IDENTIFYING CRITICAL LOCATIONS FOR CONNECTION DUCTILITY IN STEEL MOMENT RESISTING FRAMES

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11NCEE
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Graphs showing the relationship between beam rotation and number of stories for different levels of seismic demand (1.0, 1.5, 2.0 x MCE). The graphs indicate critical and non-critical locations for connection ductility.
Results of post-Northridge investigations

- **Pre-Qualified Connections:**
  - Fractures observed in MRF connection welds
  - New prequalified connections avoid weld fracture

Bruneau, Uang et al (2011) *Ductile Design of Steel Structures*
Results of post-Northridge investigations

- fractured connections grouped at floor levels
- current practice assigns single ductile capacity to all connections
- limits ability to concentrate resources at locations with highest demand

Previous research: some connections are more critical than others

How can we find the connections that are critical to the collapse capacity?
Prototype structure

- Seattle, Site Class B
- designed by Tsai and Popov (1988)
- revised for SAC (1995)
How were the plastic hinge models calibrated?

- test results from RBS connections using Lignos database (2013)
- used MATLAB multivariable optimization calibration software

Test data from Popov et al, 1998. Post-Northridge Earthquake Seismic Steel Moment Connections
Collapse analysis method

- multiple stripe analysis: 7 intensities x 40 ground motions
- scaled using the conditional mean spectrum
Locations of largest beam rotations

- median of maximum total beam rotation at intensity each stripe
Pushover Analyses

- six lateral force distribution considered

### Triangular

- Graph showing base shear (kN) vs. roof drift (%)

### Classical Modal

- Graph showing base shear (kN) vs. roof drift (%)

### Force Adaptive Pushover

- Graph showing base shear (kN) vs. roof drift (%)

### Equivalent Lateral Force

- Graph showing base shear (kN) vs. roof drift (%)

### Modified Modal

- Graph showing base shear (kN) vs. roof drift (%)

### Displacement Adaptive Pushover

- Graph showing base shear (kN) vs. roof drift (%)
Locations of largest beam rotations

- All distributions underestimated rotations at top floors
- All distributions overemphasized first floor rotations relative to upper floors
Locations of largest beam rotations

- Highest correlation with Triangular and E.L.F. distributions

- Lowest correlation with Force and Displacement adaptive distributions

- No distribution would suggest floors 1-4 are all critical
Calibrated Pushover Forces

- New lateral force distribution calibrated to match median maximum beam rotation profile at 1.5xMCE
- $\alpha$ values found to replicate forces as sum of all lateral modes

\[
(F_{\text{calib}})_j = \sum_{n=1}^{M_{\text{modes}}} \alpha_n \Gamma_n m_j \phi_{n,j} A_n(T_n)
\]

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\alpha_n$</th>
<th>$r_n \alpha_n$</th>
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<tr>
<td>1</td>
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<td>37.80</td>
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<tr>
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<td>5</td>
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<td>0.49</td>
</tr>
<tr>
<td>6</td>
<td>-2.07</td>
<td>-0.38</td>
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</table>
Conclusions

- no considered pushover methods can identify critical connections
- applications: retrofit, inspection, design
- current work: other configurations, heights, designs
- current work: selective use of high-performance connections
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How can panel zones be modelled?

- **Rigid Offsets**
- **Scissor Links**
- **Rotational Spring Box**


How did we model beams?

Bilinear

Trilinear

hinge defined with moment-rotation relation

IMK (Ibarra-Medina-Krawinkler)