"Self Healing" Building

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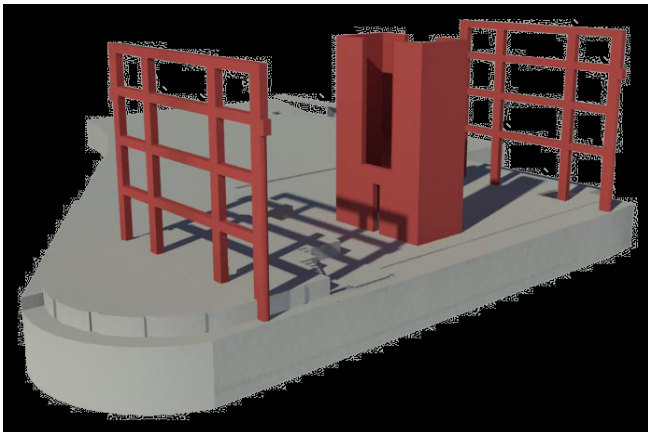
Concept: Elastic loading follows the same path on unloading, resulting in zero net strain. Inelastic loading results in a net strain and dissipated energy.
Structure: David Brower Center, Berkeley California

The David Brower Center is designed to withstand a 7.0+ magnitude earthquake which is predicted to occur within the next 30 years. "Continued functionality of the structure after a major earthquake... is a key "green" construction goal (Stevenson, Panian, Korolyk, & Mar, 2008). Buildings are designed for ULS during seismic events, but are rendered unserviceable by deflections. This building is designed to self-centre. Ground blast furnace slag was also used as a cementicious material, saving an estimated 5000 tons of CO_2 over the project. (Stevenson & Panian, Sustainability through strength, 2009)

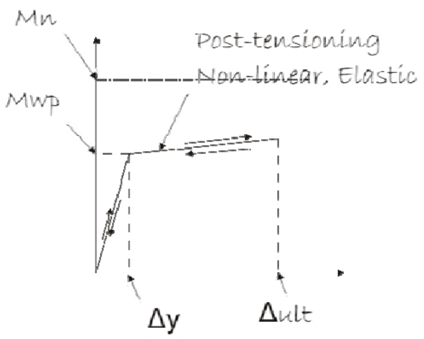
Elastic and Inelastic response
The structure uses unbonded pre-stressed moment frames and core walls. During an earthquake, the pre-stressing cable remains elastic and acts to re-centre these members. Conventional steel reinforcement absorbs energy as it yields.



David Brower Center Moment frames and core walls.
Taken from (Stevenson, Panian, Korolyk, & Mar, 2008)

Hysteresis response of combined PT and CIP frame
Figures adapted from (Stevenson, Panian, Korolyk, & Mar, 2008)

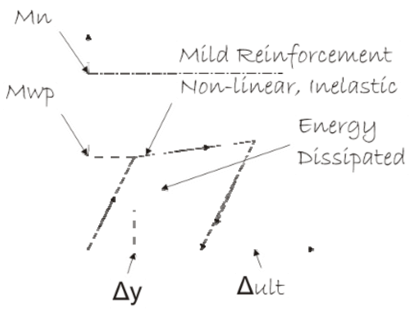
The energy dissipated is the area under the hysteresis curves. An elastic response means the member will follow the same load path during loading and unloading, resulting in no net strain. The inelastic response results in a large net displacement and a large dissipation of energy. The superimposed curve formed by the PT-RC wall encloses a large area with a small residual displacement. The idealised curves are shown below:



Flexural response of unbonded PT wall

Unbonded PT wall:

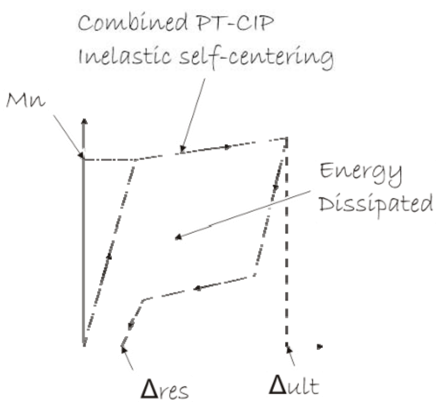
- Elastic response
- No Δresidual
- No energy dissipated



Flexural response of Conventional RC wall

Conventional RC wall:

- Inelastic response
- large Δresidual
- large energy dissipated

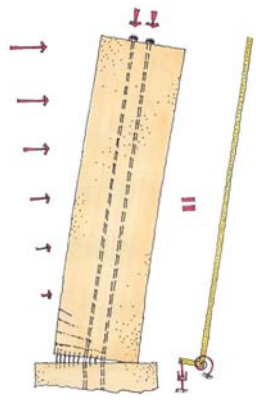


Combined response of PT-CIP wall

Combined PT-RC wall:

- Inelastic response
- small Δresidual
- large energy dissipated

Plastic hinge analysis
The reinforcing steel is concentrated in the outer part of the web, maximizing its strain. Strain is distributed over the cable length keeping the strand stress within the elastic region. If the moment due to the pre-stressed cable is greater than the plastic moment of hinge, then the joint will close after the earthquake. The concrete at the toe of the hinge must be strong enough to resist crushing.

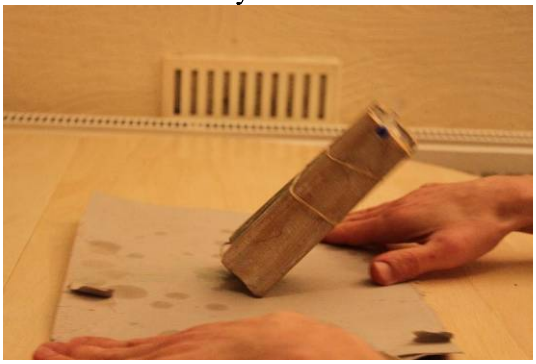


PT-RC combined mechanism. taken from (Stevenson, Panian, Korolyk, & Mar, 2008)

Part B: Model

To demonstrate this concept, a model was constructed. Elastics were used to model the pre-stressing strand and chewing gum for the steel reinforcement.

A. Elastic only



Large displacement
Returned upright

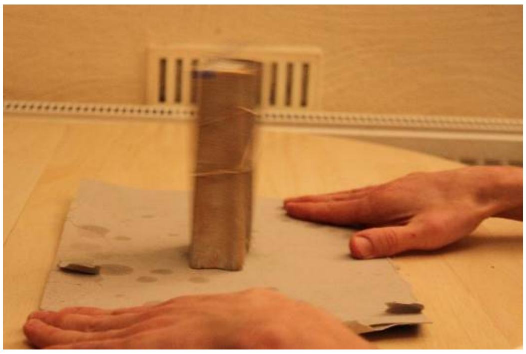
B. Gum only

Stiffer structure

Did not return upright

C. Elastic and Gum

Stiffest structure



Returned upright

References

Ji, T. (2009). Structural Concepts and finite element analysis of plane probles. Lecture Notes .
Stevenson, M., & Panian, L. (2009). Sustainability through strength. Concrete international , 3-7.
Stevenson, M., Panian, L., Korolyk, M., & Mar, D. (2008). Post-tensionel concrete walls and frames for seismic resistance. SEAOC 2008 conference proceedings (p. 8). Seismic engineering association California