

Progress on Resilience-Based Design and Assessment

Prediction of Building Damage, Repair Costs, and Building Closure Time

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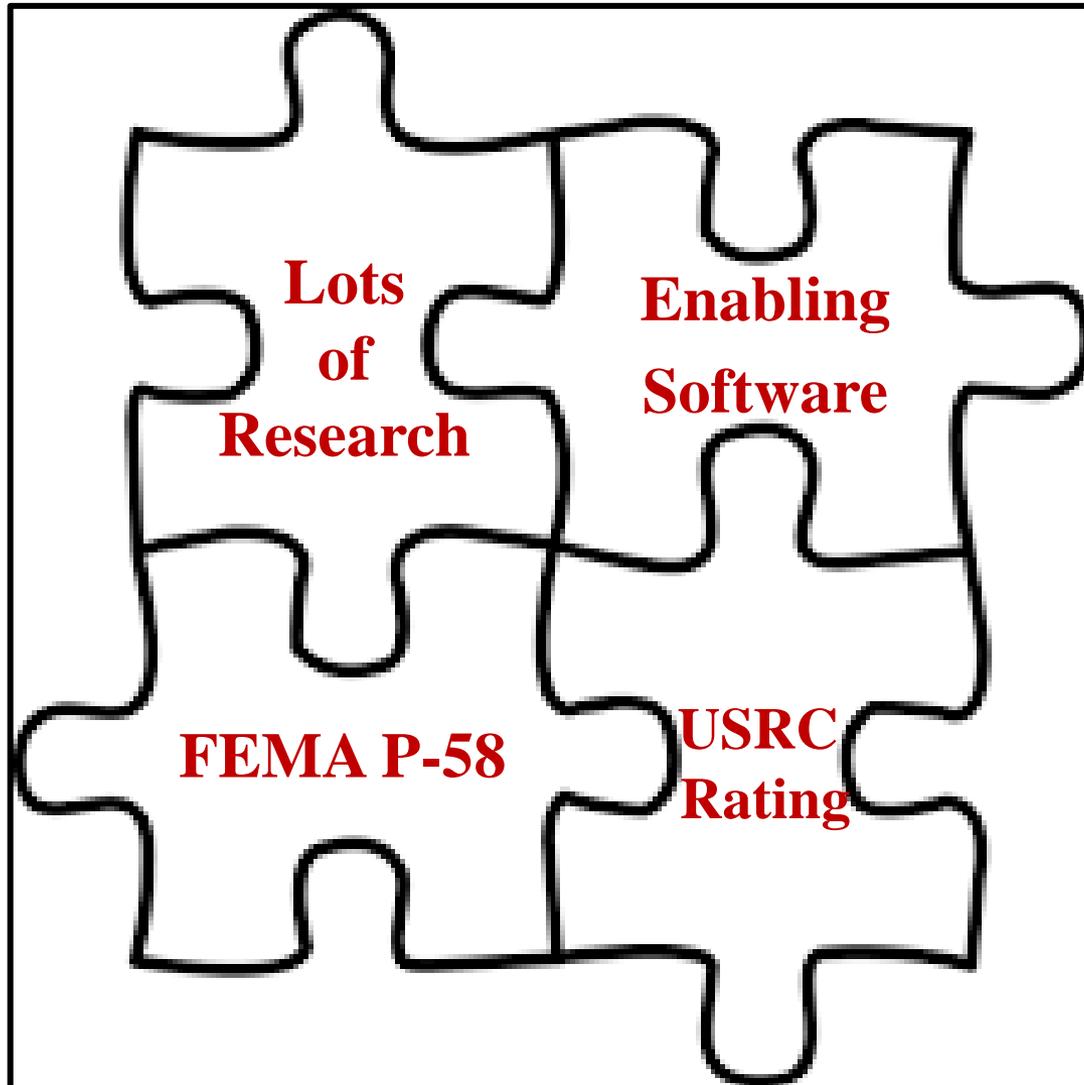
ATC-SEI: 2nd Conference on Improving the Seismic Performance of
Existing Buildings and Other Structures

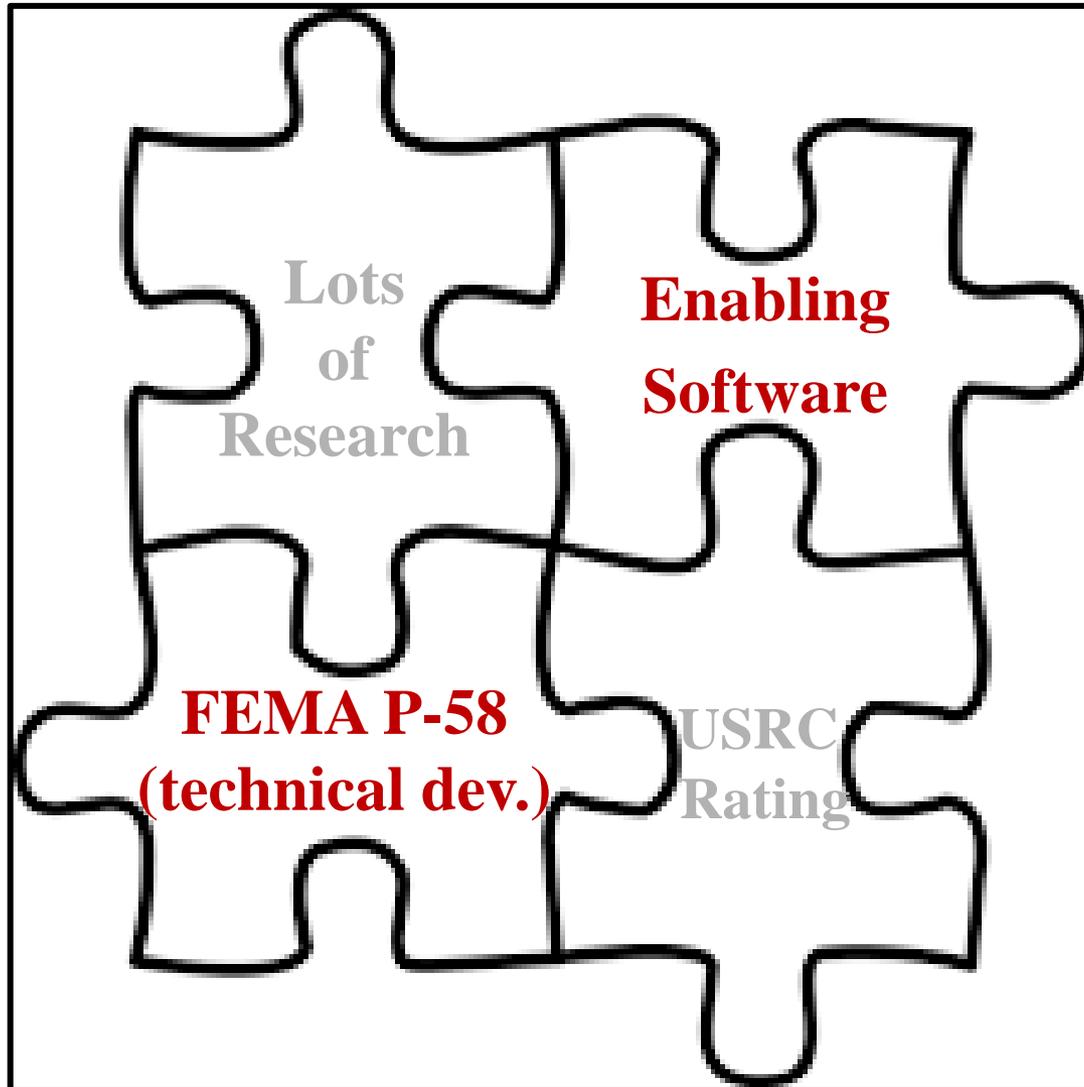
San Francisco, CA | December 10-12, 2015



**Seismic Performance
Prediction Program**

by Haselton Baker Risk Group





- The USRC is a non-profit, founded to be the implementation organization for building seismic ratings (much like U.S. Green Building Council).
- The USRC has widespread support (64 Founding organizations).
- The USRC just publically launched with 63 Certified Raters and 25 Certified Reviewers.
- There are two methods for a USRC building rating:
 - ASCE 31/41
 - FEMA P-58



- P-58 is a performance prediction methodology (10 yrs, \$12M)
- P-58 is tailored for building-specific analysis
- FEMA P-58 output results:
 - Repair costs
 - Repair time (with REDi extensions) & red tagging
 - Fatalities & injuries



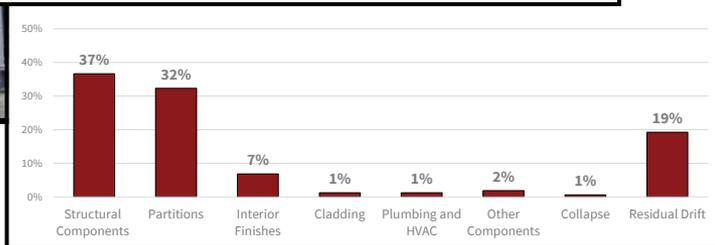
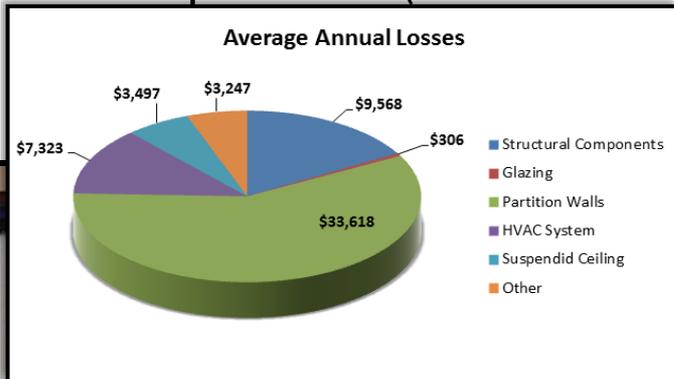
Seismic Performance Assessment of Buildings

Volume 1 – Methodology

FEMA P-58-1 / September 2012



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Seismic Performance Assessment of Buildings

Volume 1 – Methodology

FEMA P-58-1 / September 2012



- Hazard and Ground Motions
 - Soil and hazard curve
 - Ground motions (if needed)
- Structural Responses
 - Option #1: Response-history
 - Option #2: Simplified method
- Damage Prediction
 - Contents (str. and non-str.)
 - Fragility curves
- Loss Estimation (loss curves)

Typical Reaction:
Looks extremely
complicated!

- In early 2014, Jack Baker and I decided to start a software project to make it feasible to use FEMA P-58 at the pace of an engineering office.
- Our three components of this work are as follows:
 - a) Create user-friendly software to implement P-58. [done + released]
 - b) Maintain software over time (fragilities, etc.).
 - c) Improve and extending the methodology in the future (especially after ATC/FEMA Phase II work is done).
- **Our Goal:** Help enable adoption of FEMA P-58 in structural engineering practice (make it doable!).
- **ATC Coordination:** We have been in coordination with ATC from the start (so all pulling in same direction).



**Seismic Performance
Prediction Program**
by Haselton Baker Risk Group

- Hazard and Ground Motions

- Soil and hazard curve
- Ground motions (if needed)

Soil and ground motion database information embedded

- Structural Responses

- Option #1: Response-history
- Option #2: Simplified method

Simplified structural response method embedded

- Damage Prediction

- Contents (str. and non-str.)
- Fragility curves

Building contents are auto-populated

- Loss Estimation

Two-level structure:

- 1) Use initial pre-populated values
- 2) Modify inputs and dig deeper

Structure: Web deployed, automated PDF output reports, review mode



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We equip engineers with tools needed to consider damage and loss reduction directly in the building design process.

SP3 enables something never before feasible in a design office.

We help engineers and owners calculate their seismic risk by understanding and predicting earthquake performance in a whole new way.

 Learn More

 Request a Demo

 Already a member? Login Now!

Total number of simulated earthquakes to date

94,393,220



Comprehensive

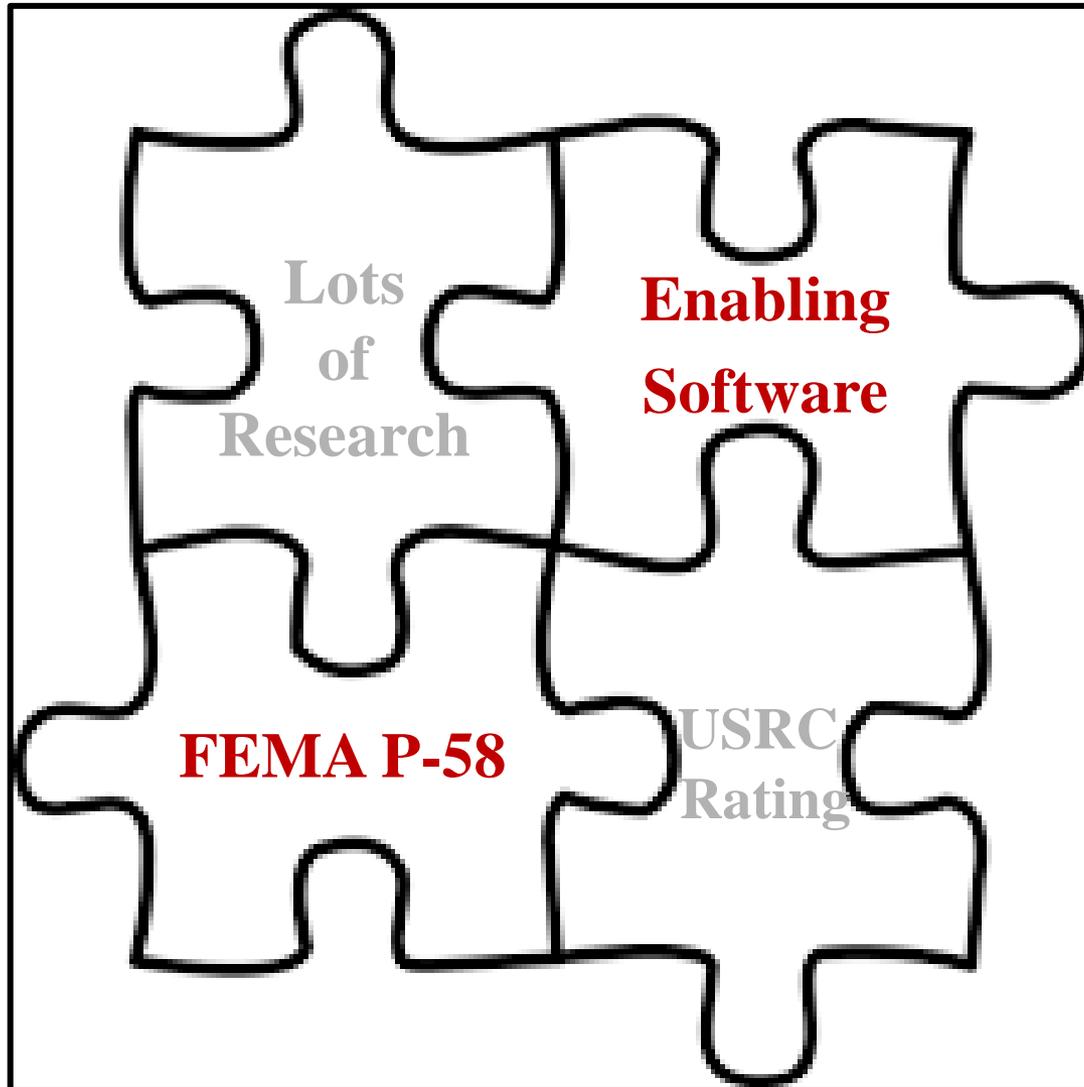
SP3 implements cutting-edge research to equip engineers to comprehensively estimate seismic damage, loss, and building repair time.



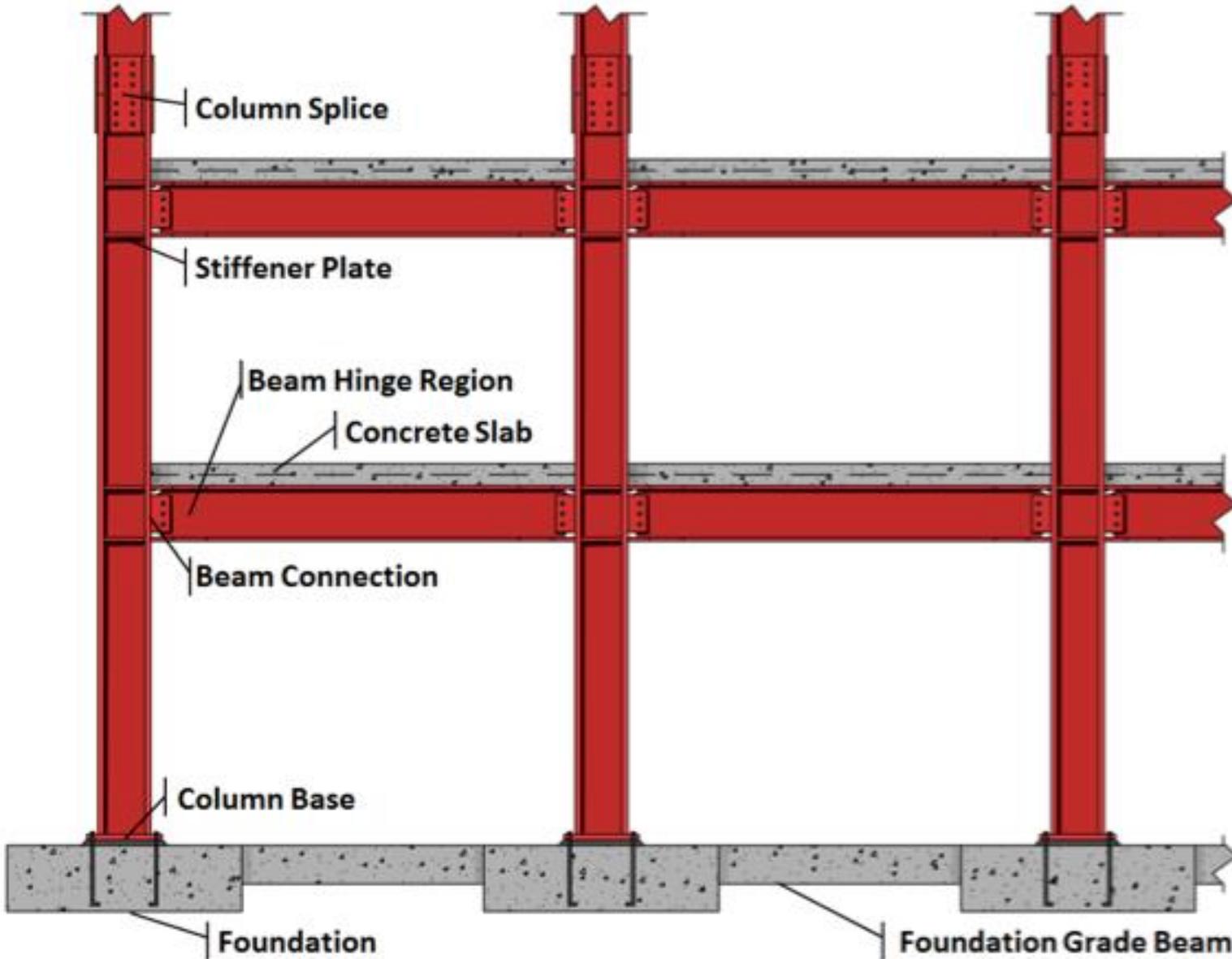
Efficient

SP3 uses stream-lined analysis methods to give results in a matter of hours (rather than days or weeks), with user-defined inputs to refine the analysis at any step.

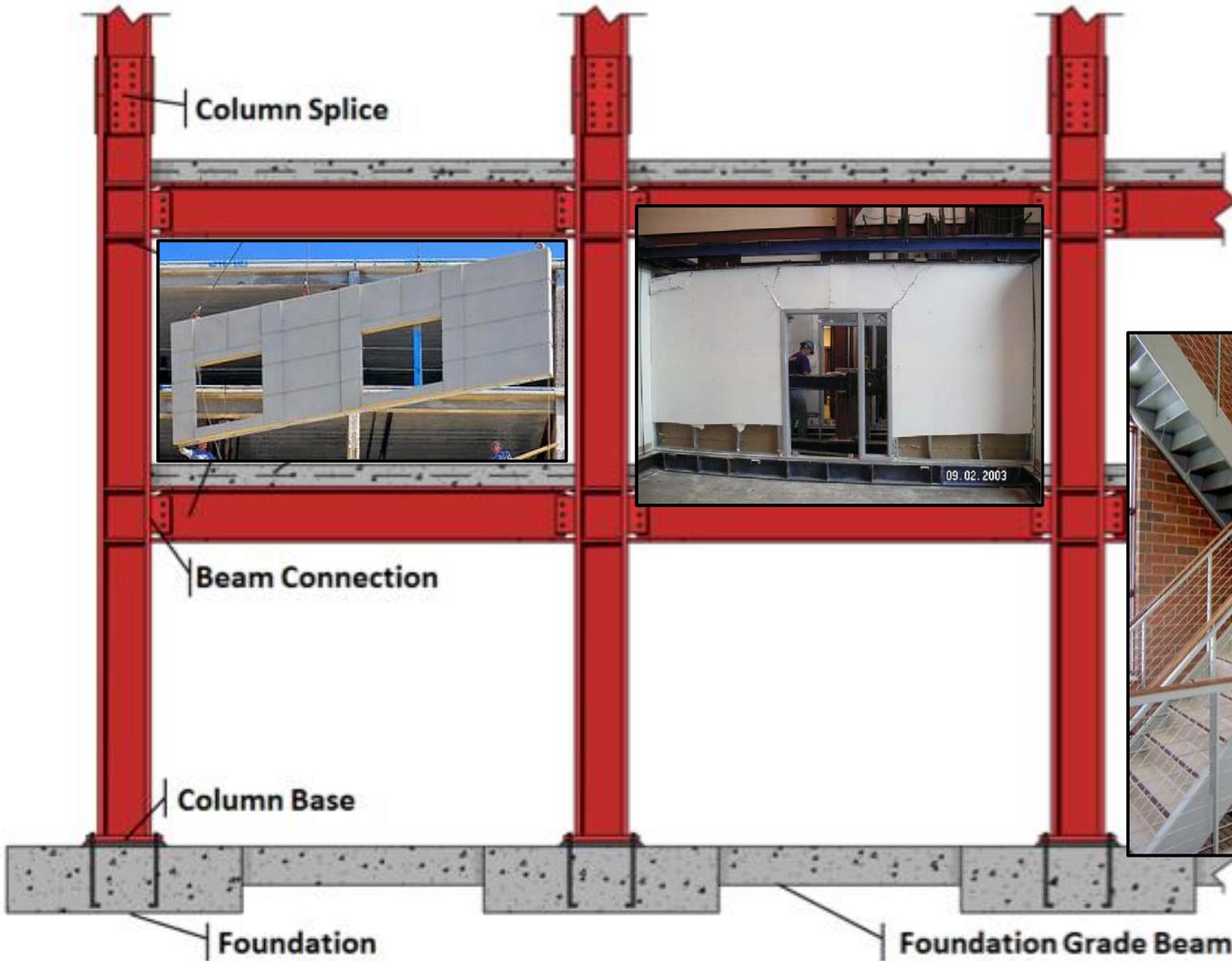
SP3 In the Marketplace



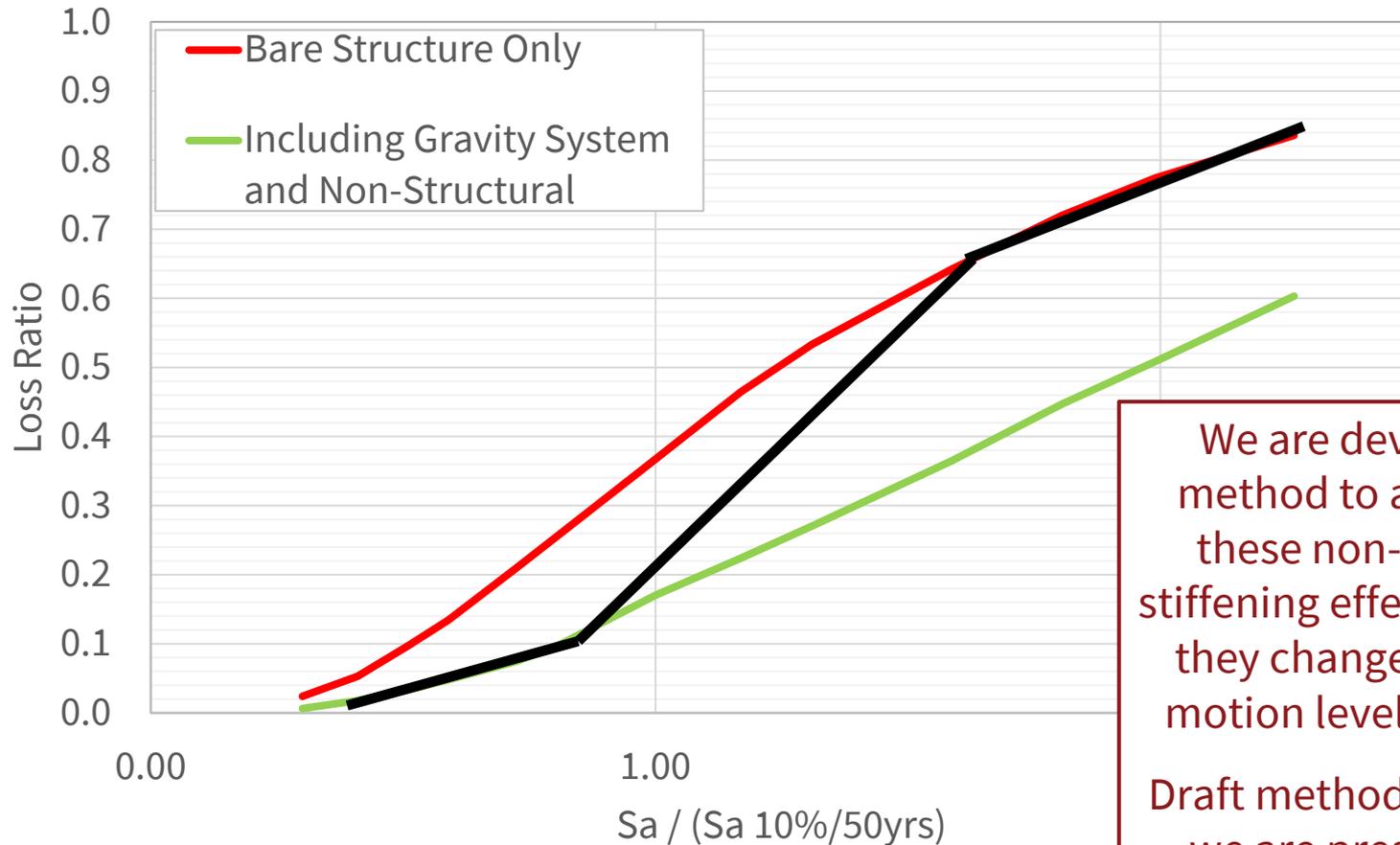
- The ATC-58 project is in Phase II and the focuses are:
 - Benchmark performance of code-compliant buildings.
 - Dissemination of the ATC-58 tools.
 - Some additional technical refinements. One current focus is treatment of stiffness of non-structural components (to discuss).
- Funding by the National Science Foundation (SBIR program):
 - We have also been awarded \$200k thus far from NSF (and likely \$30k more in early 2016 and possibly \$750k in late 2016).
 - Funding is being used to develop the SP3 software, and for additional technical developments to enable broad use of FEMA P-58.
 - This work is being actively coordinated with ATC (so all pulling on same end of the rope!).
 - One current focus is to create an Enhanced Simplified Method, so the engineer can predict structural responses without needing to run response-history analysis.



As structural engineers, we are accustomed to just modeling the *structure* of the building.



The problem is that there is a lot more in the building once it's built!

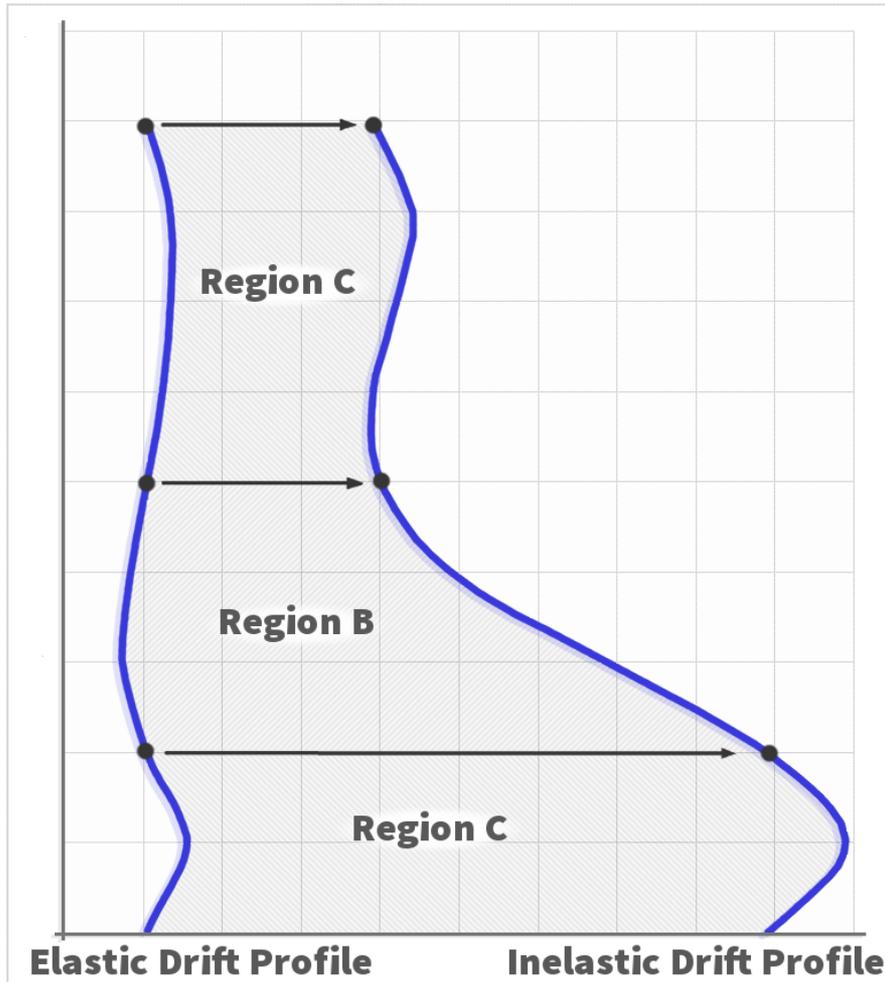


We are developing a method to account for these non-structural stiffening effects (and how they change as ground motion level increases).
 Draft method is done and we are presenting for review on Monday.

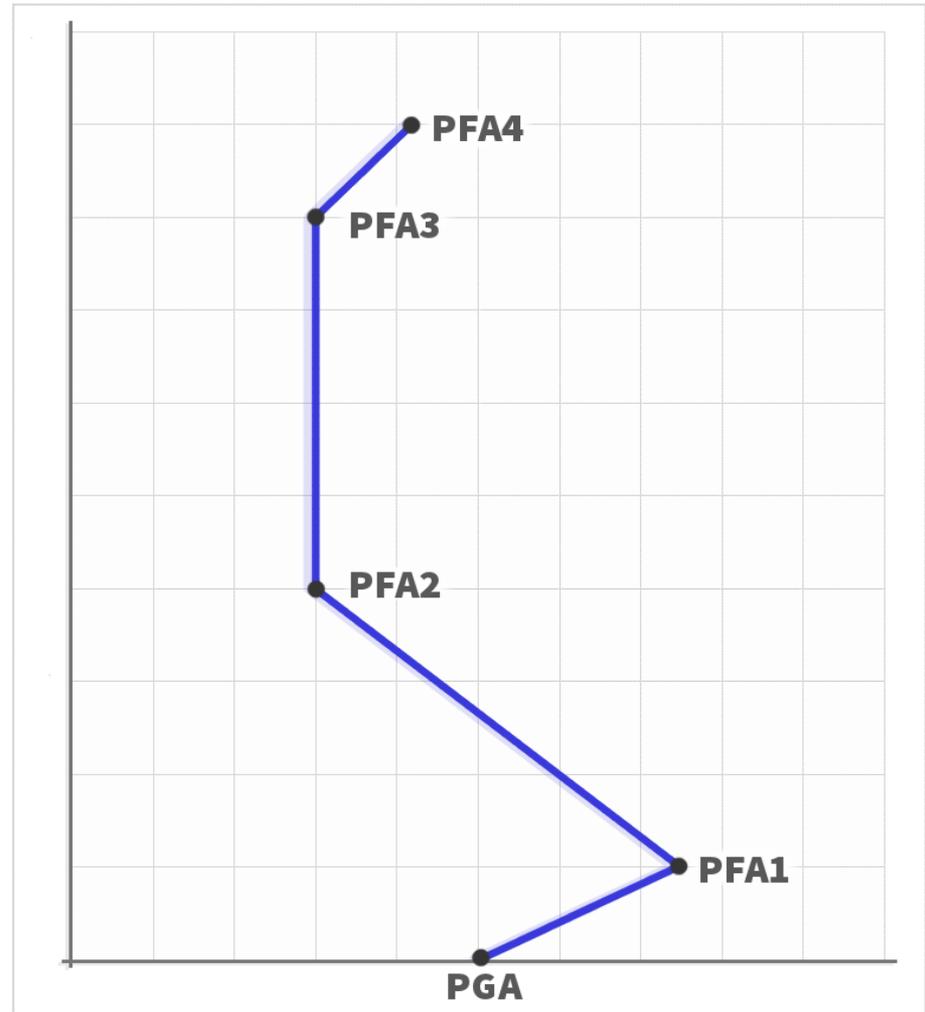
- The objectives is to create an Enhanced Simplified Method that:
 - Predicts peak drifts, floor accelerations, and residual drifts.
 - Is general to as many building systems as possible and works for taller buildings (up to 40 stories?).
 - Works for higher levels of nonlinearity (and tracks the damage localization, so displaced shape is not always the same).
 - Works for buildings with strength/stiffness irregularities.
 - Includes assessment of response correlations (so the 90th percentile values are closer to RHA results).
- Basic components of the methodology:
 - Based on modal analysis with 3+ modes. User can input model properties, or they can be estimated based on structural system.
 - Uses elastic responses from modal analysis and then applies inelastic modification factors.
 - Inelastic modification factors are calibrated based on OpenSees analyses (but approach is structured to be as general as possible).

- Current status and next steps:
 - We have a Beta version completed for frame buildings up to 20-25 stories, including both ductile and non-ductile behavior. This is based on use of 50-60 RC frame OpenSees models from 1-20 stories (SMF, OMF, 1960's).
 - We are currently collecting many sets of OpenSees research models to we can extend this method to be well-calibrated for other systems (RC walls, concentric braced frames, BRBs, wood light frame, etc.).
 - Frame method implementing into SP3 early next year.
 - Full generalized method completed and implemented late winter or early spring.

Story Drifts:



Floor Accelerations:



- This is an exciting time of new developments:
 - **FEMA P-58:** Provides building-specific estimates of loss, repair time, and fatality/injury (with cause-and-effect level of detail).
 - **USRC Ratings:** Provides a standard way to communicate performance.

- **Question:** As a structural engineering profession, what will we do with these new developments? How can we leverage this for more resilient infrastructure?
 - Advanced design including 3Ds - safety + loss + recovery time
 - Advanced retrofit including 3Ds - safety + loss + recovery time
 - Advanced loss assessments (PML, more detailed SRA, etc.)
 - Advanced risk assessments for insurance
 - Other?

- Thanks you for your time.
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