Development of Seismic-Resistant Welded Connections for Deconstruction and Reuse of Steel Structures

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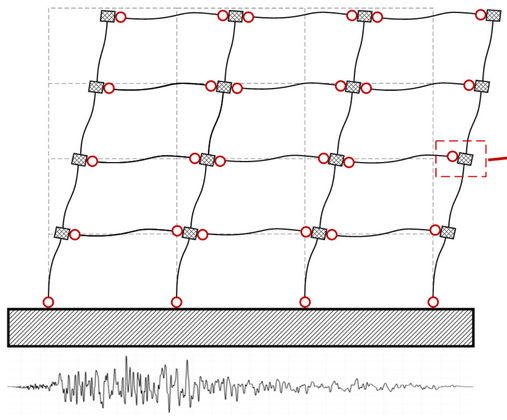
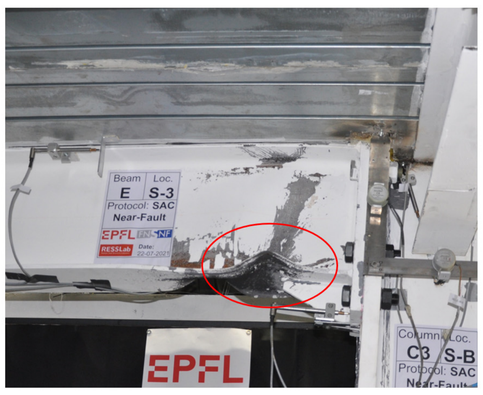
1. Background & Objectives

The Problem: Reuse steel structures after earthquakes

***Key challenge*:** Current seismic design tends to concentrate the inelastic deformation near the steel beam ends

- Plastic hinge location



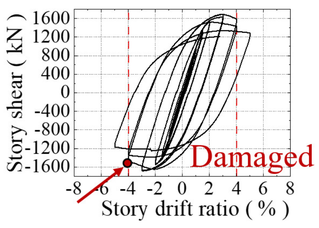


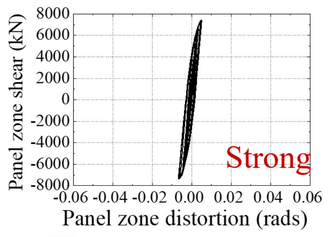
Local buckling of beam

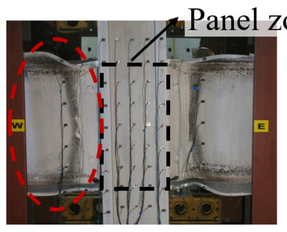
2. Weak Panel Zone Concept

- Strong *vs* Weak panel zone design

Global response | **Panel zone response** | **Observations**

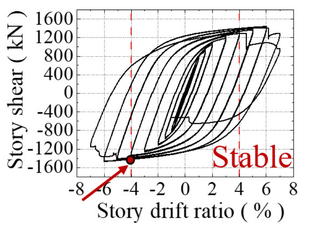


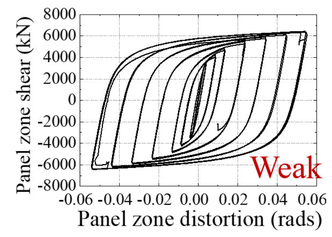


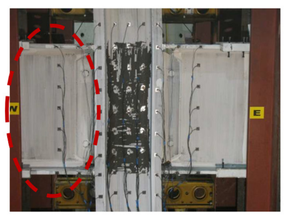


Strong panel zone design

vs







Weak panel zone design

(Source: Shin and Engelhardt, 2013)

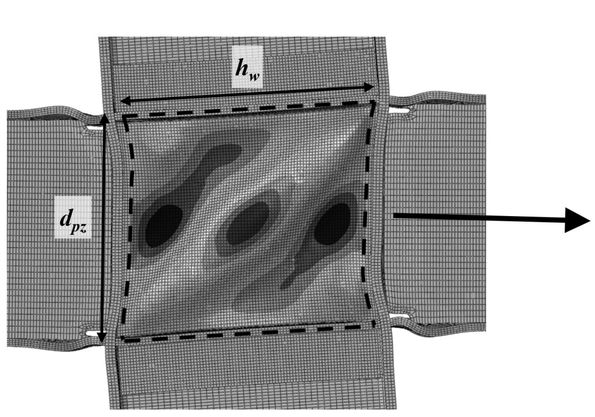
Weak panel zone design provides potential for reusing structural steel members after the earthquake

3. Slenderness Requirements

How? Two Steps!

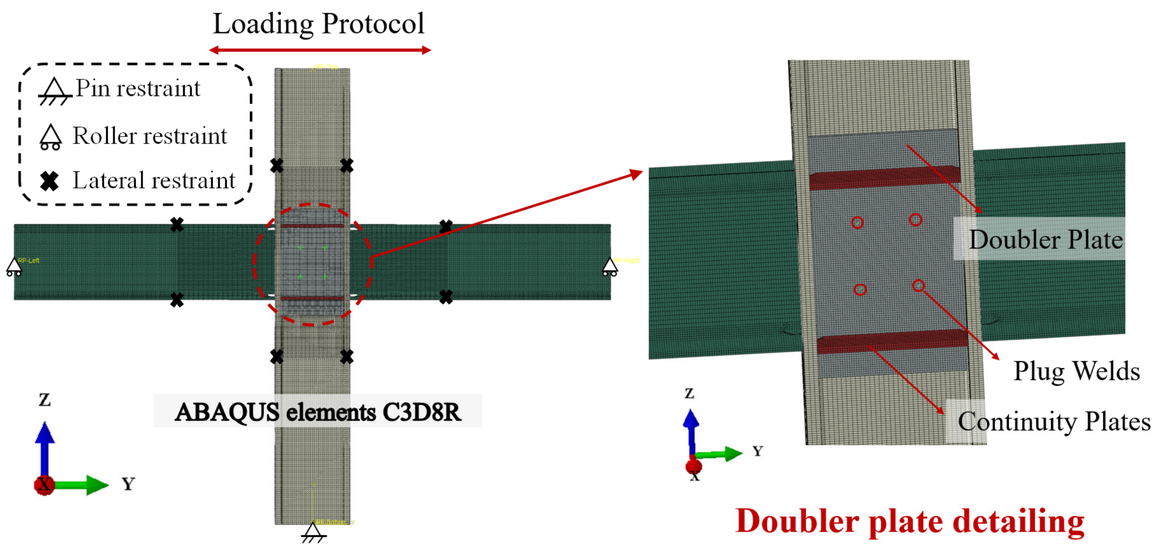
- Analytical Solution & Proposed Recommendations
- Validation with Finite Element Simulations & Experiments

- Analytical approach to inelastic plate buckling



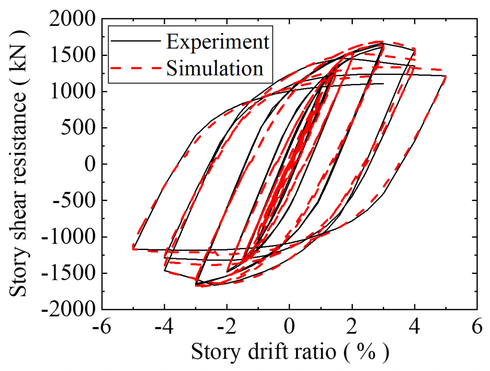
$$\iiint_V \left(\dot{\sigma}_{xx}\dot{\varepsilon}_{xx}+\dot{\sigma}_{yy}\dot{\varepsilon}_{yy}+\dot{\tau}_{xy}\dot{\gamma}_{xy}+\dot{\tau}_{xz}\dot{\gamma}_{xz}+\dot{\tau}_{yz}\dot{\gamma}_{yz}\right)dV+\iint_A -2\tau_{xy}t_w\frac{\partial\dot{w}}{\partial x}\frac{\partial\dot{w}}{\partial y}dA=0$$

- Continuum finite element model



Doubler plate detailing

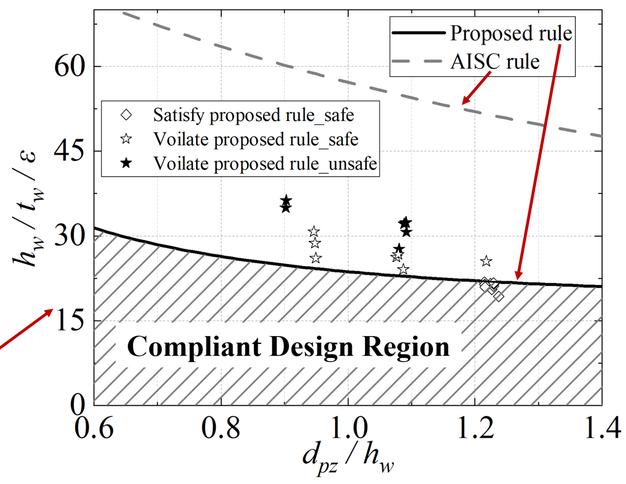
- Validation of Proposed Slenderness Rules



$$\frac{h_w}{t_{pz}} \le \begin{cases} \varepsilon\cdot\sqrt{240+320\cdot\left(\frac{h_w}{d_{pz}}\right)^2}, & \frac{d_{pz}}{h_w}>1 \\ \varepsilon\cdot\sqrt{320+240\cdot\left(\frac{h_w}{d_{pz}}\right)^2}, & \text{Otherwise} \end{cases}$$

$$\varepsilon=\sqrt{235/f_y}$$

Proposed slenderness rule

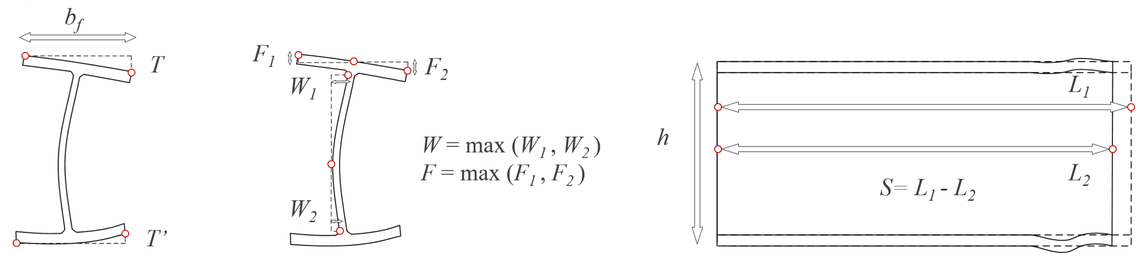


Validation with Finite Element Simulations

4. Limits for Geometric Tolerances

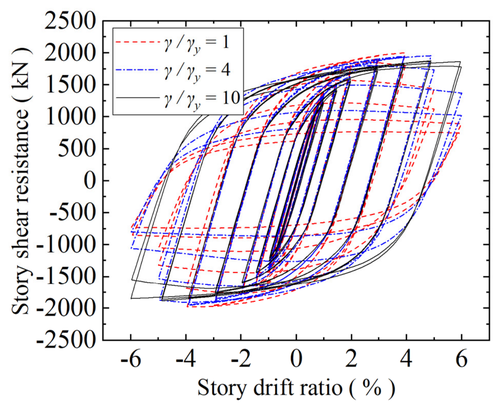
Quantifying the benefits of adopting weak panel zone design

- Geometric tolerances in current standards



- Comparison of connections with different panel zone strengths

Global response



γ_y : panel zone yield shear distortion

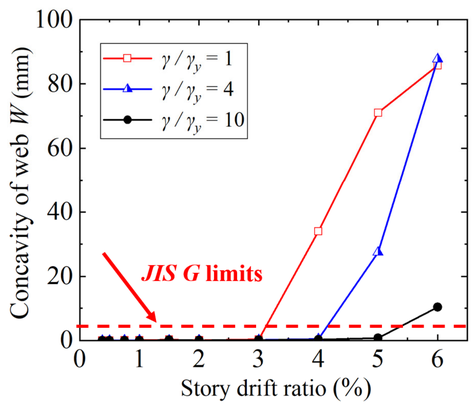
Panel zone design | **Deformed shape at SDR of 4%**

"Strong" — $\gamma/\gamma_y = 1$

"Moderate" — $\gamma/\gamma_y = 4$

"Weak" — $\gamma/\gamma_y = 10$

Concavity of web *W* | **Panel zone design** | **Deformed shape of SDR of 4%**



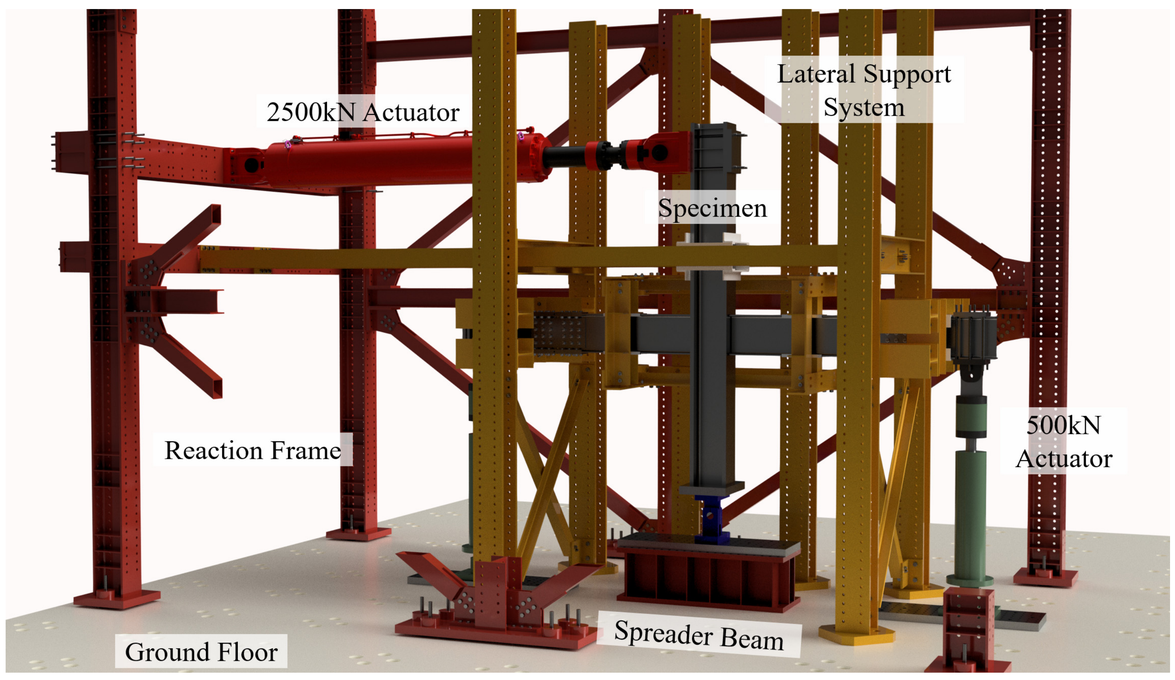
"Strong" — $\gamma/\gamma_y = 1$

"Moderate" — $\gamma/\gamma_y = 4$

"Weak" — $\gamma/\gamma_y = 10$

5. Full-Scale Experiments

- Development of connections for enabling deconstruction



ACKNOWLEDGMENT GIS-EPFL ENAC