Aftershock Seismic Vulnerability and Time-dependent Risk Assessment of Bridges

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Research team

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Motivation

- Caltrans uses the following table to relate bridge seismic damage to post-earthquake functionality and repair priorities

Bridge system damage states	BSST-0 MINOR	BSST-1 MODERATE	BSST-2 EXTENSIVE	BSST-4 COMPLETE
ShakeCast Inspection Priority levels	Low	Medium	Medium-High	High
Likely Immediate Post-Event Traffic State	Open to normal public traffic – No Restrictions	Open to Limited public traffic – speed/weight/lane restrictions	Emergency vehicles only – speed/weight/lane restrictions	Closed (until shored/braced) – potential for collapse
Traffic Operation Implications Is closure/detour needed? Are traffic restrictions needed?	 Very unlikely Unlikely	 Unlikely Likely	 Likely Very Likely	 Very likely Very Likely - Detour
Emergency Repair Implications Is shoring/bracing needed? Is roadway leveling needed?	 Very unlikely Unlikely	 Unlikely Likely	 Likely Very Likely	 Very likely Very Likely - Detour
Component Damage Range Primary components Secondary components	 CDT-0 to 1 CDT-0	 CDT-1 to 2 CDT-1	 CDT-2 to 3 NA	 Above CDT-3 NA

Mangalathu, S., Jeon J-S., Padgett, J. E., DesRoches, R., "ANCOVA-based Grouping of Bridge Classes for Seismic Fragility Assessment", *Engineering Structures*, Vol. 123, 2016, pp 379-395.

Aftershock Vulnerability and Time dependent Risk Assessment of Bridges

Motivation

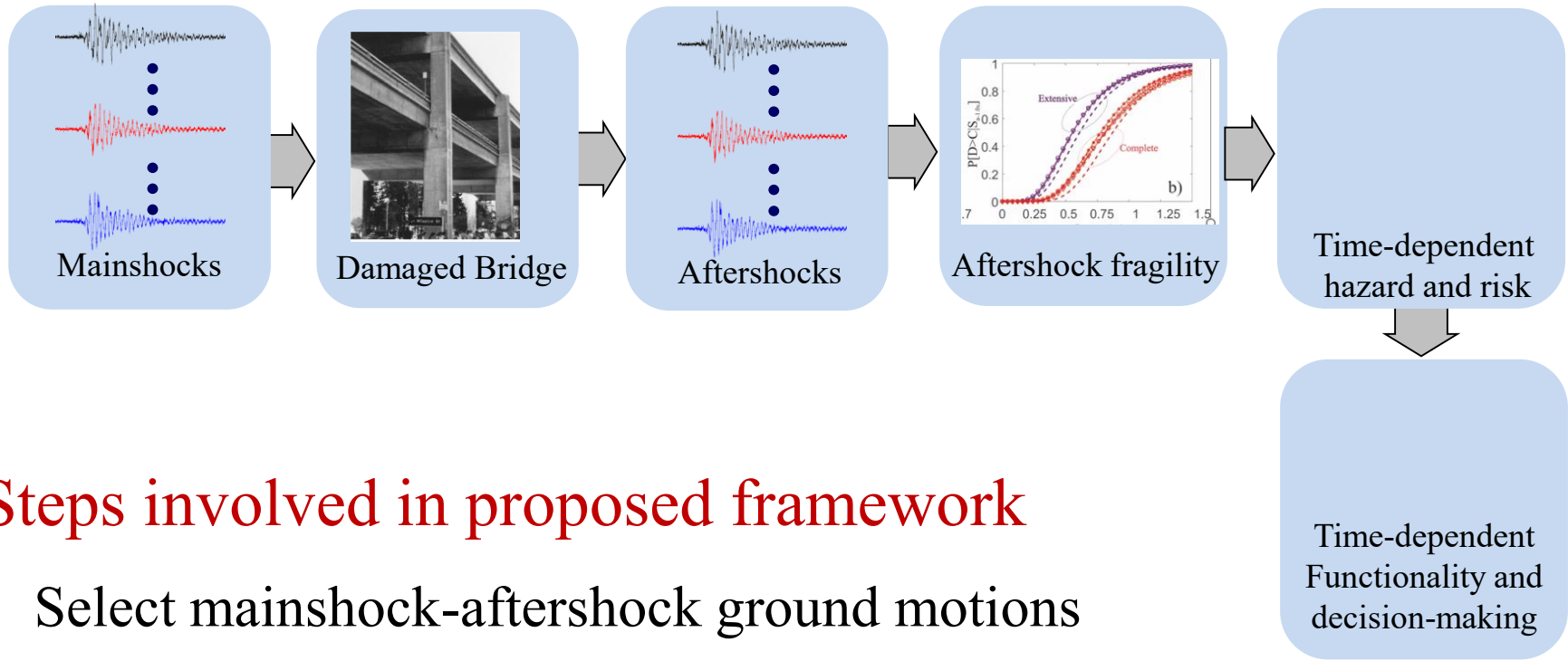
- The extent to which 'residual structural capacity' and 'time-dependent aftershock hazard and risk' inform these damage-functionality and inspection priority relationships is unclear.

Goals / Overall Objective

- Conduct aftershock seismic vulnerability and time-dependent risk assessment of typical California bridges

- Use results from vulnerability and risk assessments to inform decisions regarding the appropriateness and timing of inspections and post-event closure (partial and complete)

Aftershock Vulnerability and Time dependent Risk Assessment of Bridges



Steps involved in proposed framework

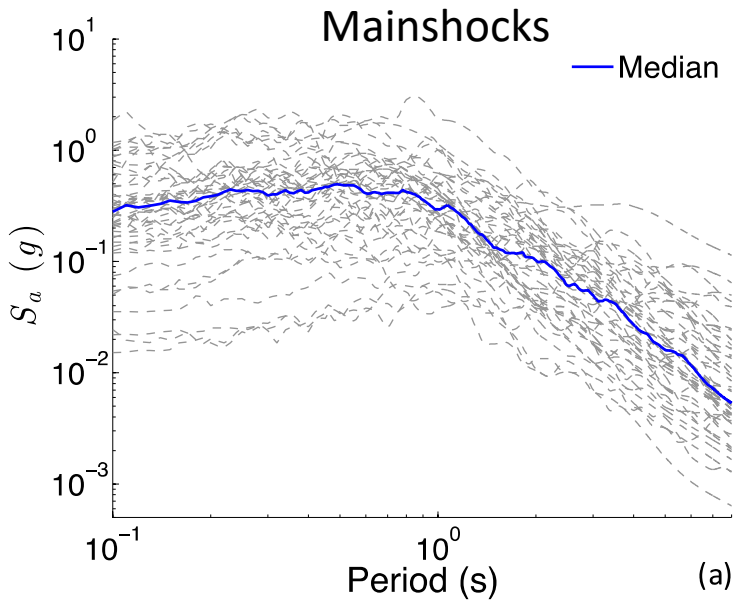
- Select mainshock-aftershock ground motions
- Create structural models of bridge structures
- Conduct mainshock and mainshock-aftershock fragility analysis
- Quantify time-dependent hazard (APSHA) and risk (Markov Chain Models) assessment
- Establish time-dependent risk and functionality/inspection relationships

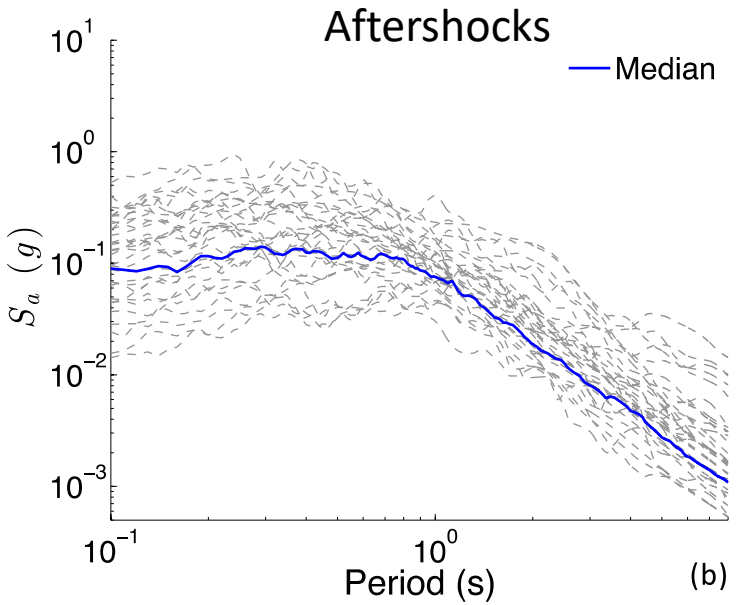
Selection of ground motions

- Past studies have reported non-negligible differences in frequency content of mainshock (MS) and aftershock (AS) records
- Therefore, it's best to use actual MS-AS sequences in response history analysis

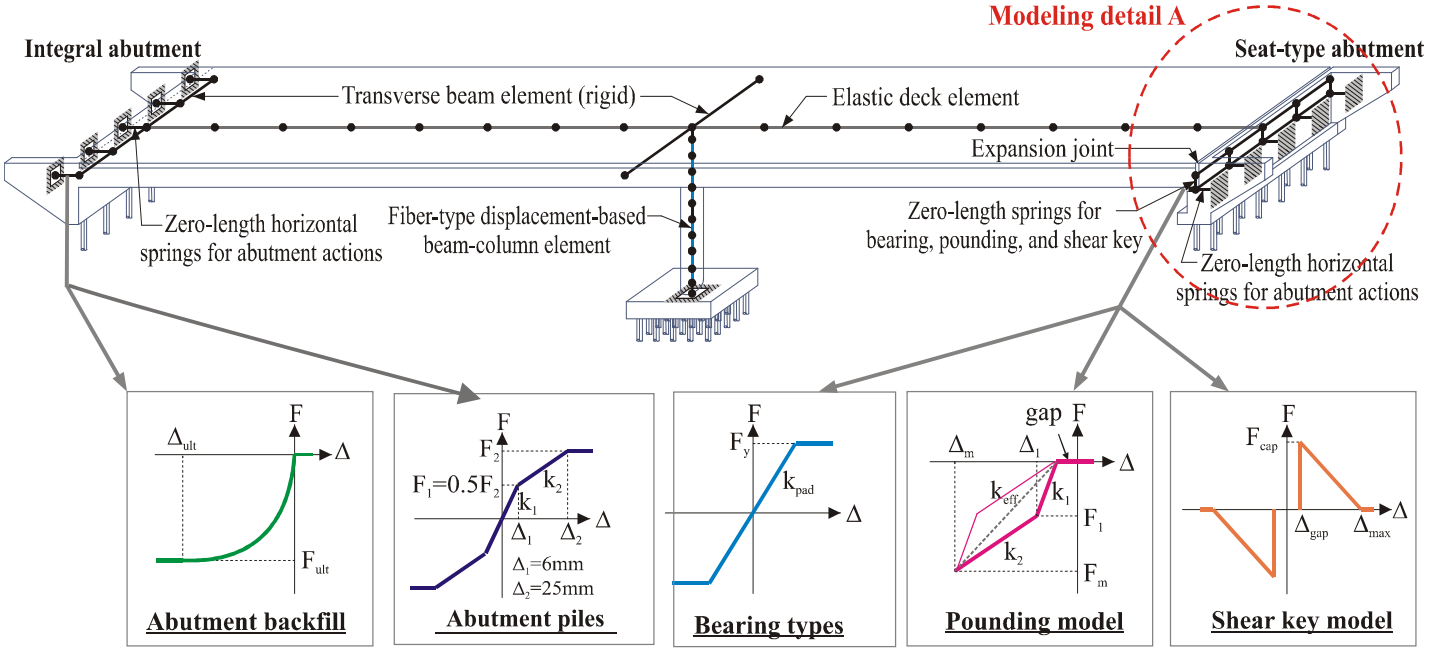
Selection of Mainshock/ Aftershock ground motions

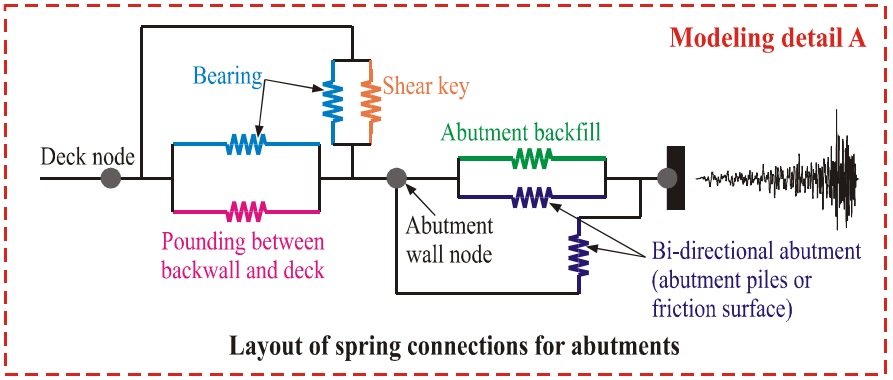
- Set of 46 record-pairs
- Class 1 and Class 2 events in PEER-NGA West2 database
- $5.8 \leq M_{w,MS} \leq 7.6$
- $4.0 \leq M_{w,AS} \leq 7.2$





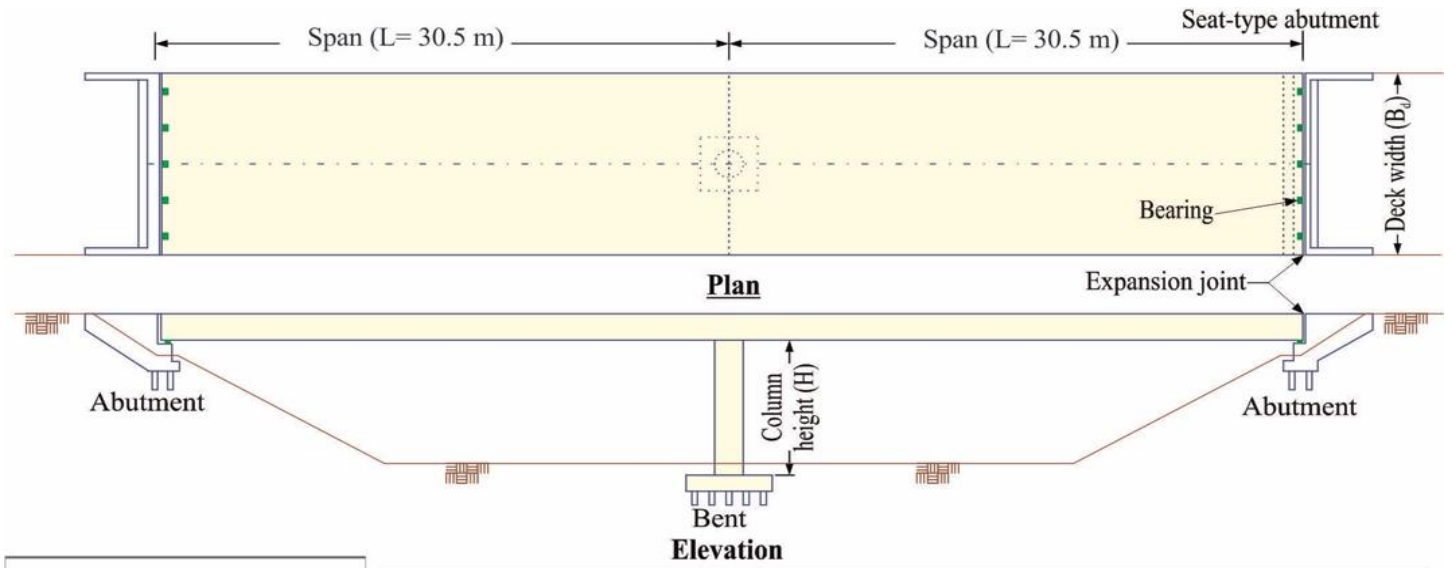
Modeling of Bridge Structures

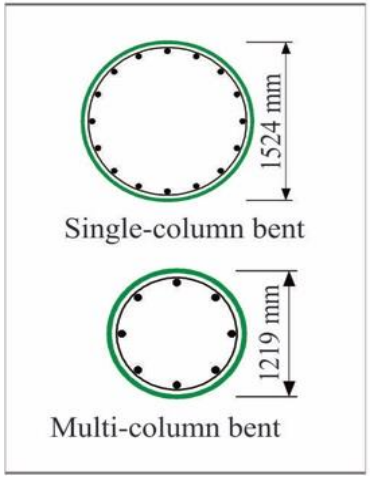


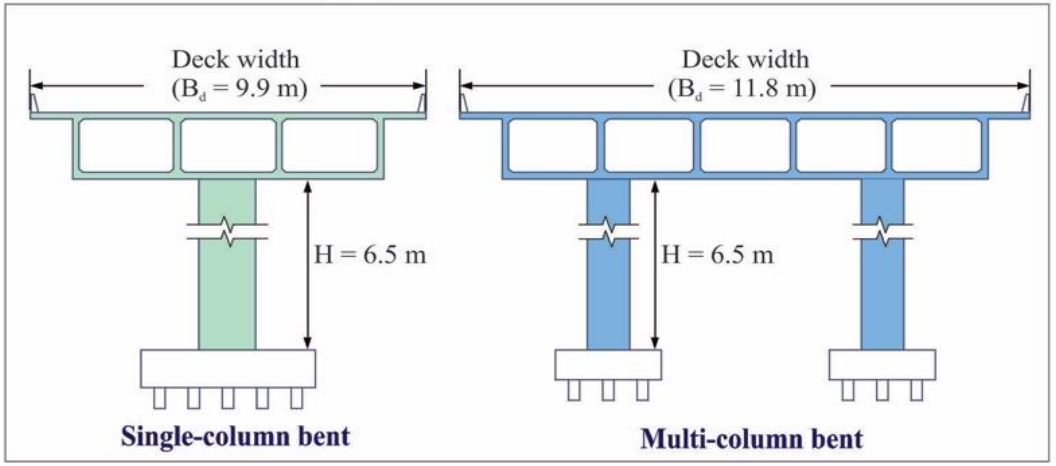


Mangalathu, S (2017). Performance based grouping and fragility analysis of bridges in California. Ph.D. Thesis. Georgia Tech, USA

Selected Bridge Cases







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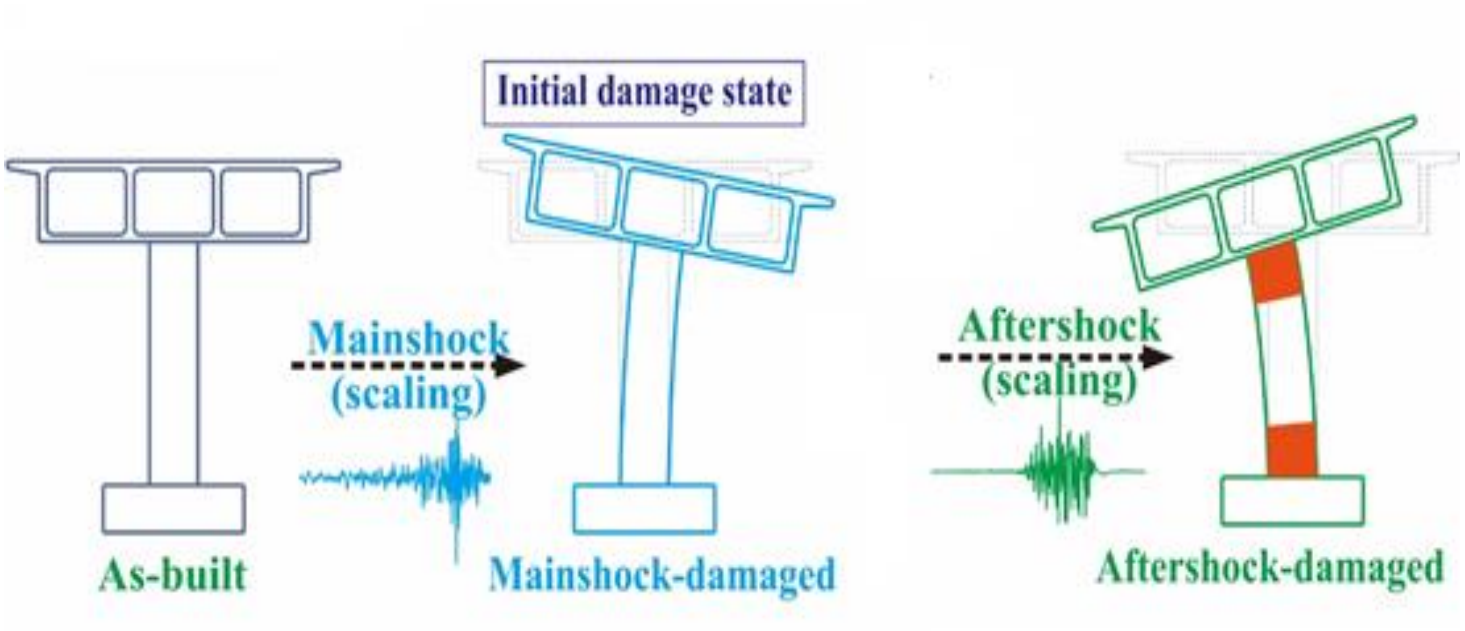
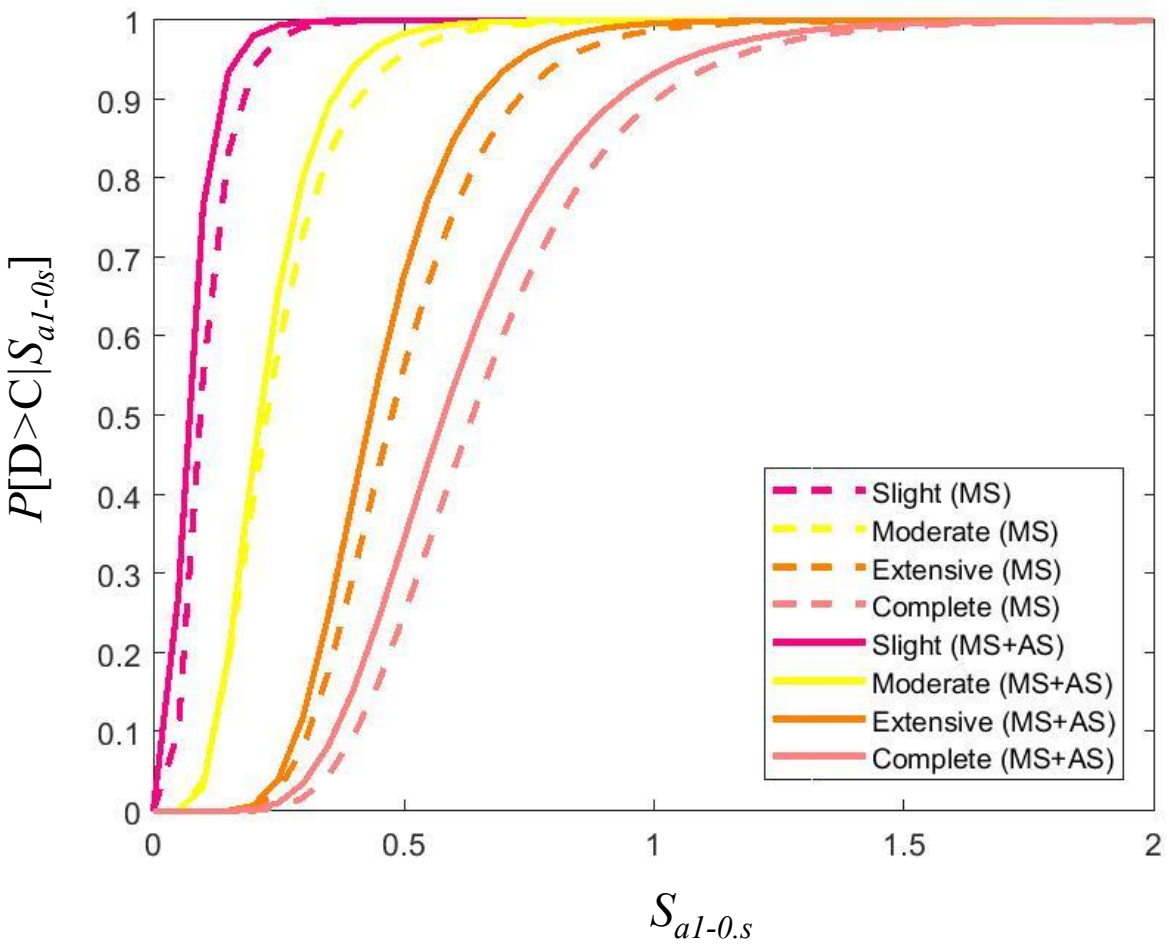
Aftershock Fragility Analysis

- **Aftershock fragility:** A conditional probability that determines the likelihood that a damaged structure will meet or exceed a specified level of damage, given an aftershock intensity measure and an initial damage state associated with the mainshock [**mainshock-damage-dependent aftershock fragility**].



Aftershock Fragility Analysis



Aftershock fragility of two-column bridge in “slight” damage state after mainshock

Ongoing research directions

- Perform aftershock probabilistic seismic hazard analysis (APSHA) to quantify time-dependent post-mainshock hazard.
- Implement Markov Chain Model that integrates time-dependent hazard curves and mainshock-damage-dependent-fragilities to quantify time-dependent risk
- Use time-dependent risk outcomes to inform bridge functionality and inspection priorities
- Consider other typical California bridge types