Fragility Analysis of Retrofitted Multi-Column Bridge Bent Subjected to Near Fault and Far Field Ground Motion

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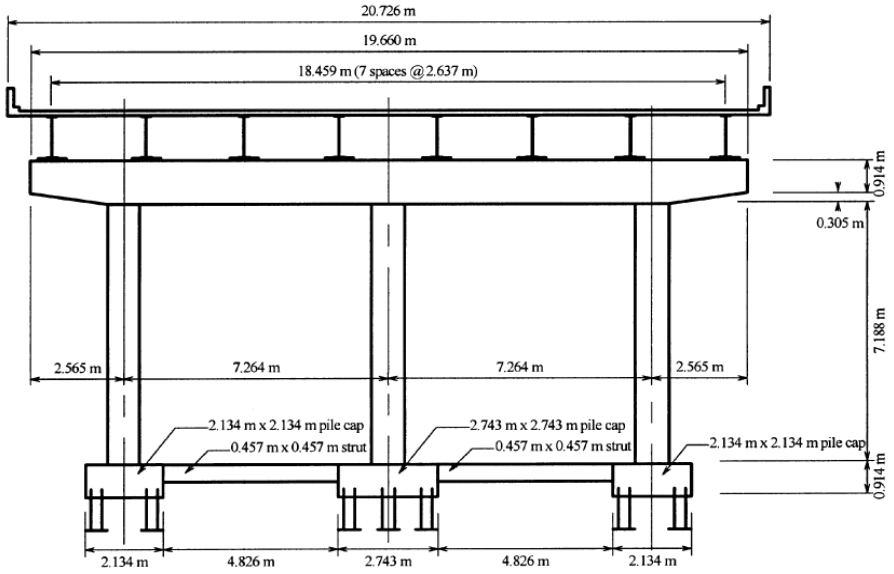
ACI Spring Convention 2018, Salt Lake City

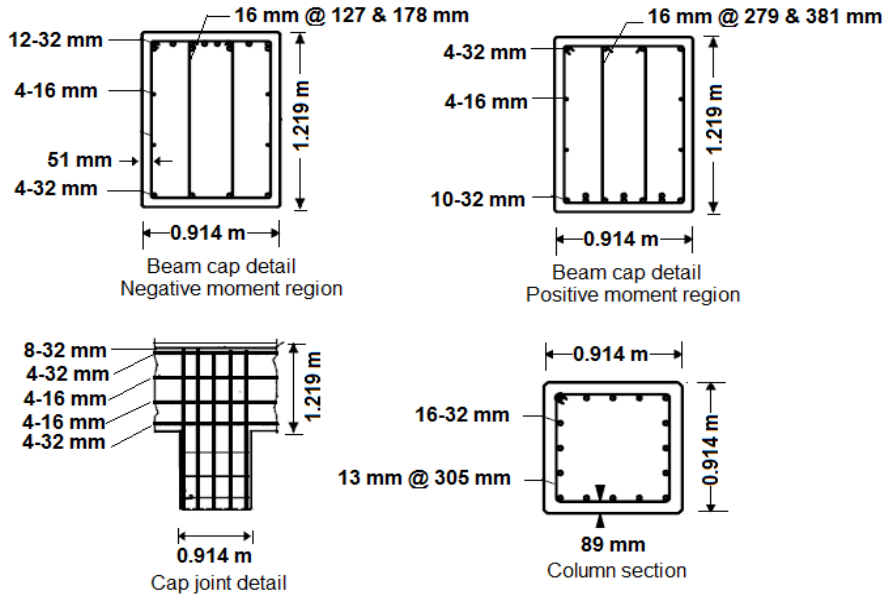
Background

Why Damages Happen?

- Inadequate capacity
- Insufficient transverse reinforcement
- Inadequate lap splice length
- Poor detailing
- Lap splices in potential flexural hinge regions

Details of Bridge Bent





South Temple Bridge Bent (adapted from Pantelides and Gergely, 2002)

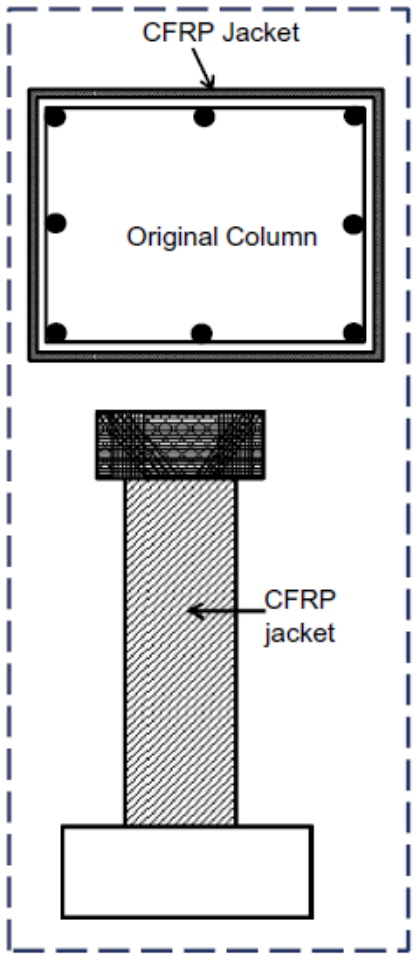
Deficiencies

- Inadequate reinforcement
- Insufficient transverse reinforcement
- Non-seismically designed

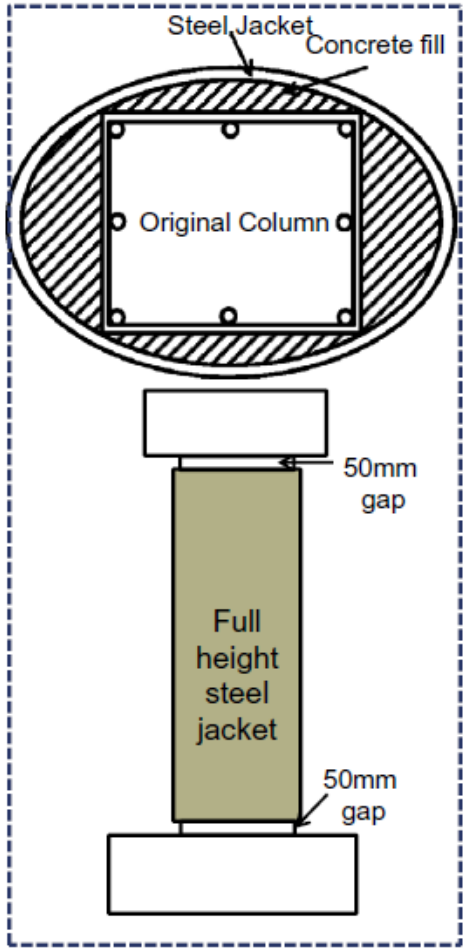
Different Retrofit Techniques

- Carbon Fiber Reinforced Polymer (CFRP) Jacketing
- Engineered Cementitious Composite (ECC) Jacketing
- Steel Jacketing
- Concrete Jacketing

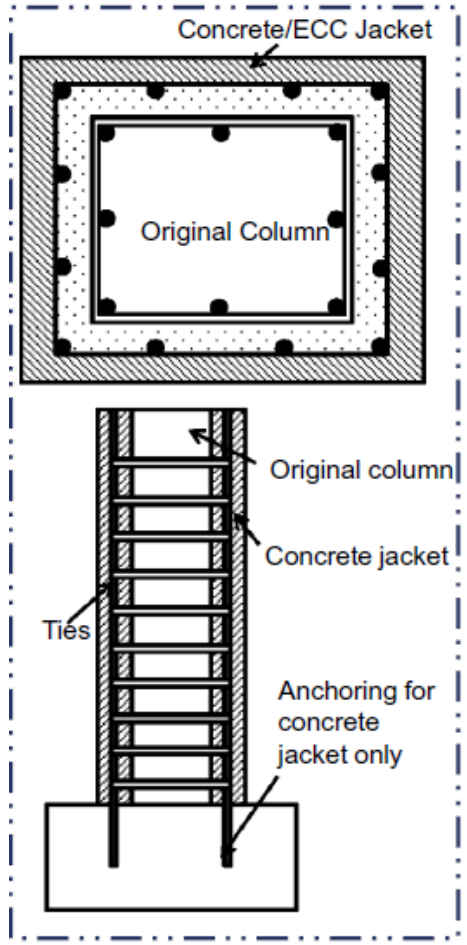
Retrofit Design



CFRP Jacket

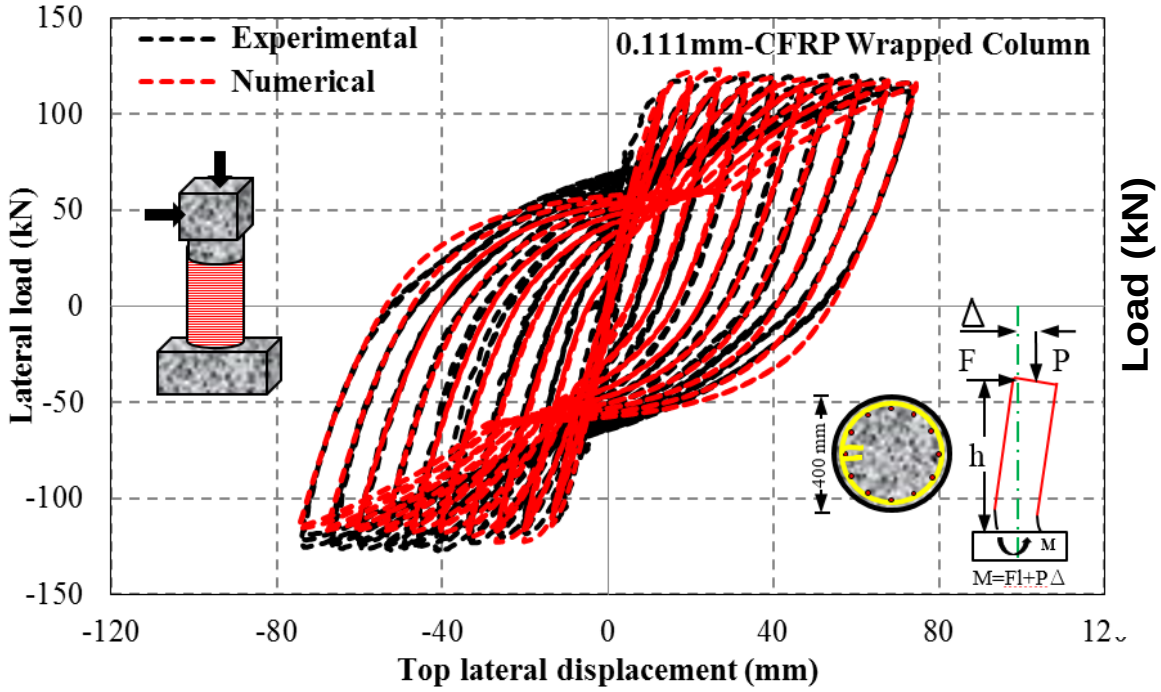


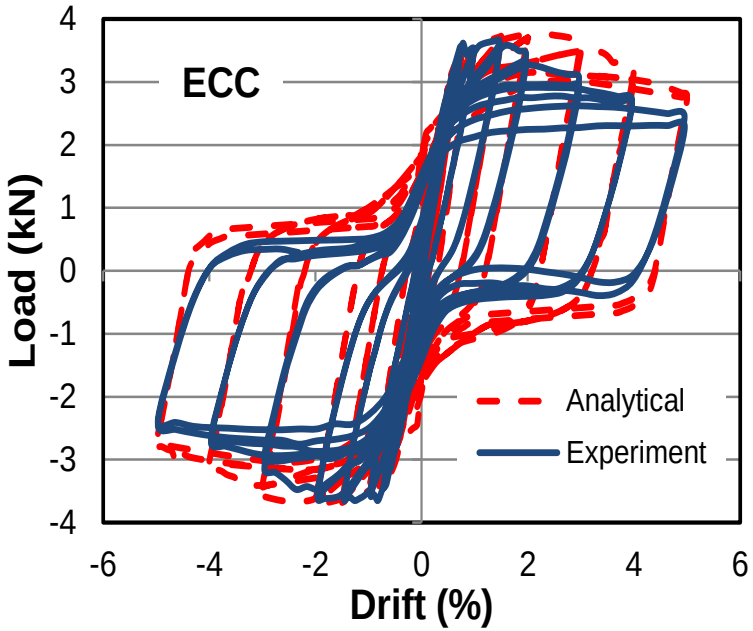
Steel Jacket



Concrete and ECC Jacket

Model Validation





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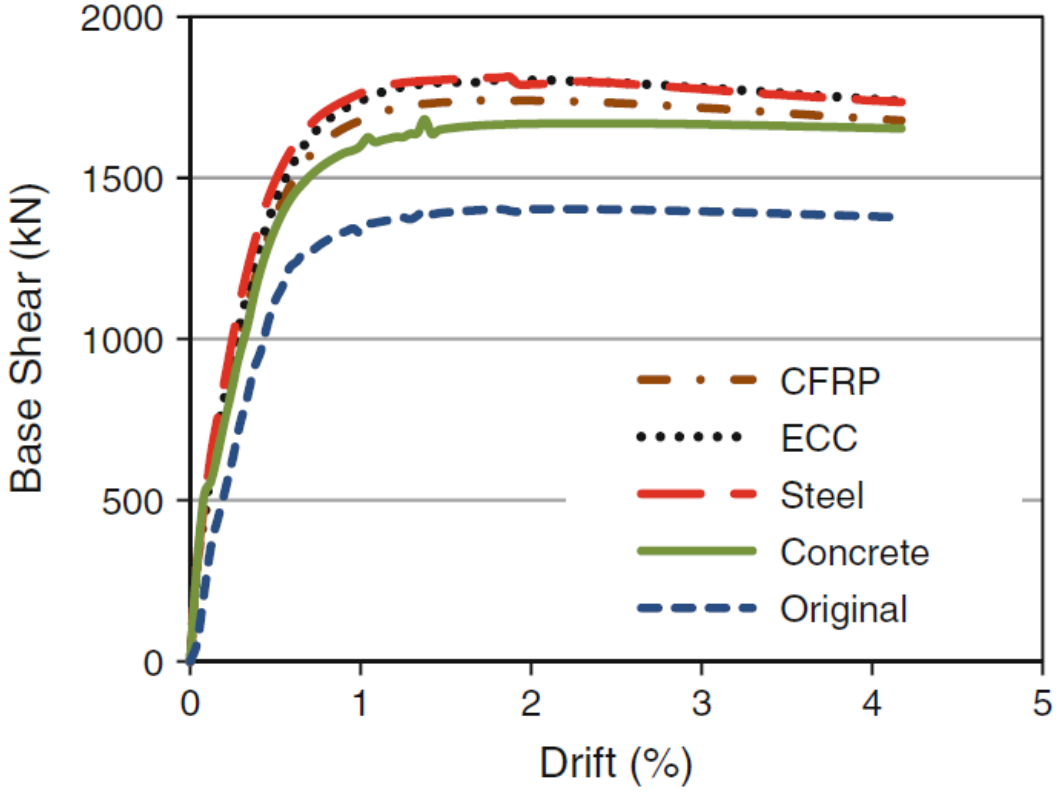
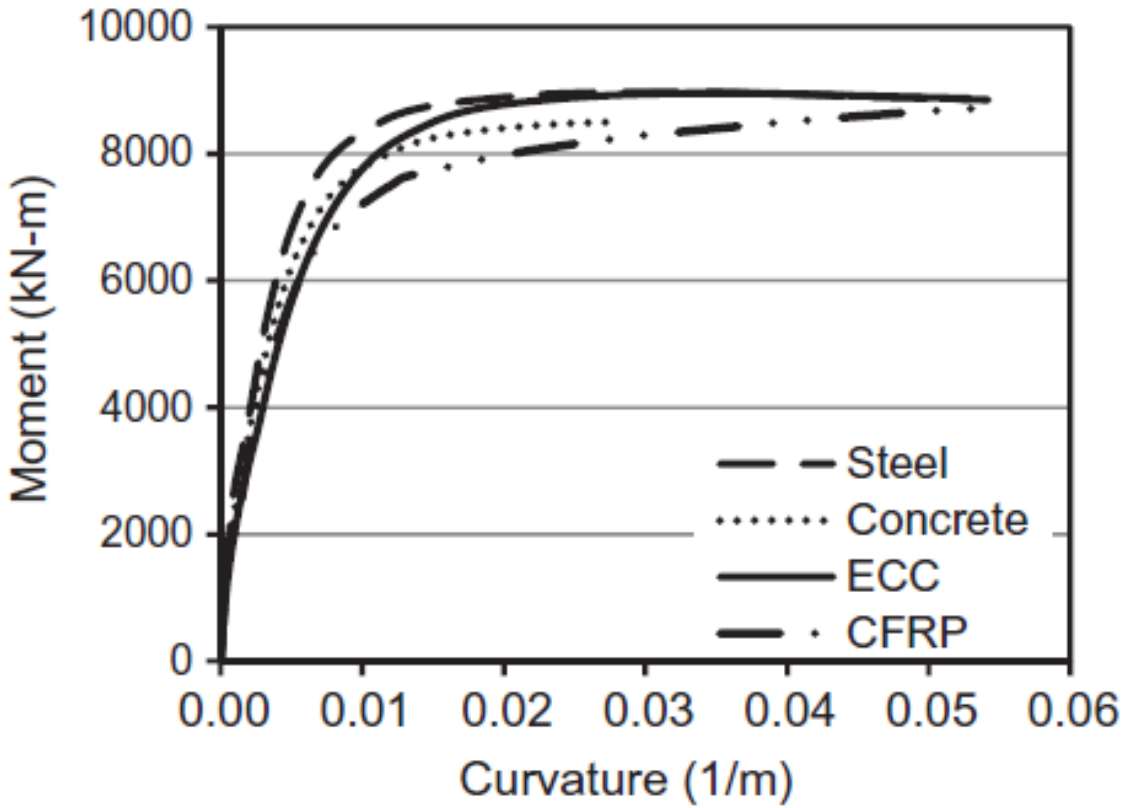
Engineering Structures, 105-117

Retrofit Design

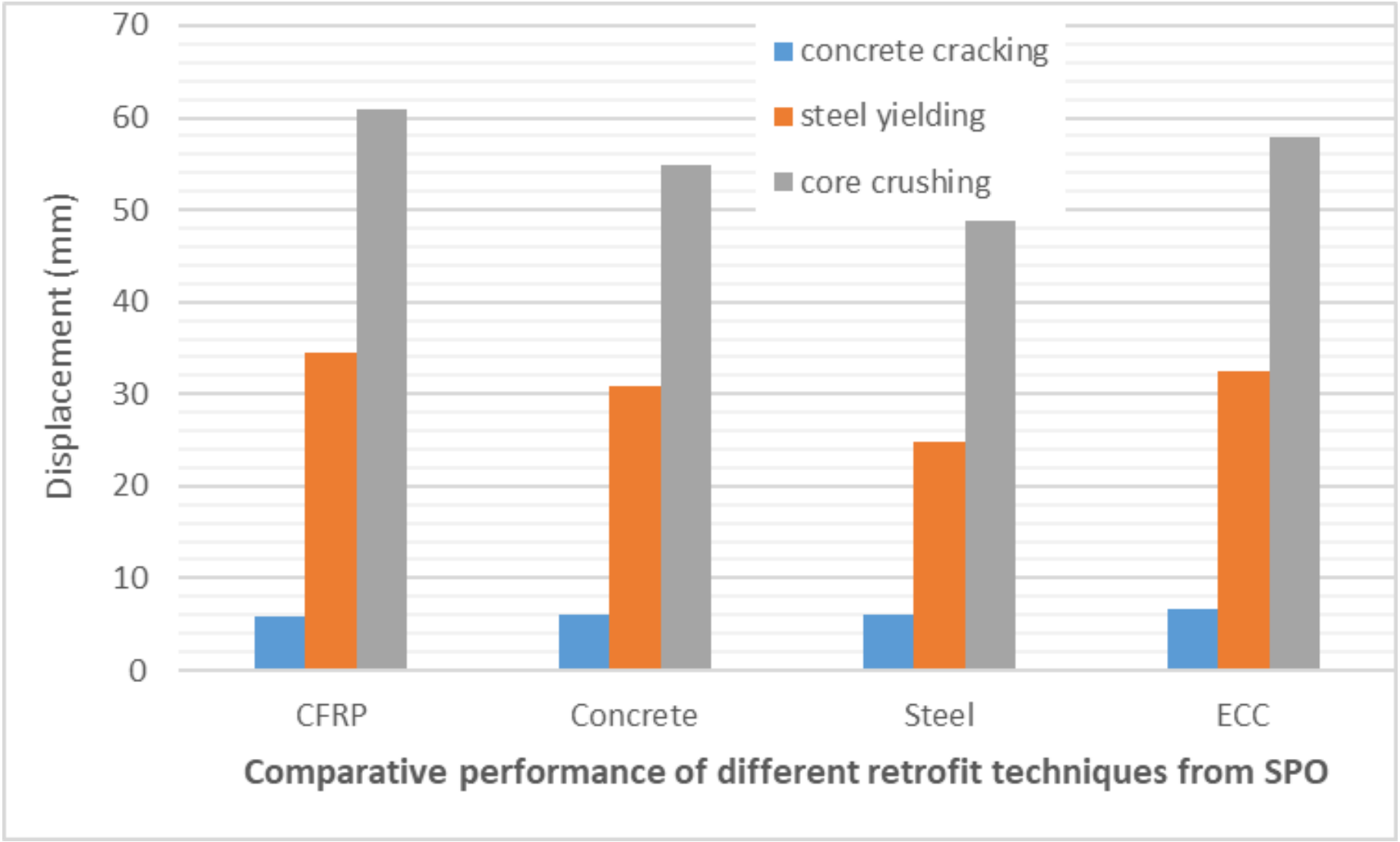




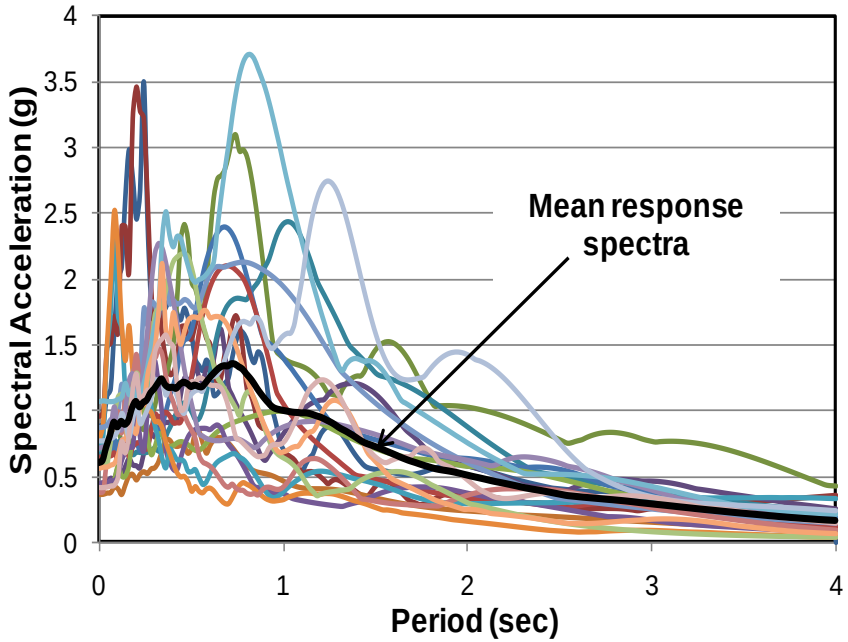
Defining Damage States

- Response from Pushover Analysis
- Response from Incremental Dynamic Time History Analysis

Damage States from Static Pushover (SPO) Analysis

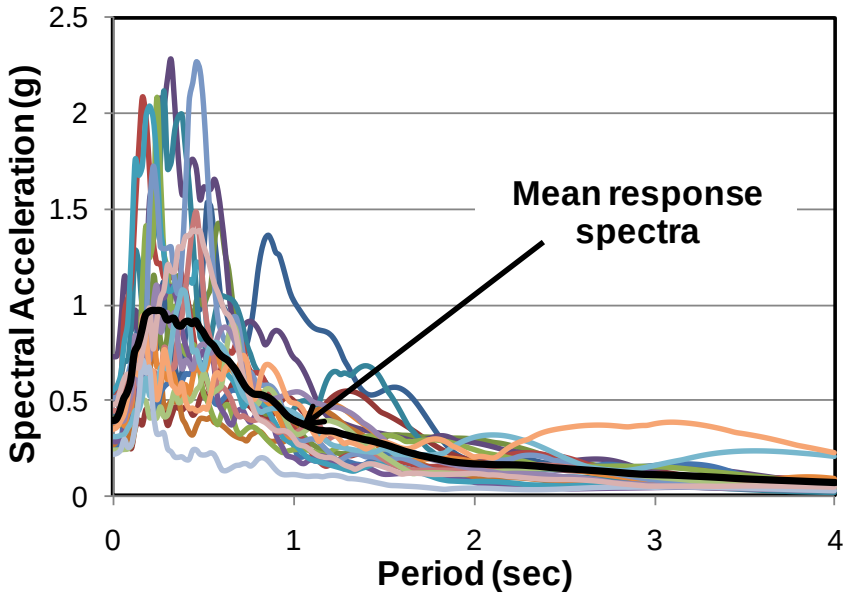


Ground Motions



Near-Fault Ground Motions

Epicentral distance < 10 km
SAC Steel Project (2000)



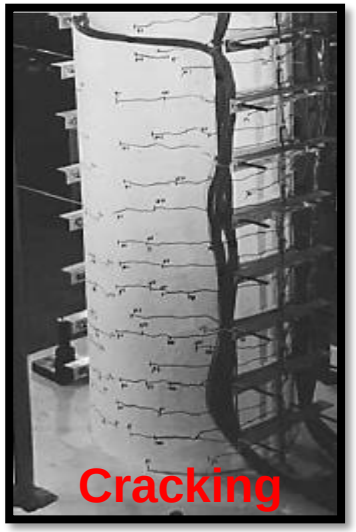
Far Field Ground Motions

Epicentral distance >10 miles
ATC (2009)

Performance Criteria

Displacement at the onset of:

- Concrete cracking
- Longitudinal rebar yielding
- Core concrete crushing



Distribution of Performance Criteria

- To find a suitable probability distribution function
- Represent the variations in observed performance points
- Probabilistic application of performance-based design

Distribution of Yield Displacement

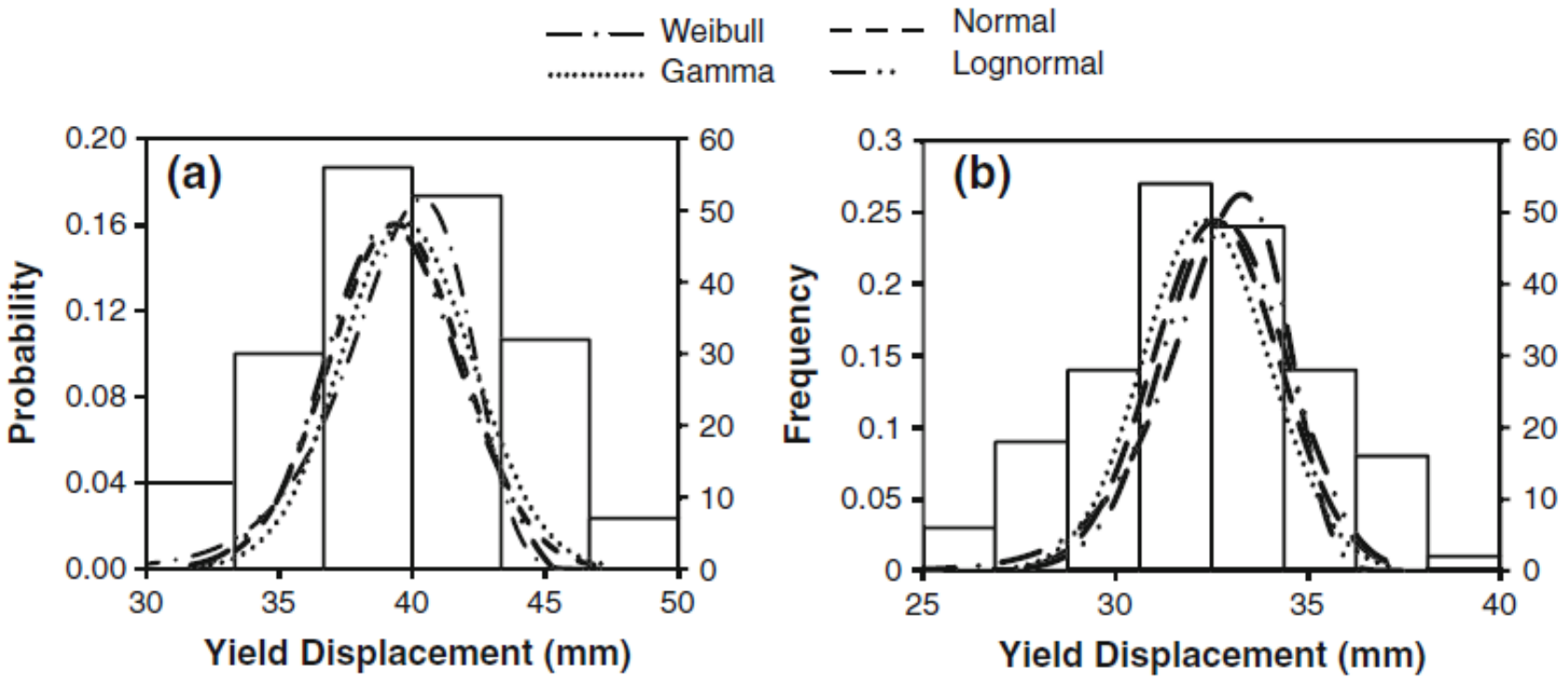


Fig. Probability density function of measured yield displacement with fitted statistical distributions for (a) CFRP, (b) concrete

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Distribution of Yield Displacement

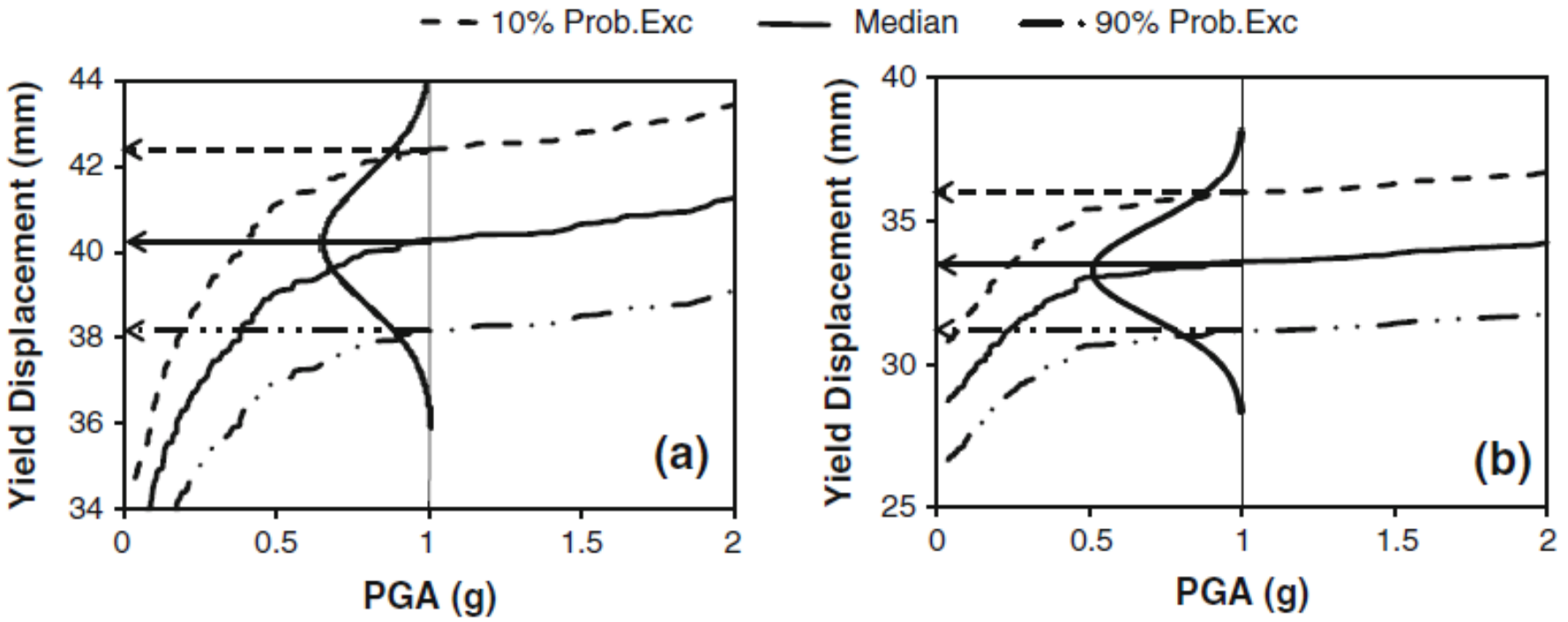

Fig. Response function of the measured yield displacement with fitted statistical distributions for (a) CFRP, (b) Concrete

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Distribution of Yield Displacement

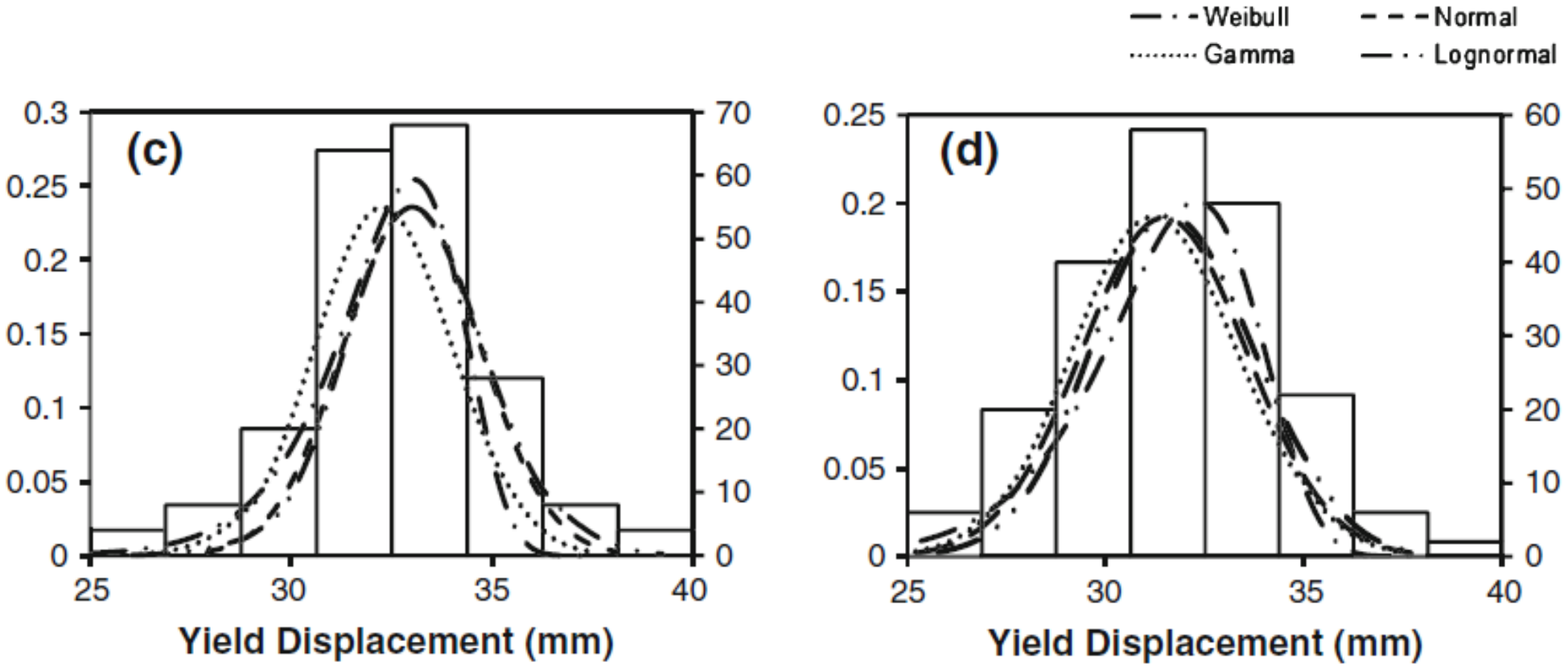

Fig. Response function of the measured yield displacement with fitted statistical distributions for (a) ECC, (b) Steel Jacket

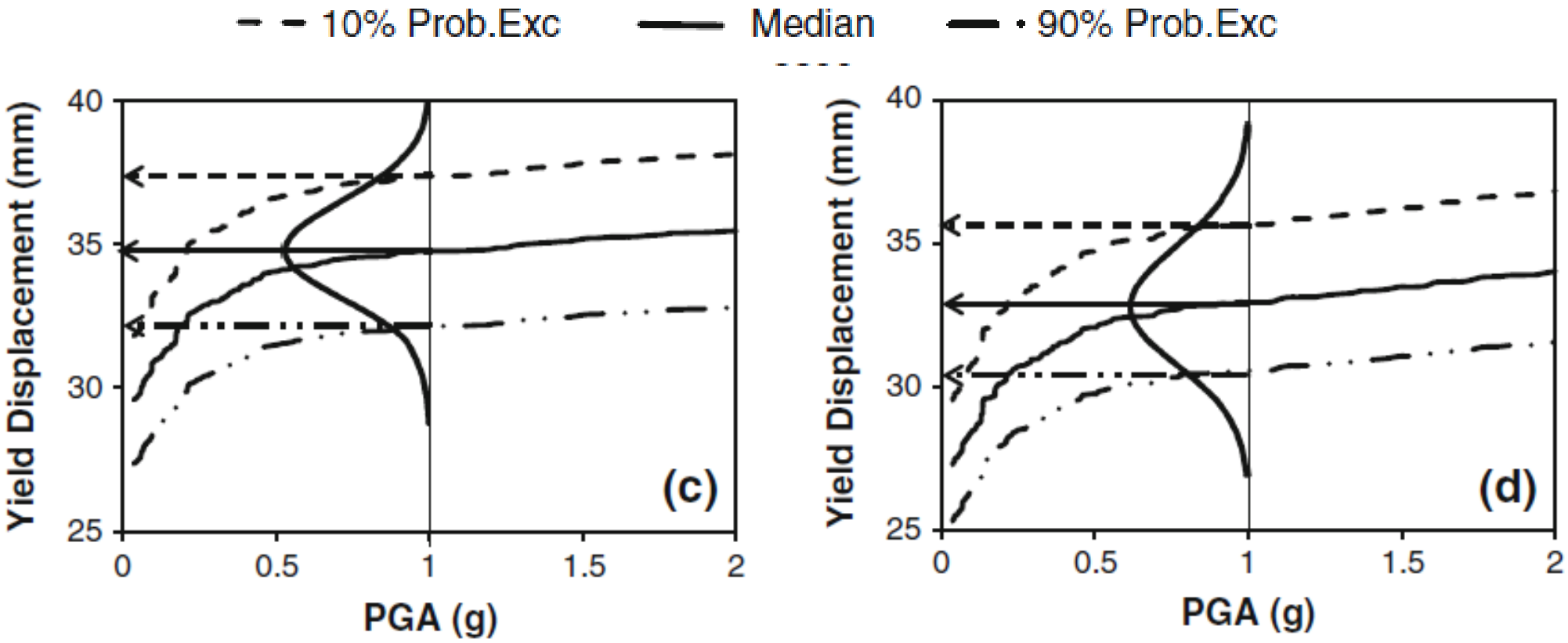

Fig. Response function of the measured yield displacement with fitted statistical distributions for (a) ECC, (b) Steel jacket

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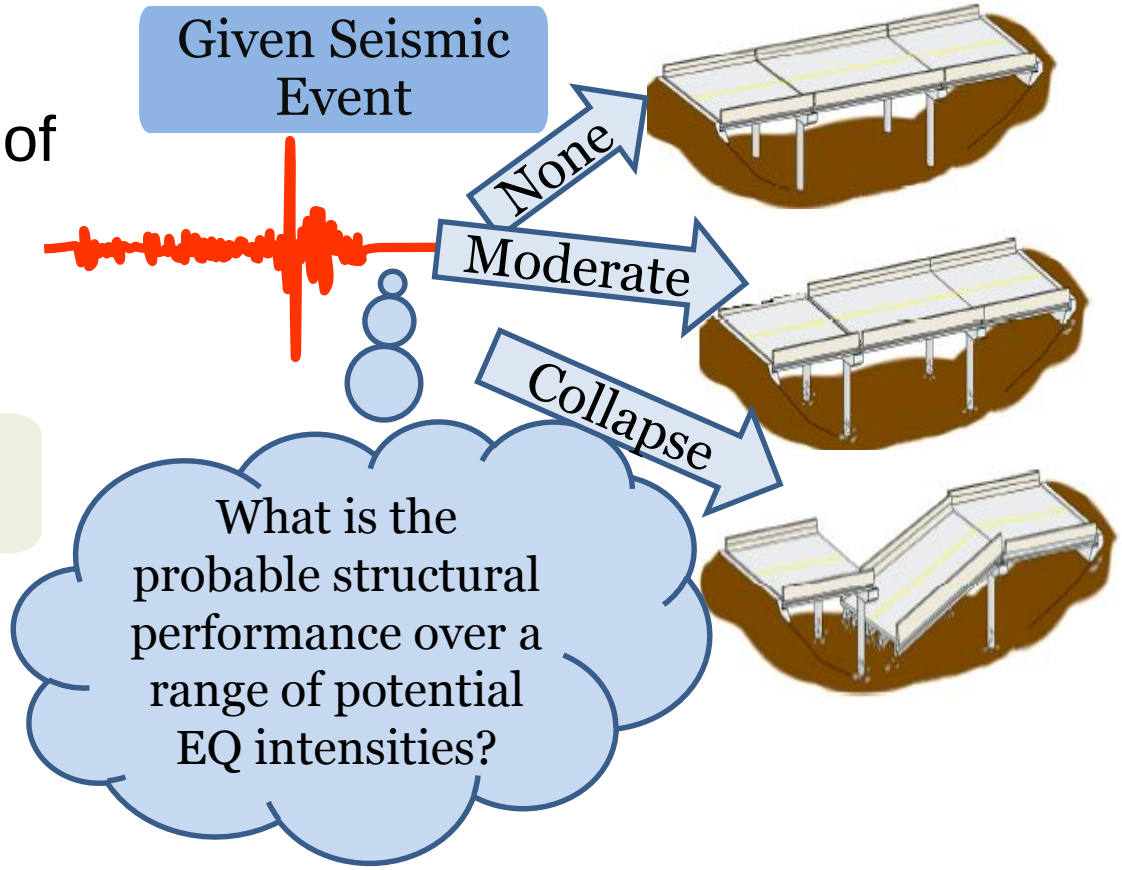
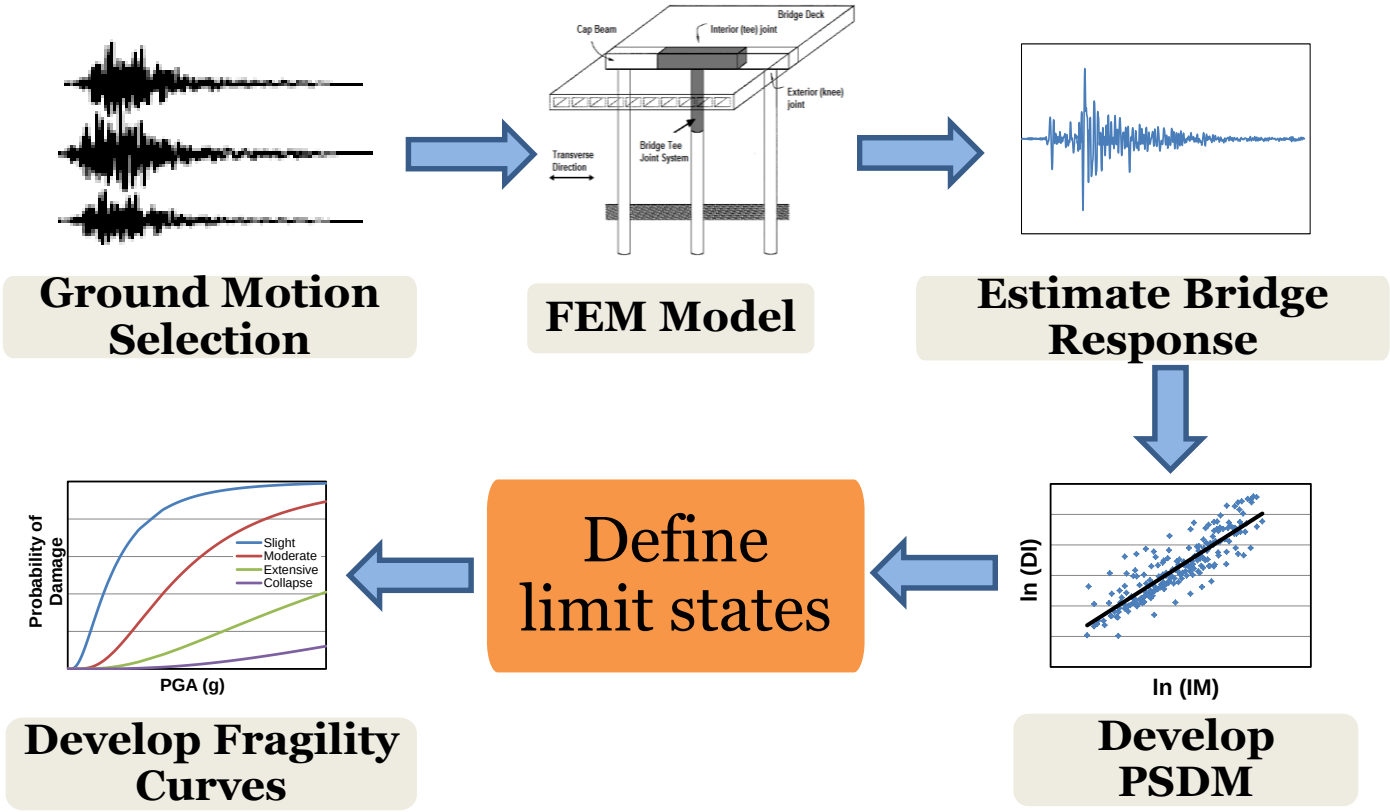
Seismic Fragility

Seismic fragility indicates the conditional probability of damage

Fragility = $P[LS|IM=y]$



Methodology



Intensity Measure (IM) and Demand Parameter (EDP)

IM: PGA

- ✓Efficacy
- ✓Utility
- ✓Adequacy
- ✓Proficiency ,

EDP: Ductility demand

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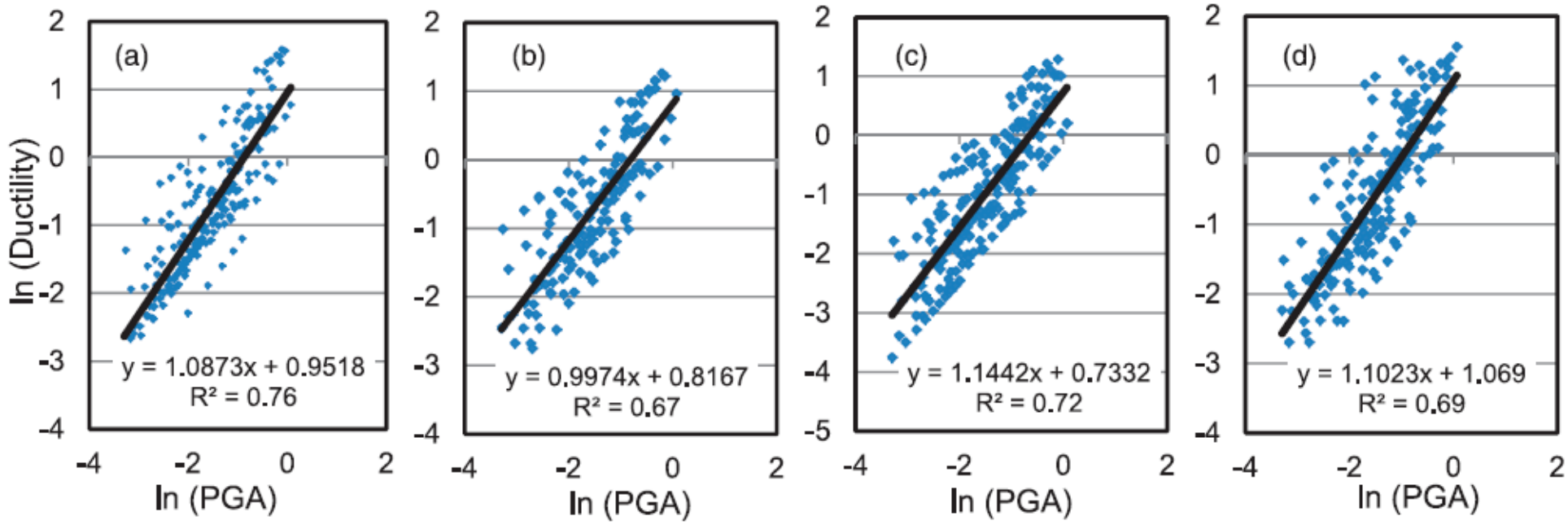
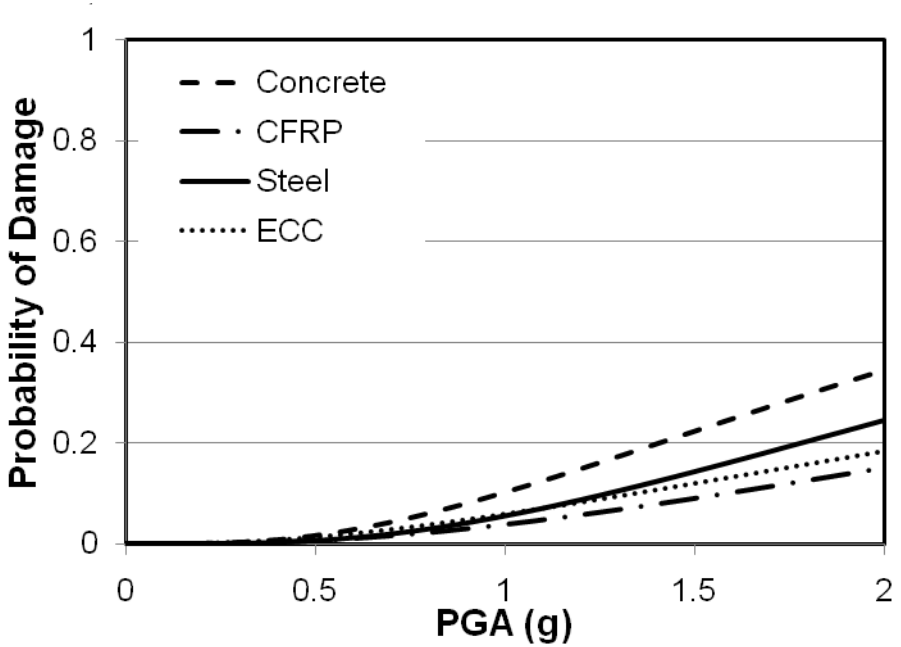
Journal of Bridge Engineering, ASCE 108 (10), 992-1004

PSDM-NF Ground Motions

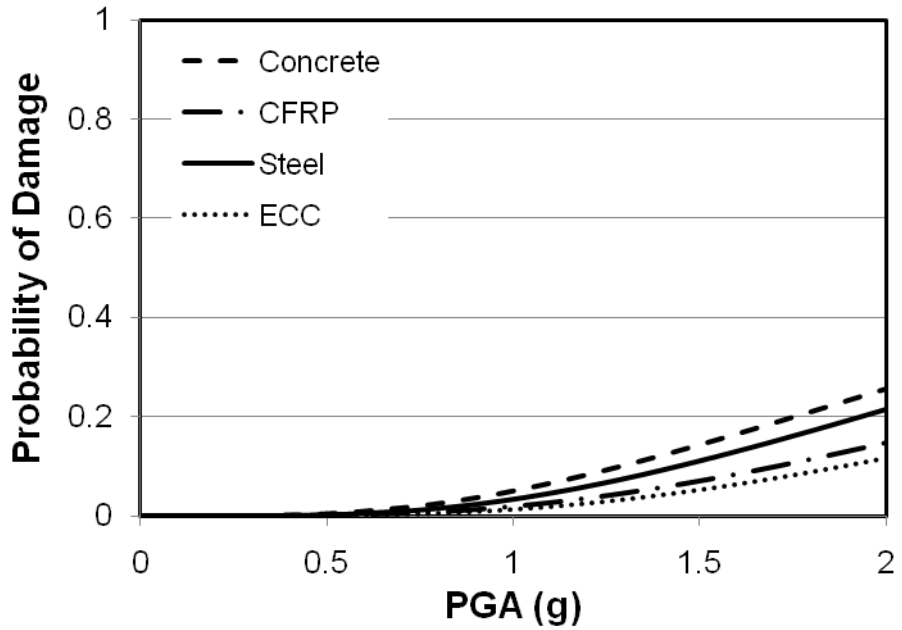


Comparison of the PSDMs for bridge bent retrofitted with (a) steel jacketing; (b) CFRP jacketing; (c) ECC jacketing; (d) concrete jacketing, for near-field ground motion

Fragility Curves-NF



Fragility Curves-FF



Median PGA

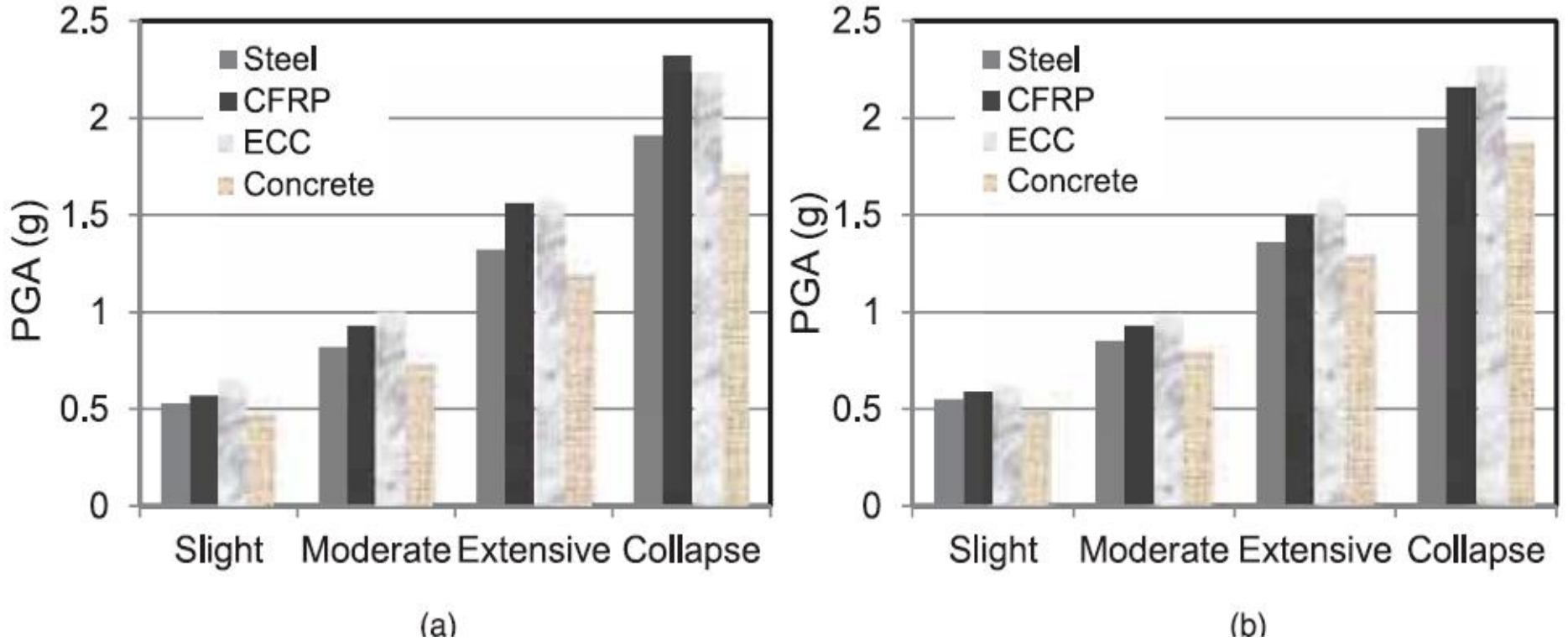


Fig. Comparison of median values of PGA for the bridge bent retrofitted with different retrofitting techniques for (a) near-field ground motion; (b) far-field ground motion

Conclusions

- Damage states from static pushover analysis vs incremental dynamic analysis
- Effectiveness of a retrofit technique in mitigating probable damage measured using fragility curves
- Fragility curves can be utilized to:
  - estimate potential seismic losses
  - selection of suitable retrofitting techniques
  - retrofitting prioritization,
  - post-earthquake rehabilitation decision making, and

Thanks for your attention

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Acknowledgements