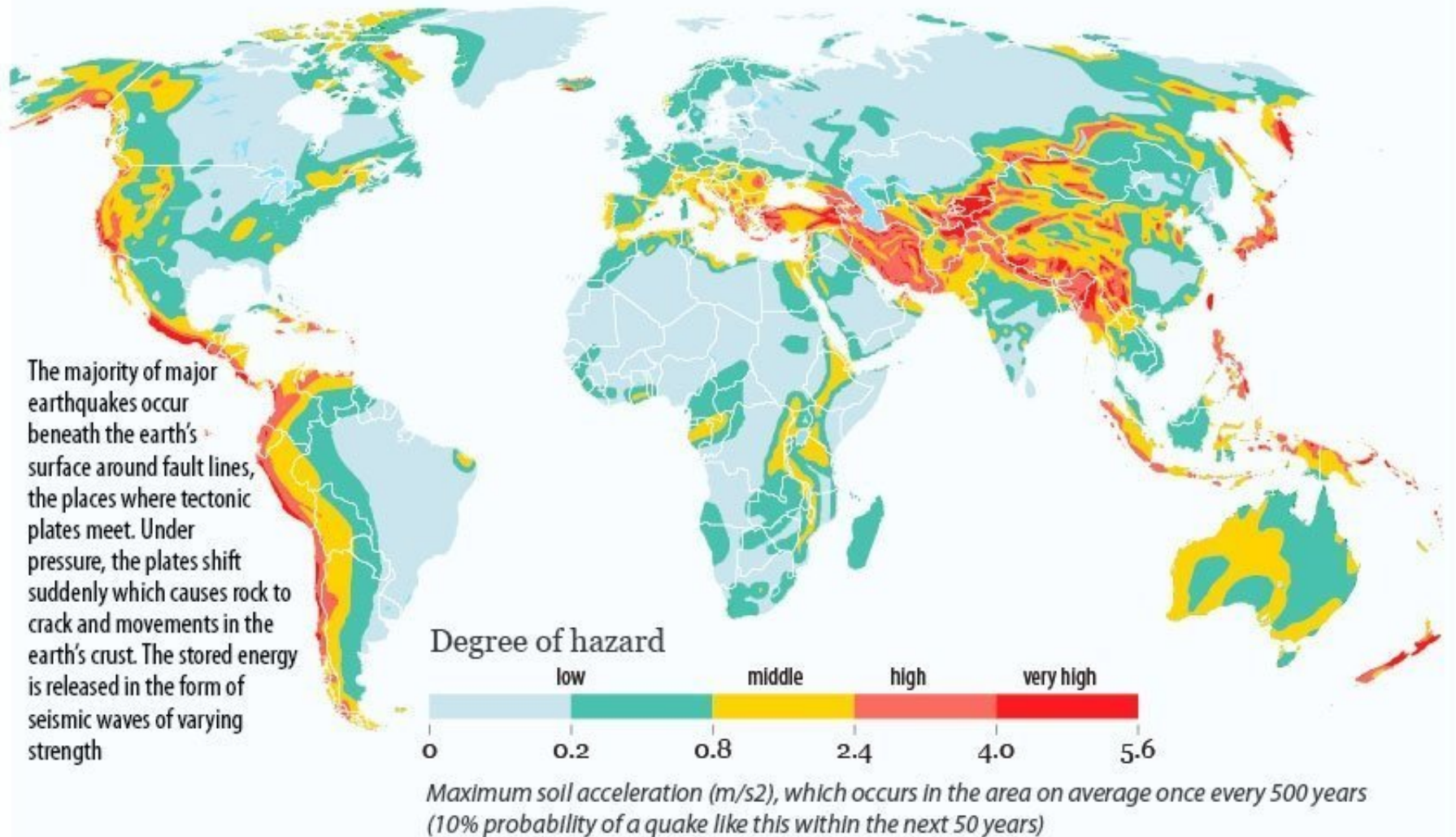


Seismic Resiliency

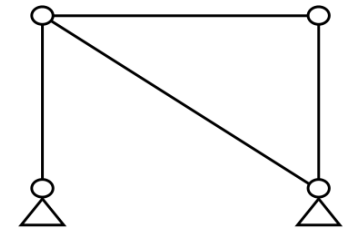
Dr. Michael Gray

October 9, 2014

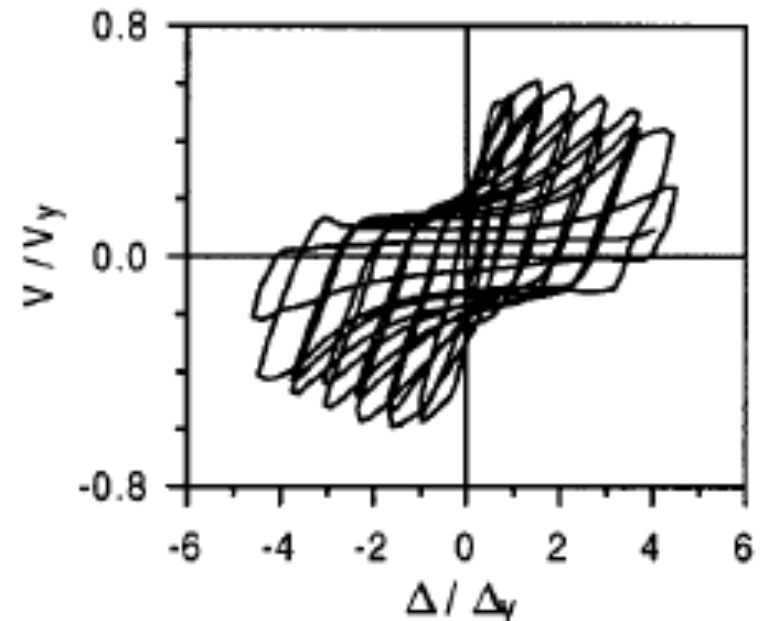
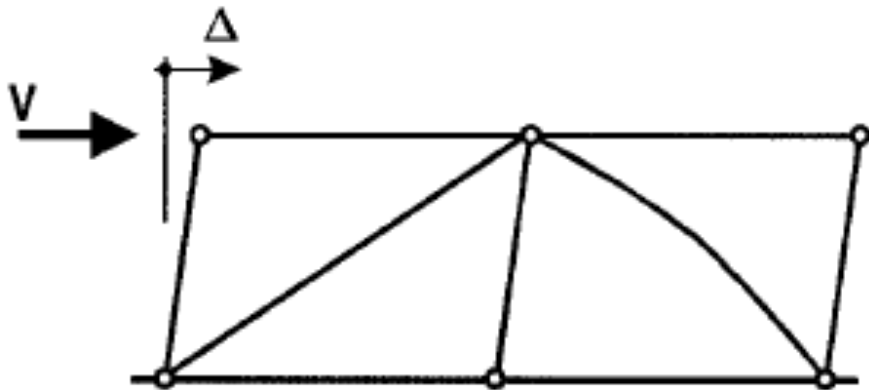
Seismic hazard map

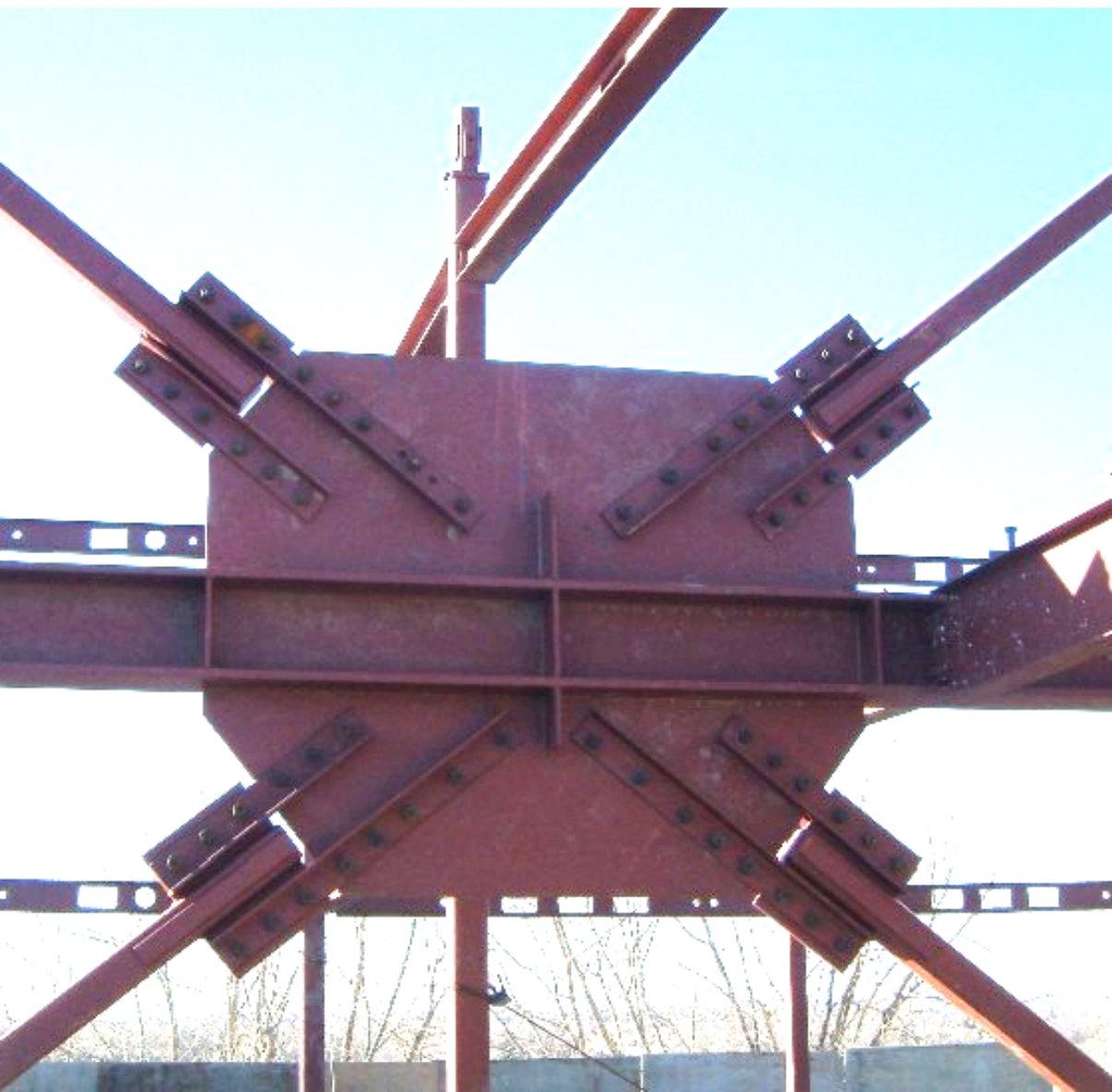


Earthquake Response of Braced Frames



As a frame deforms beyond its elastic range, its brace members are intended to **yield in tension** and **buckle in compression**





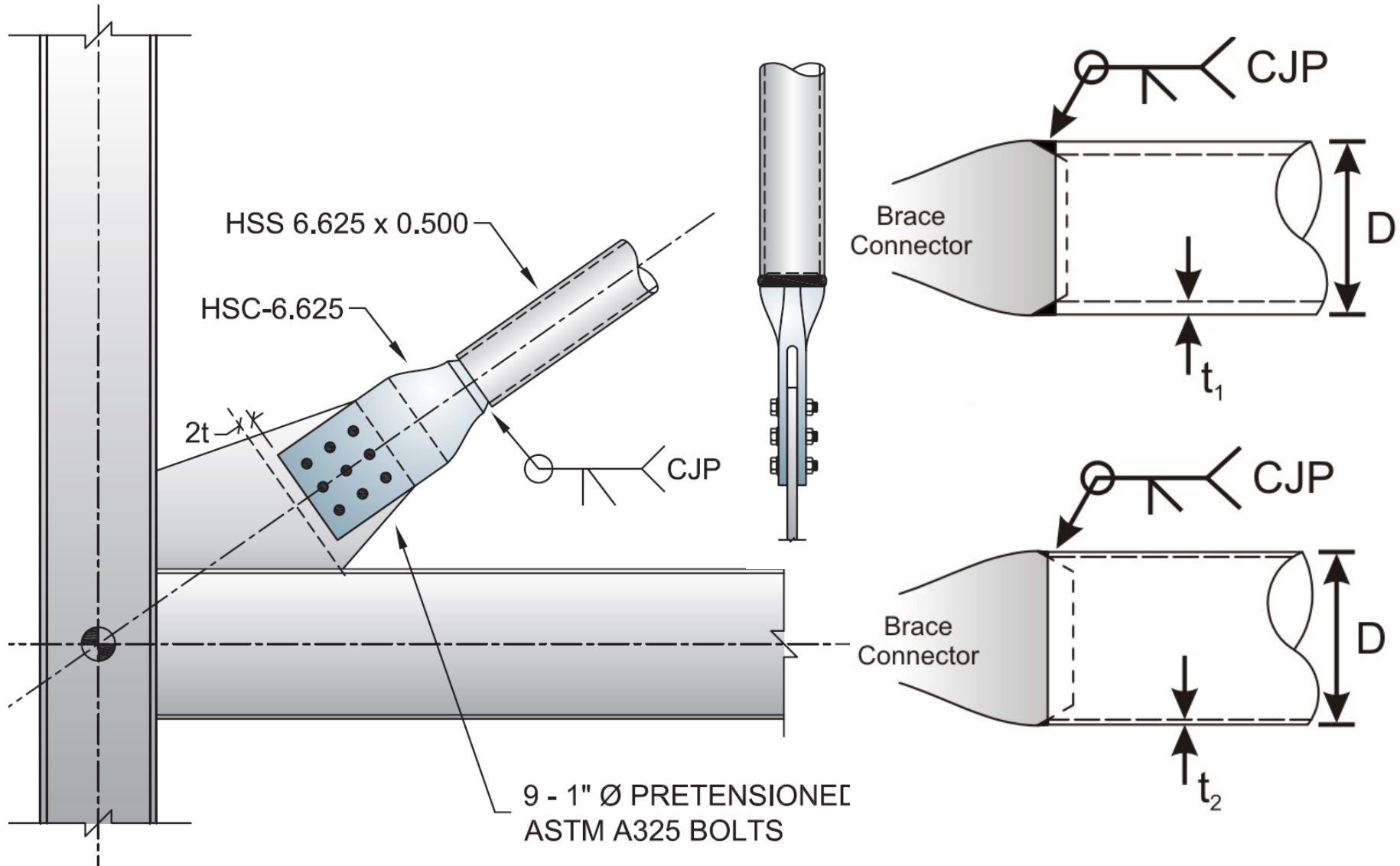
Concepción, Chile

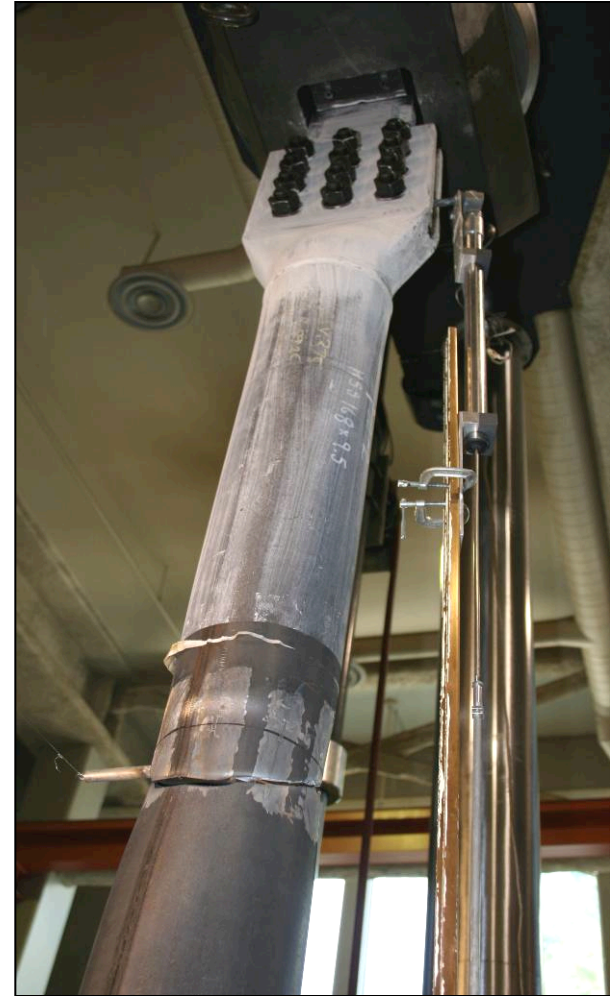


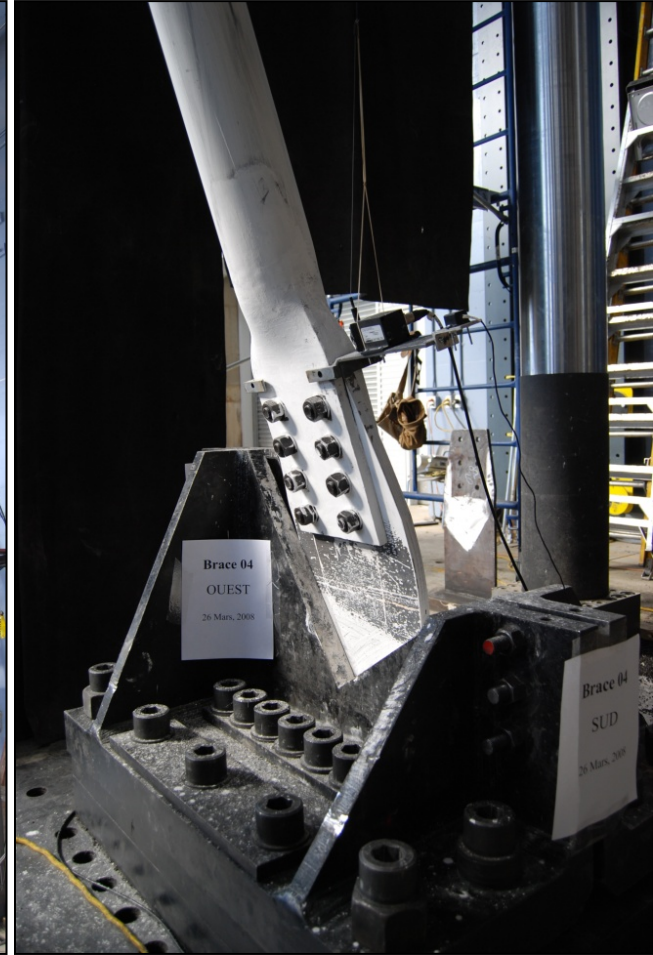
Tohoku, Japan

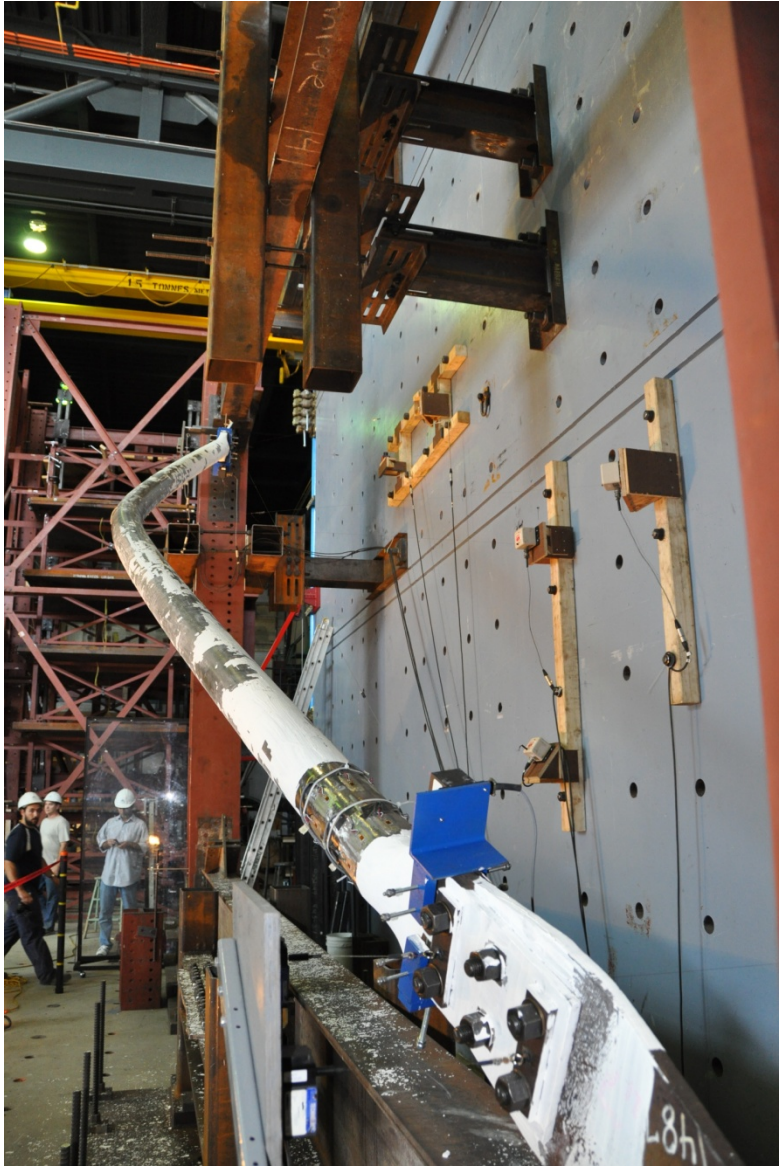


High Strength Connector

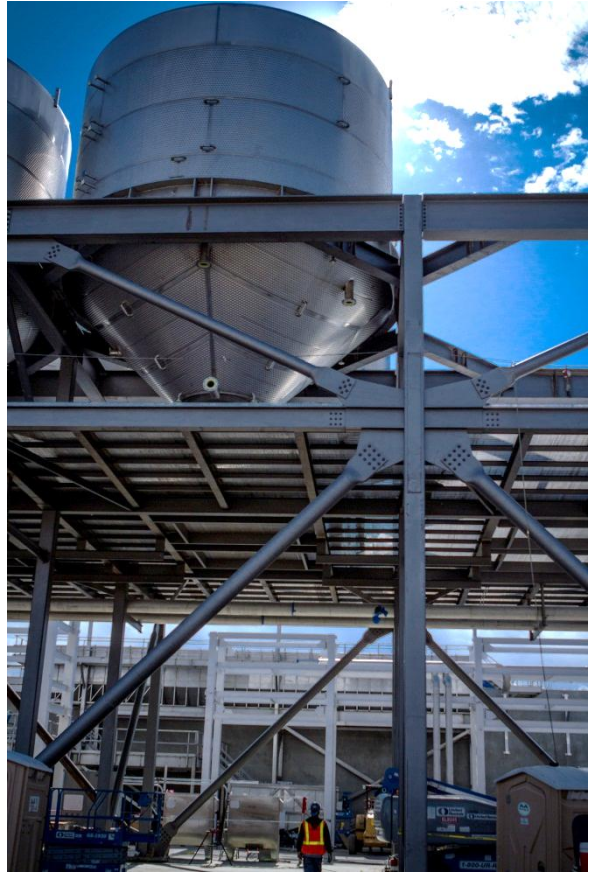






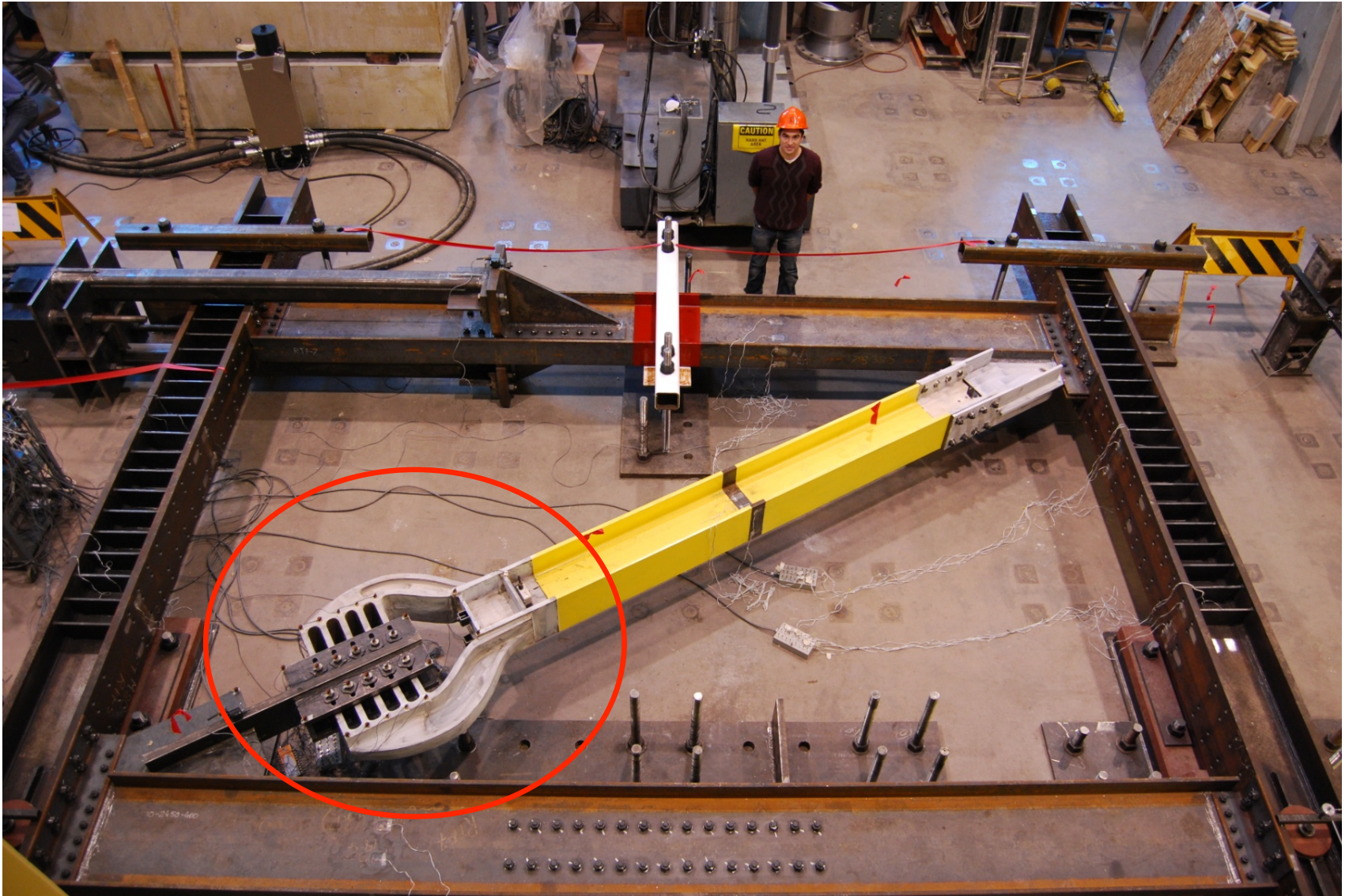




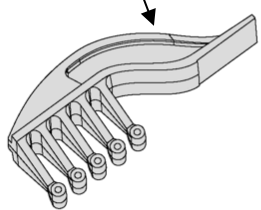




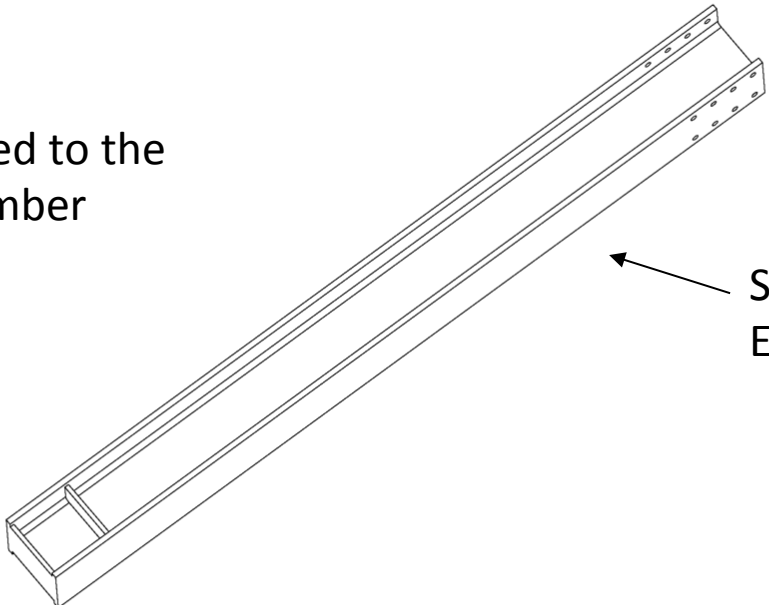
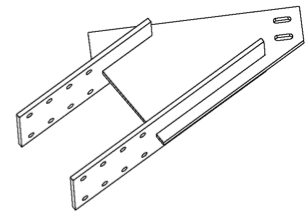
Yielding Connector



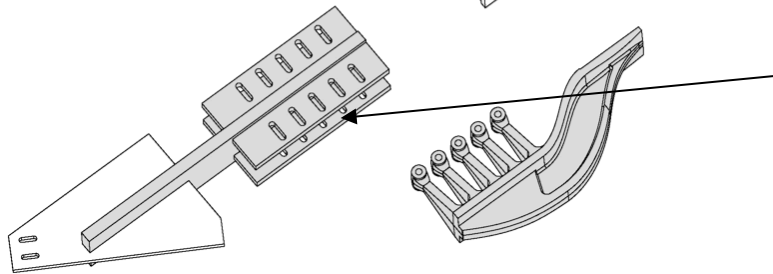
Two Cast Arms Welded to the End of the Brace Member

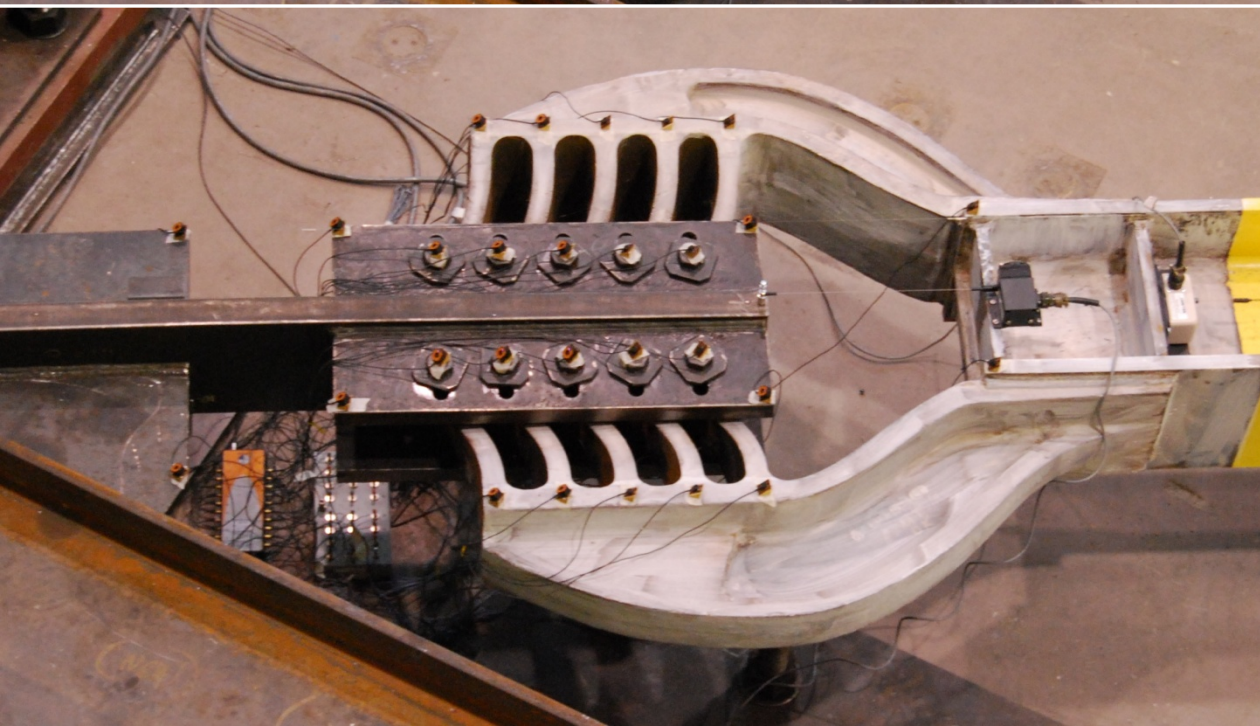
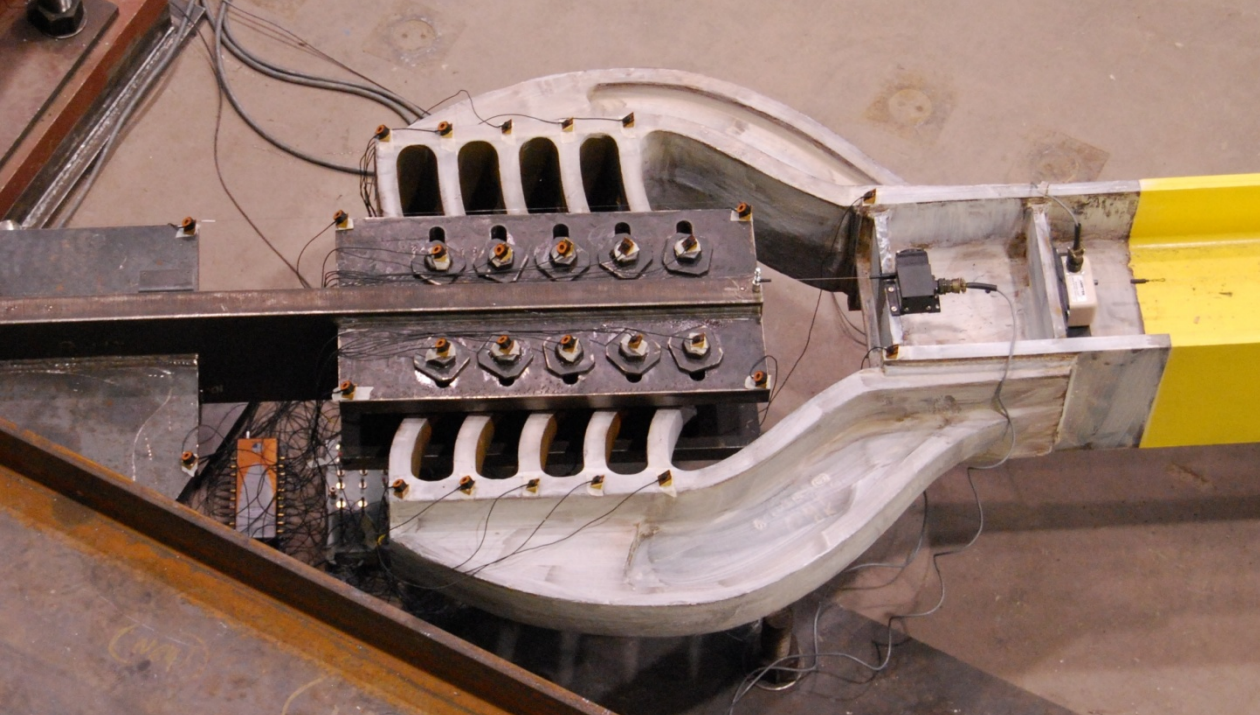


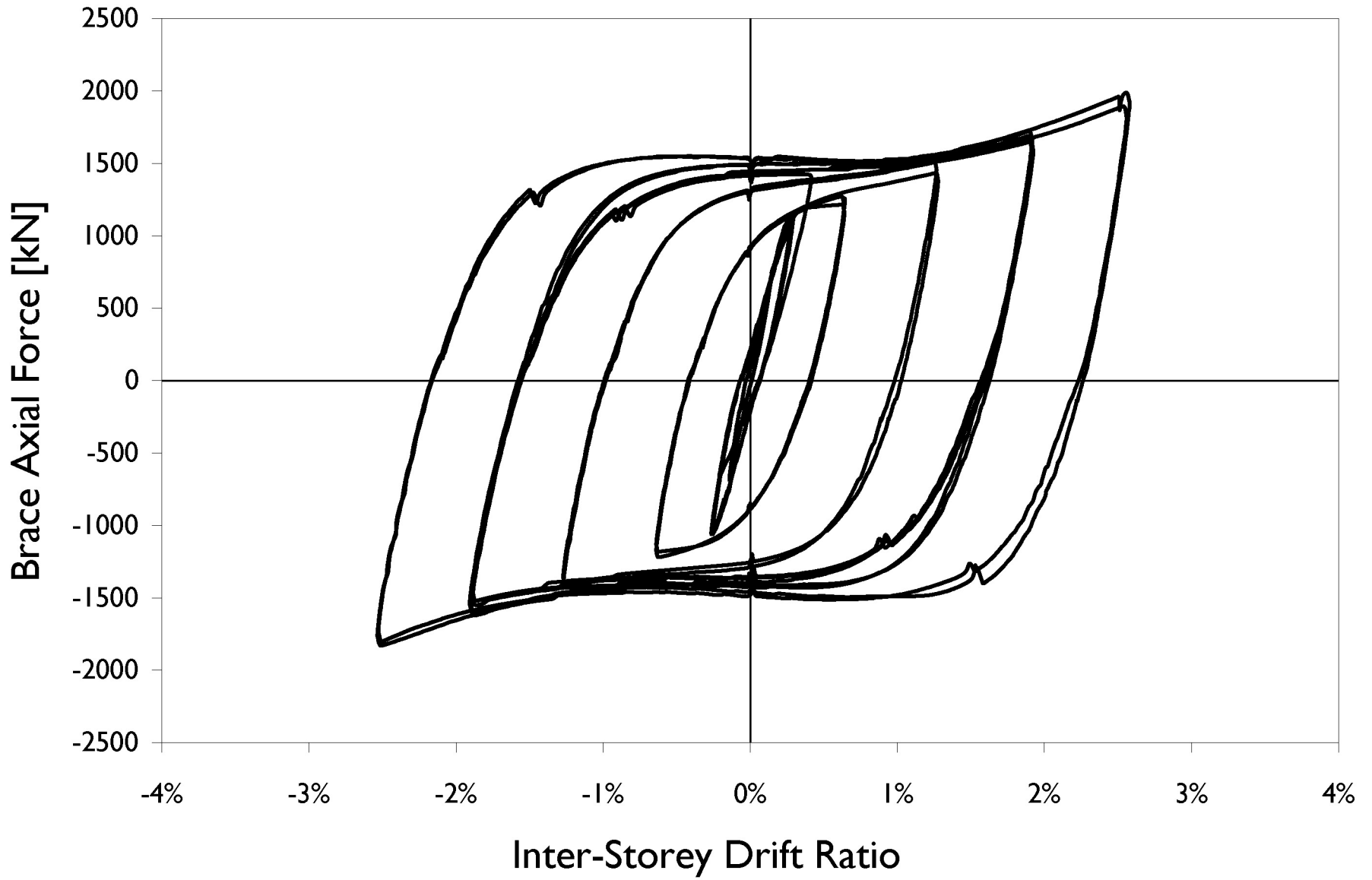
Standard Fabricated Elements



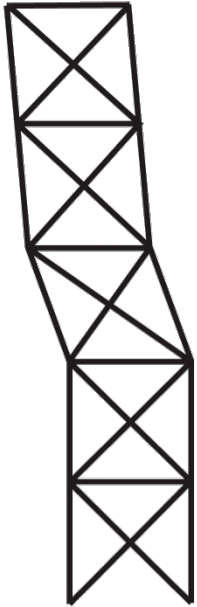
Machined Splice Plate Assembly Welded to Corner Gusset



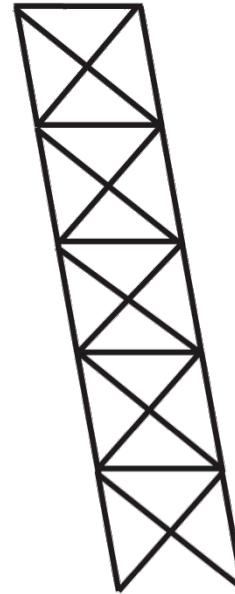




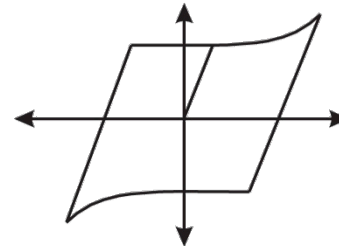
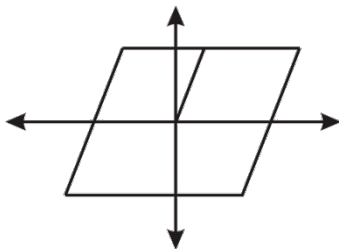
Effect of Post-Yield Stiffness



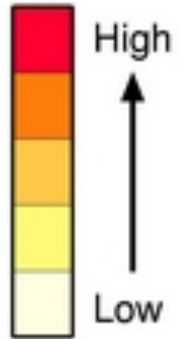
Traditional
braced frame
with low
post-yield
stiffness



Scorpion
braced frame
with
increasing
post-yield
stiffness



**Aléa
Relatif** **Relative
Hazard**



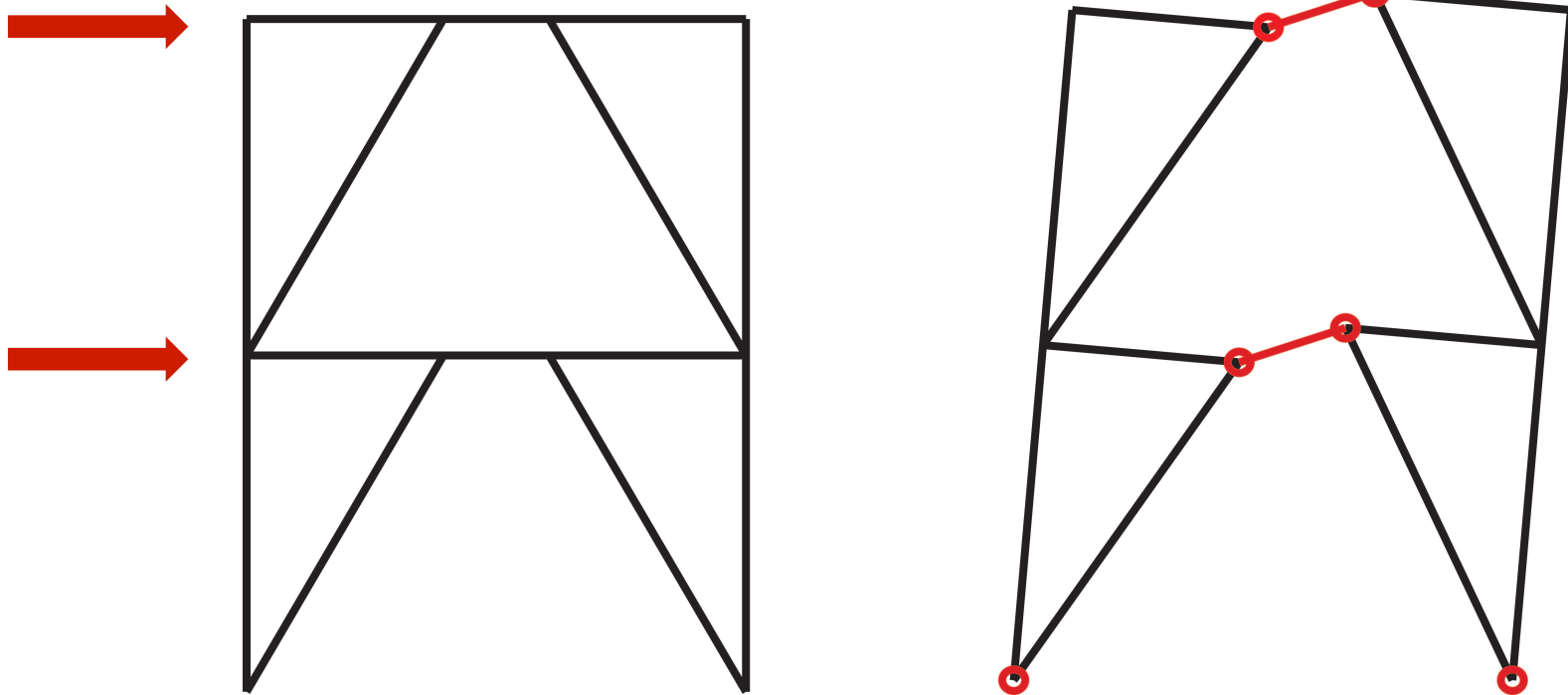
2010

**Seismic Hazard Map
Geological Survey of Canada
Carte d'Aléa Séismique
Commission Géologique du Canada**



Eccentrically Braced Frames

As a frame deforms beyond its elastic range, the beams **yield in shear** in the central “link”





Simpson, 2009

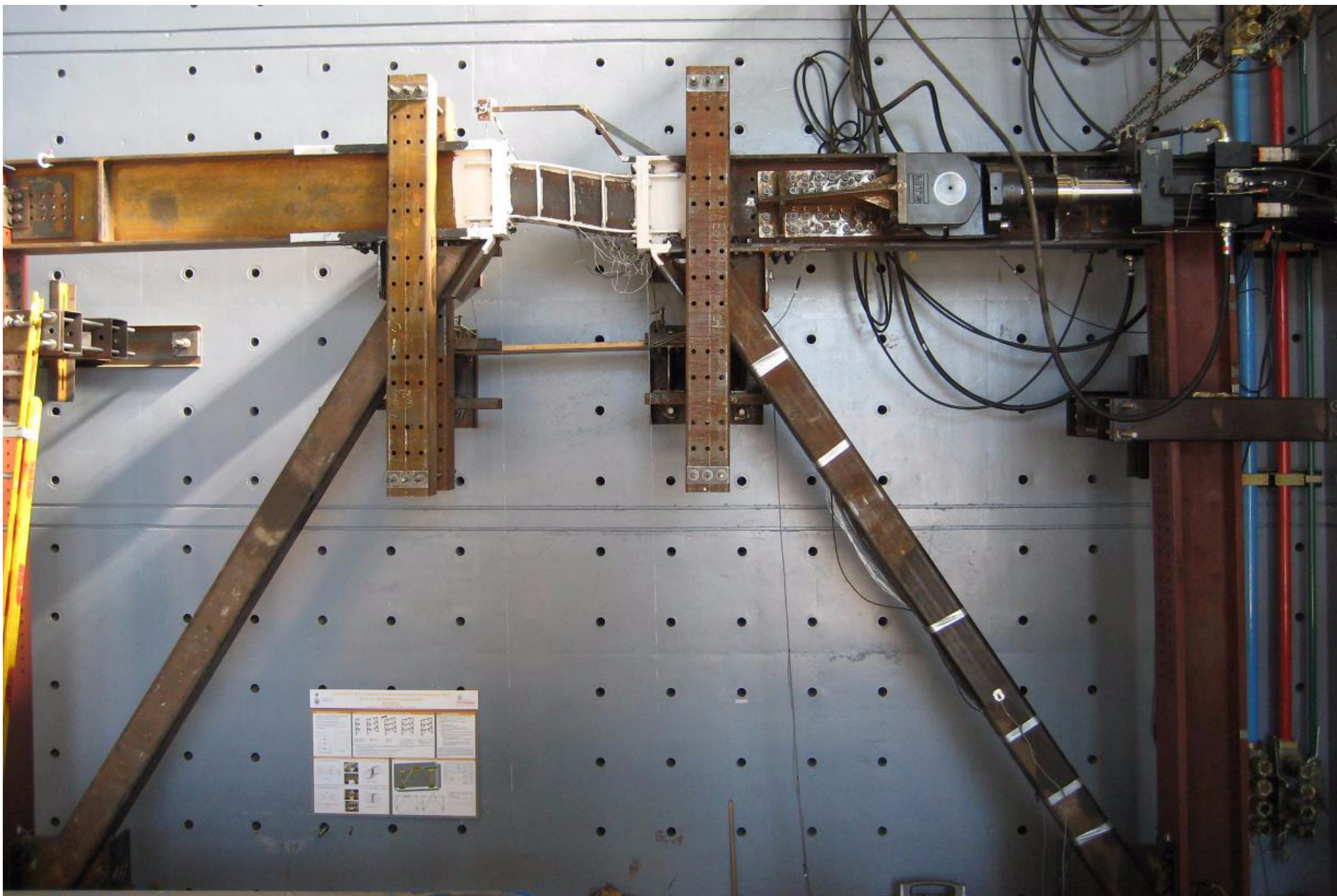


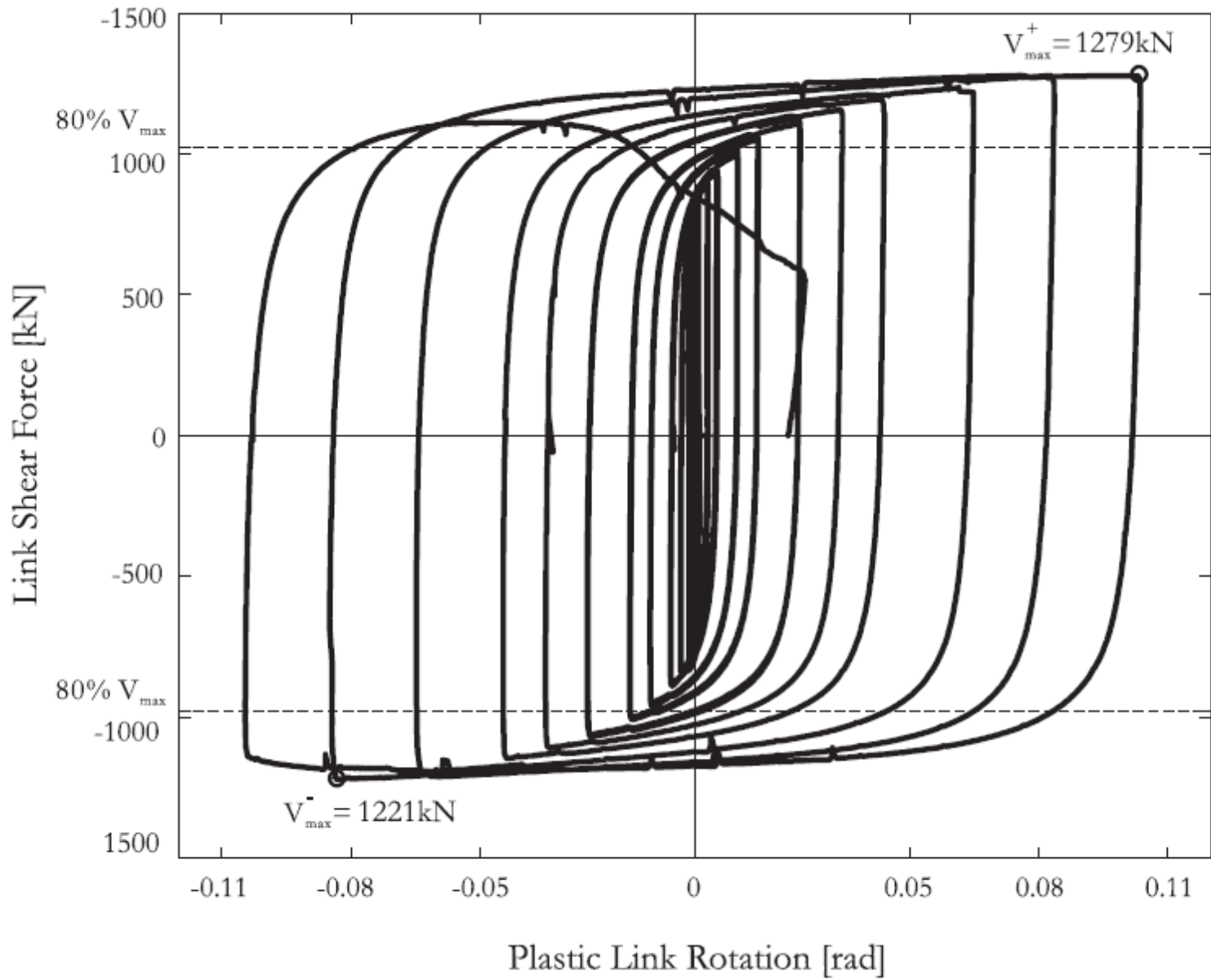


Mansour, 2010



Mansour, 2010



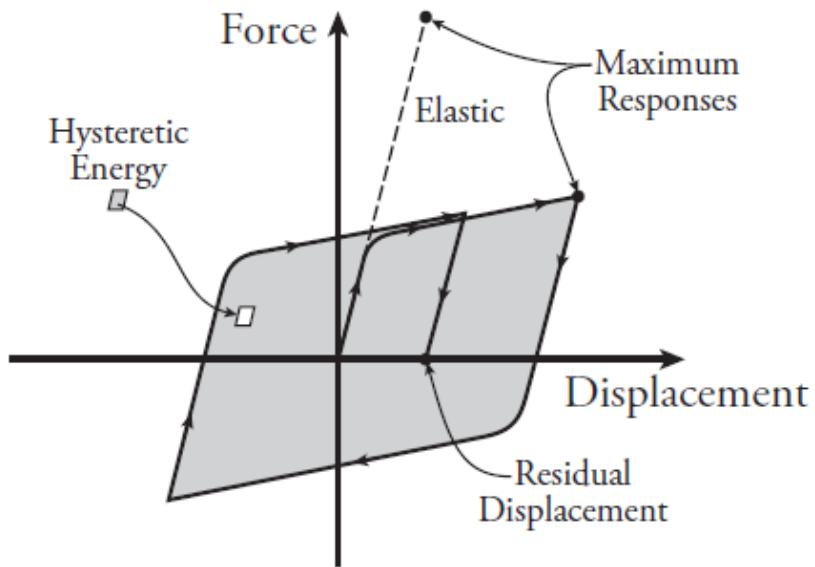


Replaceable Links in Christchurch, NZ

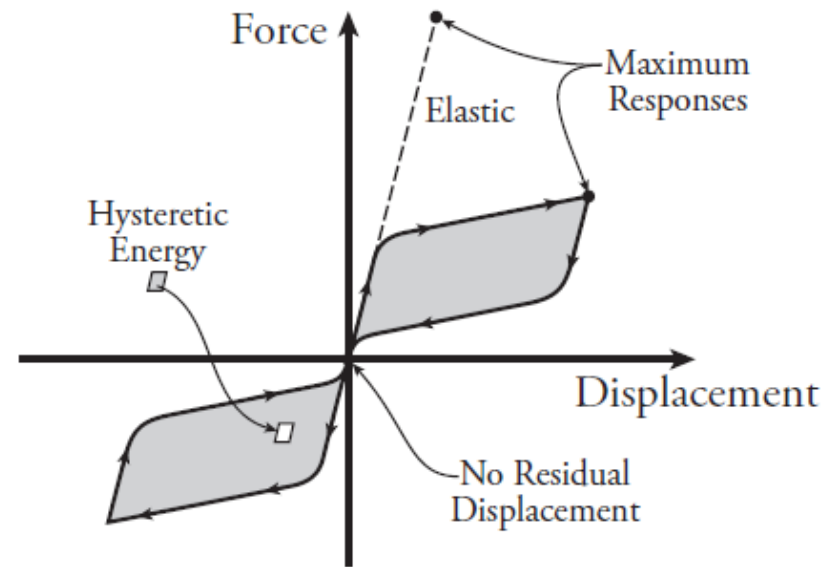


Self Centring Systems

YIELDING/FRICTION SYSTEM

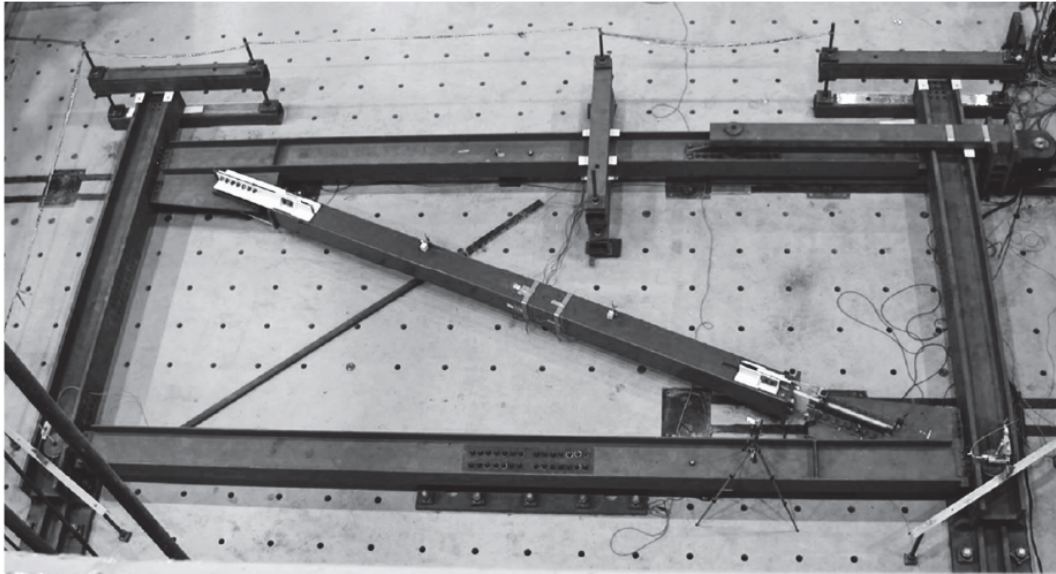


SELF-CENTERING SYSTEM

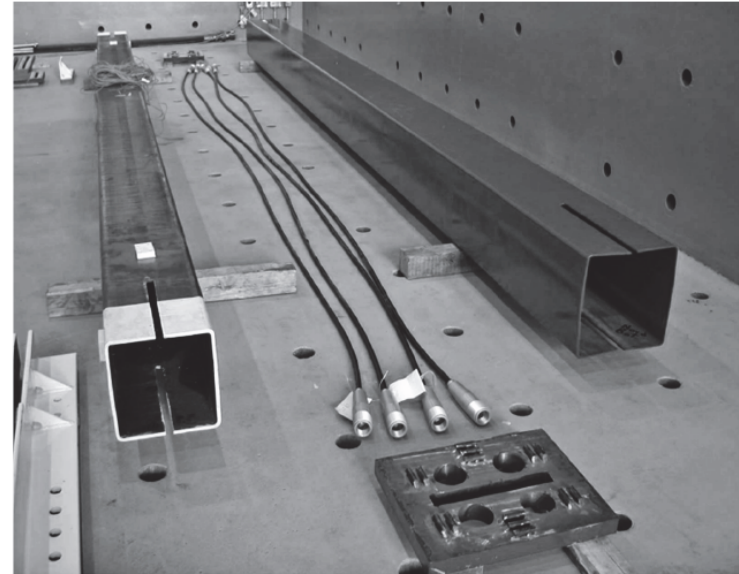


Self-Centring Brace

TEST SETUP PHOTO

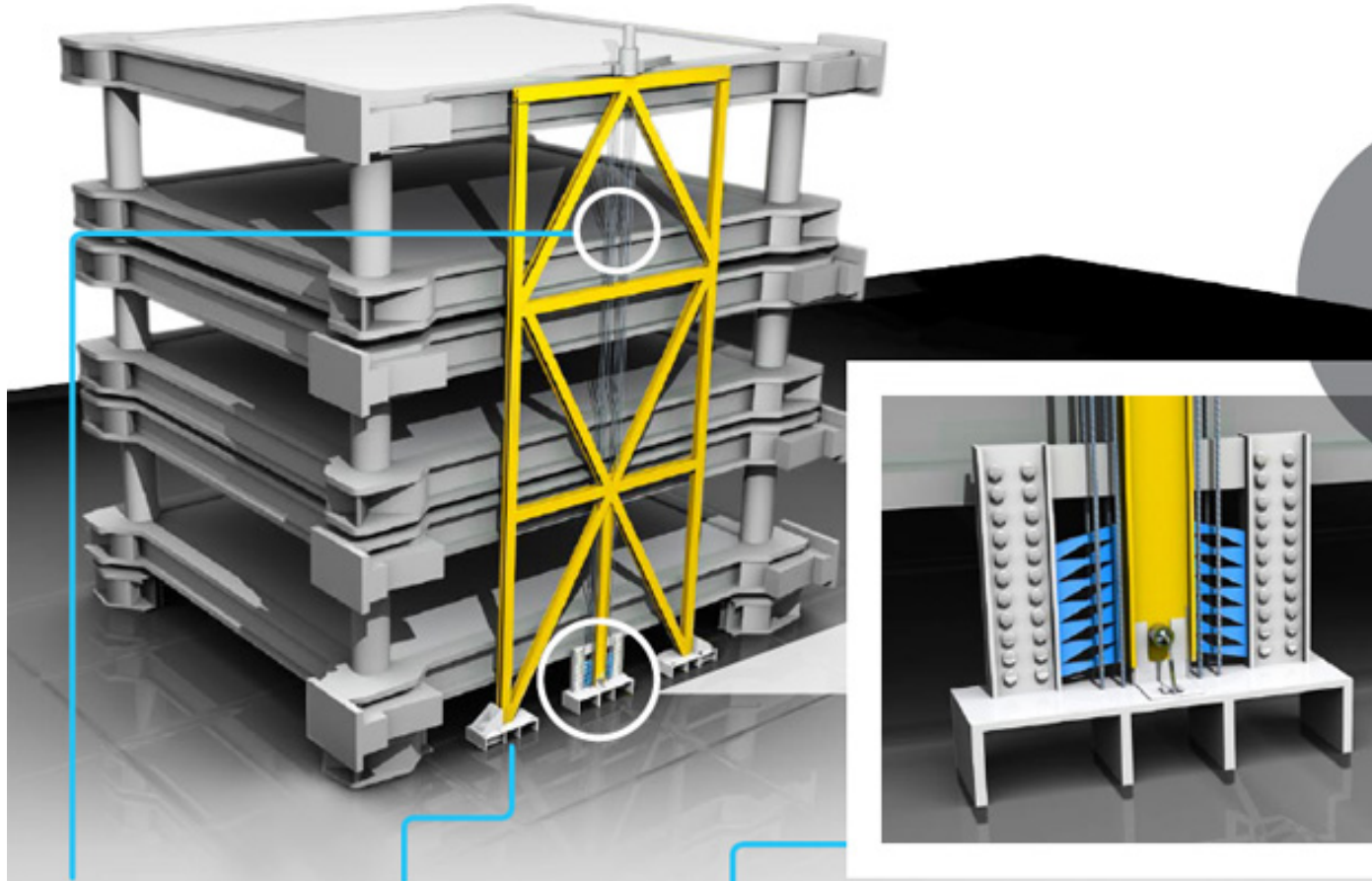


DISASSEMBLED SCED BRACE



Erochko, 2013

Rocking Frame



Post-tensioning
provides self-
centering

Column bases
designed to uplift

Energy dissipation
via steel plates

Policy to Improve “Seismic Resiliency”



- The City of San Francisco has created a Mandatory Soft-Story Program requiring building owners to retrofit multi-unit residential buildings
- Affects approx. 5000 buildings

Christchurch, 2011



- The loss of life in Christchurch resulted from the collapse of two buildings
- It was estimated that 900 buildings would require demolition in the Central Business District (Kaiser et al., 2012)

Thank You!

#CRCISFF

www.crci.utoronto.ca