SEISMIC PERFORMANCE OF BRIDGES AFFECTED BY LATERAL SPREADING

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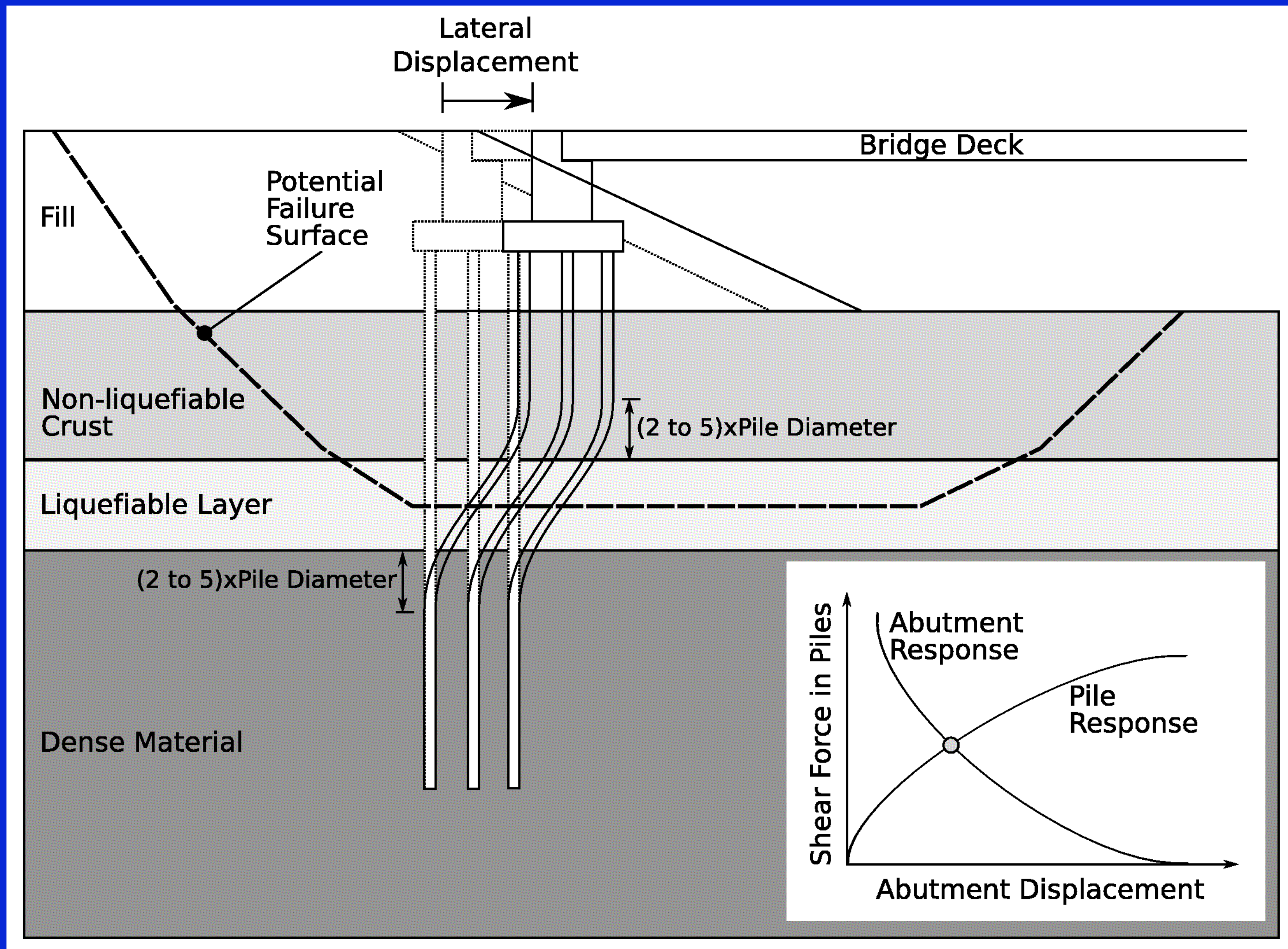
PROBLEM



Lateral
Displacement
Bridge Deck
Fill
Potential
Failure
Surface
Non-liquefiable
Crust
(2 to 5)xPile Diameter
Liquefiable Layer
(2 to 5)xPile Diameter
Dense Material
Shear Force in Piles
Abutment
Response
Pile
Response
Abutment Displacement

Probabilistic Simplified Approach

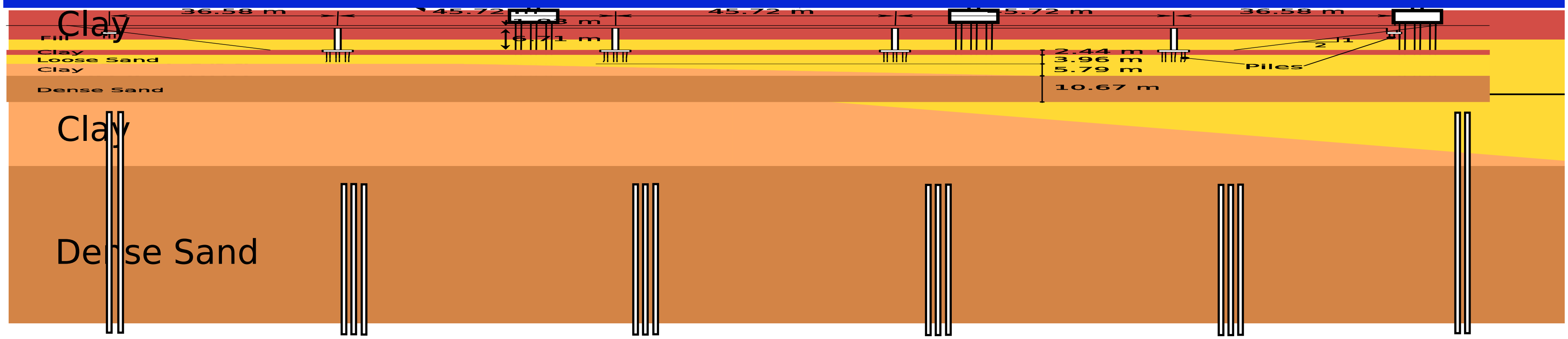
Ledezma and Bray 2008 – PEER Report

1. Post-earthquake bridge condition can be related to lateral seismic displacement

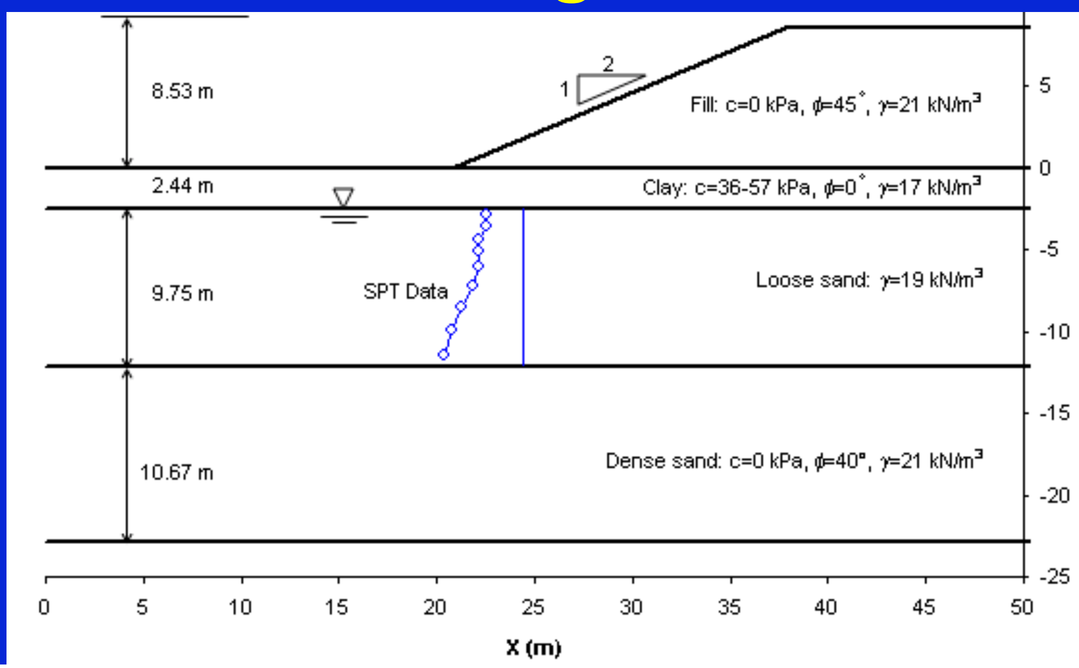
2. Estimate lateral seismic displacement for ground motion hazard levels

$$\lambda(dv) = \int_{dm} \int_{edp} \int_{im} G(dv \mid dm) \left| dG(dm \mid edp) \right| \left| dG(edp \mid im) \right| \left| d\lambda(im) \right|$$

Example Bridge



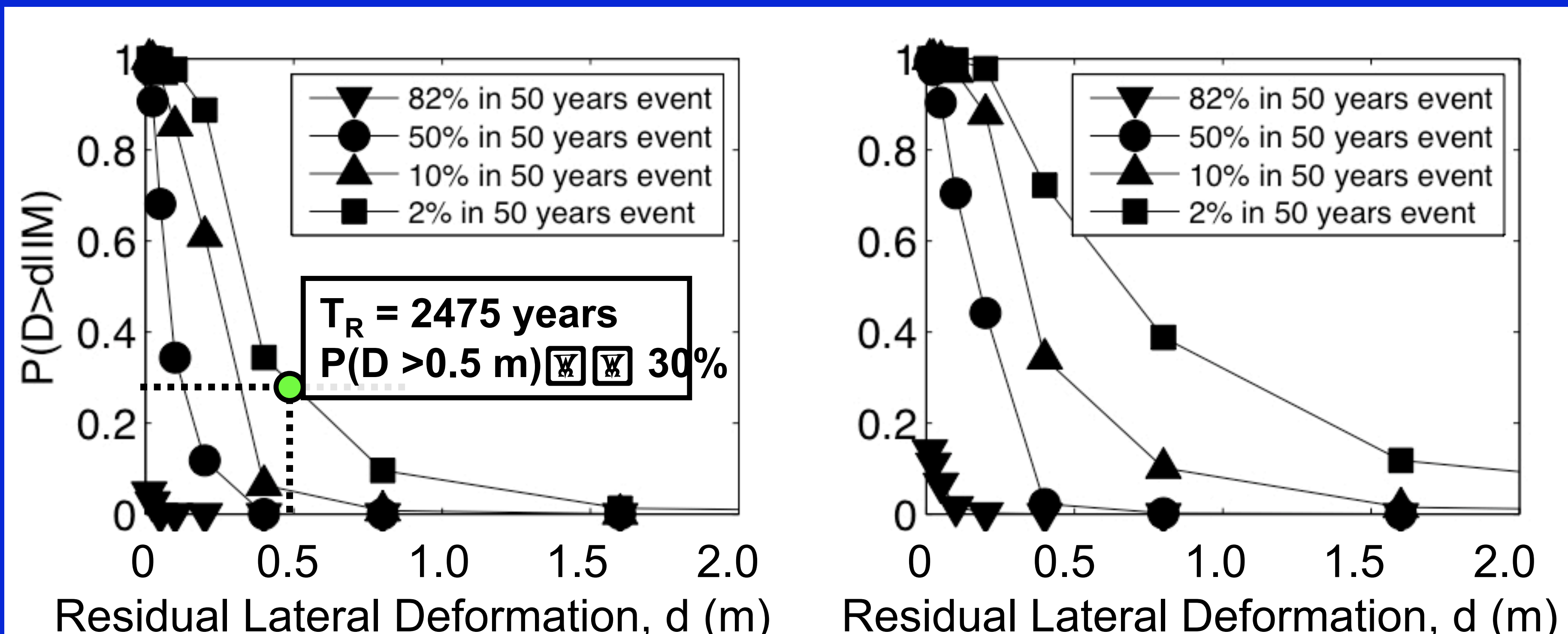
Right Abutment



SPT Data

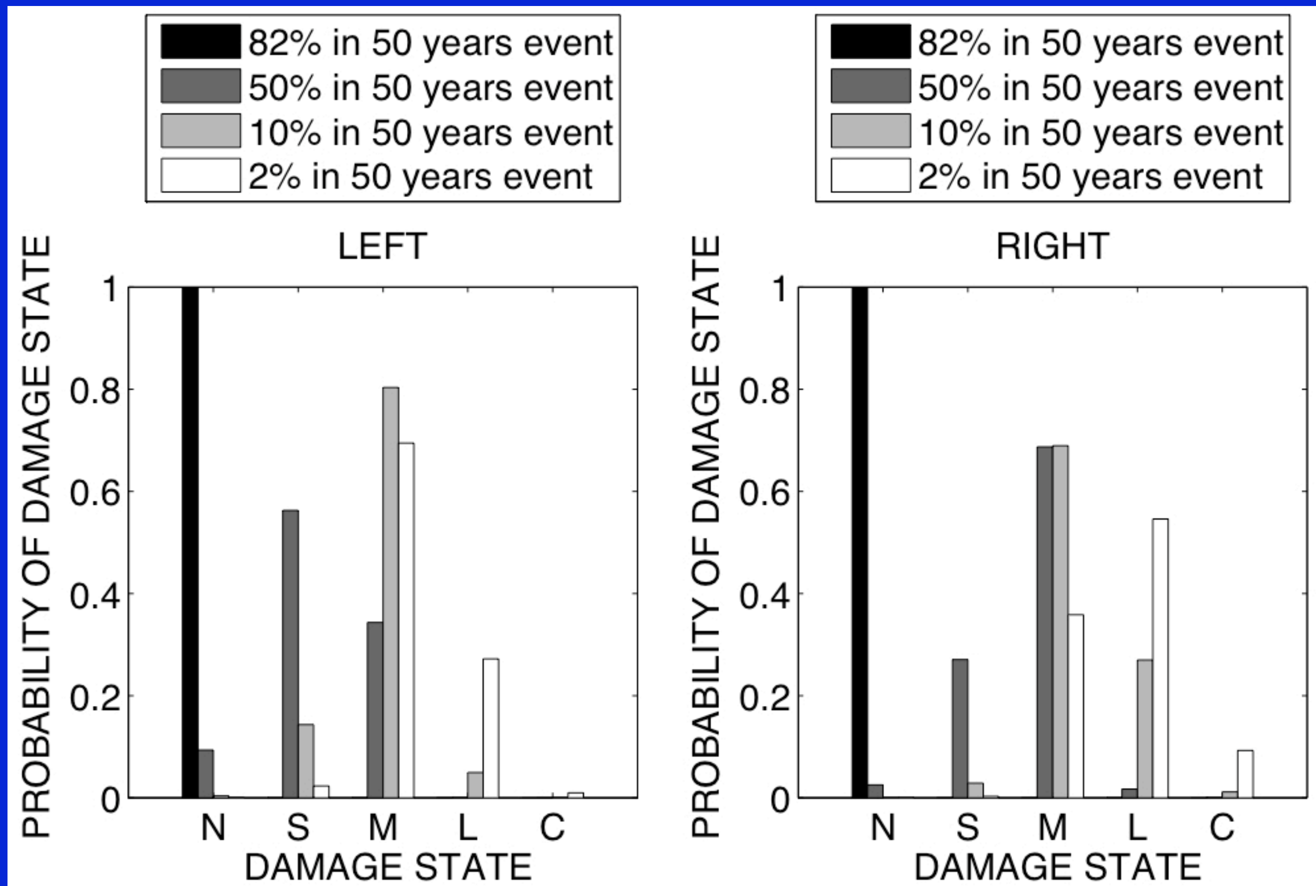
Depth (m)	N1,60-CS
2.83	13
3.57	13
4.33	16
5.12	16
6.00	16
7.19	18
8.53	22
9.91	25
11.43	28

Overall Probability of Displacement Exceeding a Threshold at Selected Ground Motion Hazard Levels



LEFT ABUTMENT **RIGHT ABUTMENT**

Probable Damage State



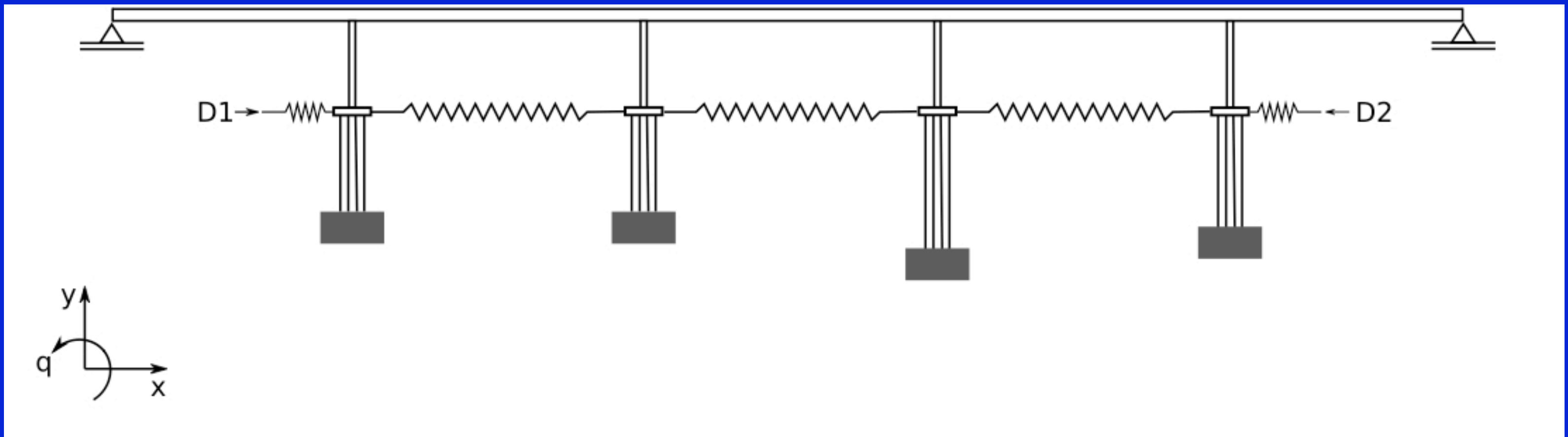
Seismic Displacement(inches)	Damage Level	Median Downtime
0 – 1”	Negligible	0
1” – 4”	Small	0
4” – 20”	Moderate	0
20” – 80”	Large	1day
> 80”	Collapse	60 days

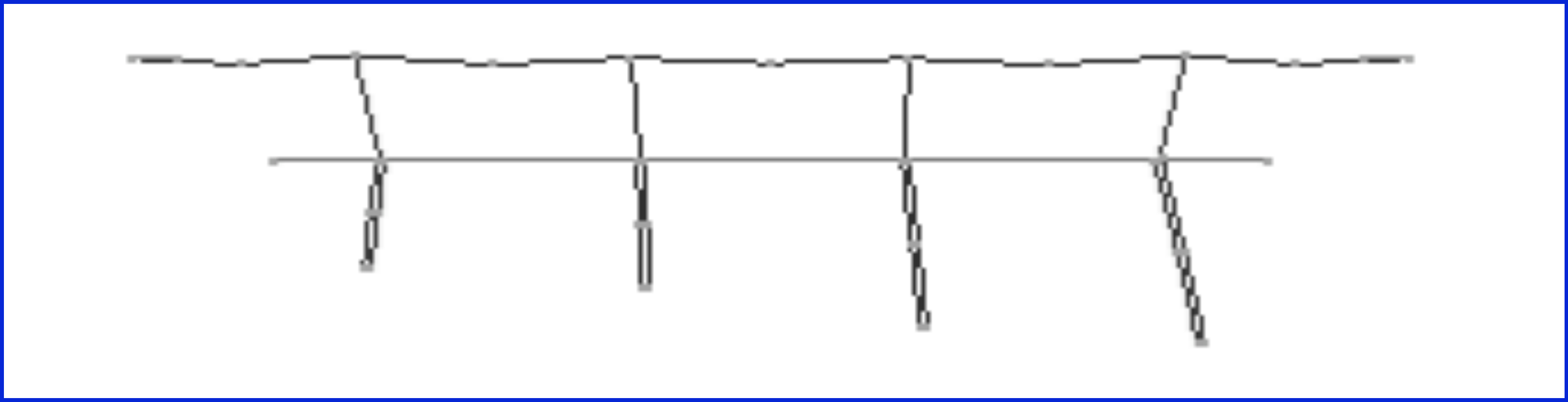
μ

Expected Repair Cost Ratios & Downtimes (low uncertainty)

	Left Abutment				Right Abutment			
	Prob. Of Exceedance in 50 yrs				Prob. Of Exceedance in 50 yrs			
	82%	50%	10%	2%	82%	50%	10%	2%
Mean	0.0 0	0.03 0	0.11 1.5 hr	0.21 1 day	0.0 0	0.08 0.5 hr	0.21 1 day	0.37 6 days
Standard Deviation	0.0 0	0.05 0	0.10 1 hr	0.19 .5 day	0.01 0	0.07 0.5 hr	0.19 .5 day	0.22 4 days

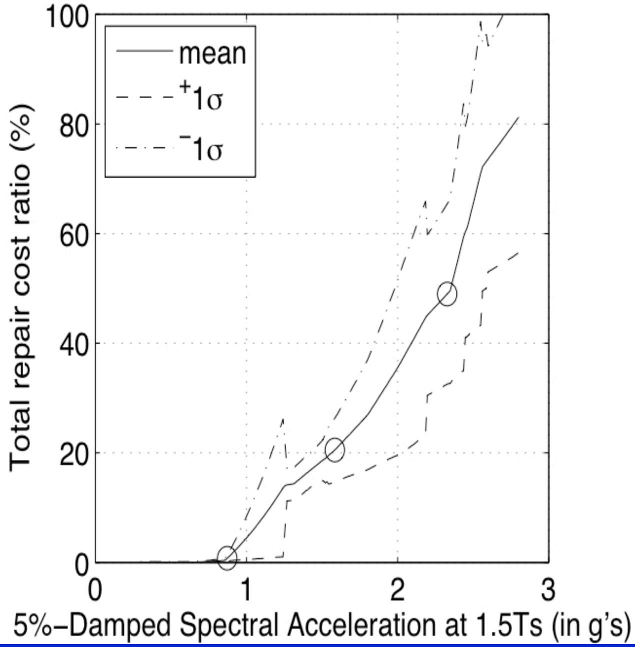
Simplified Coupled Soil-Foundation-Bridge Model

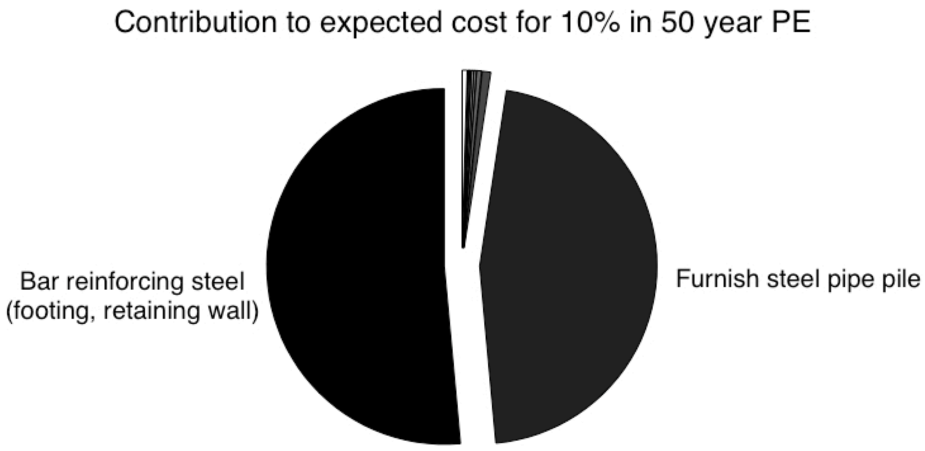


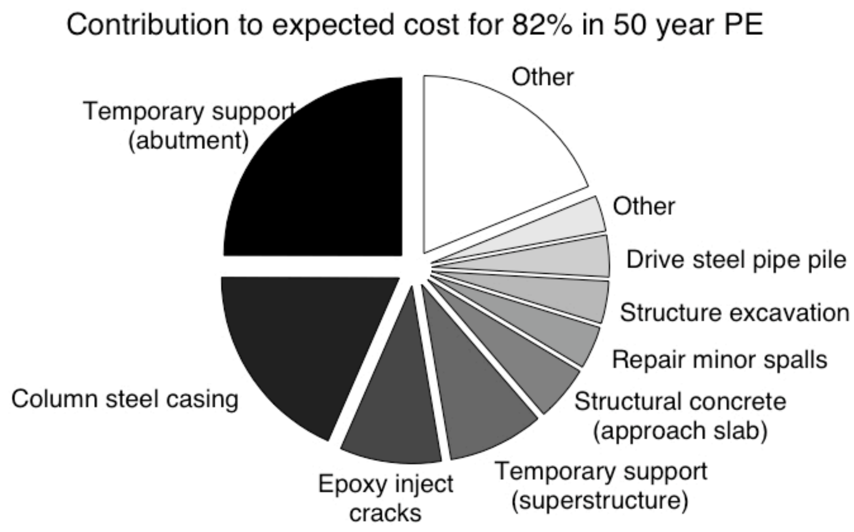


Based on Mackie and Stojadinovic Model and Data File

Contribution to Repair Cost







EVALUATE RELATIVE IMPORTANCE OF KEY FACTORS IN SEISMIC DISPLACEMENT ESTIMATE

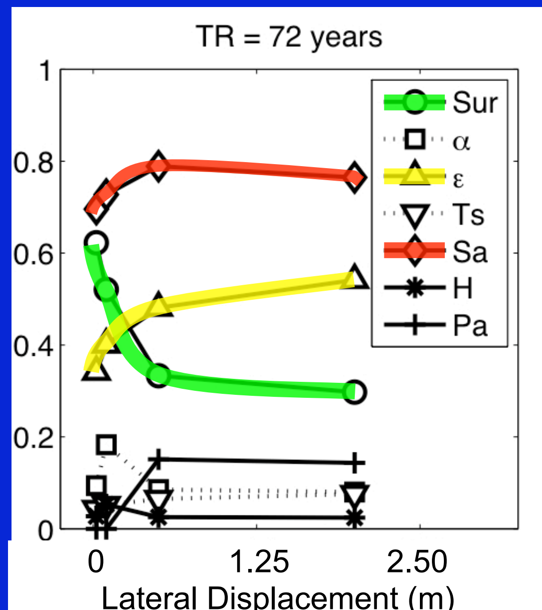
Potentially important factors:

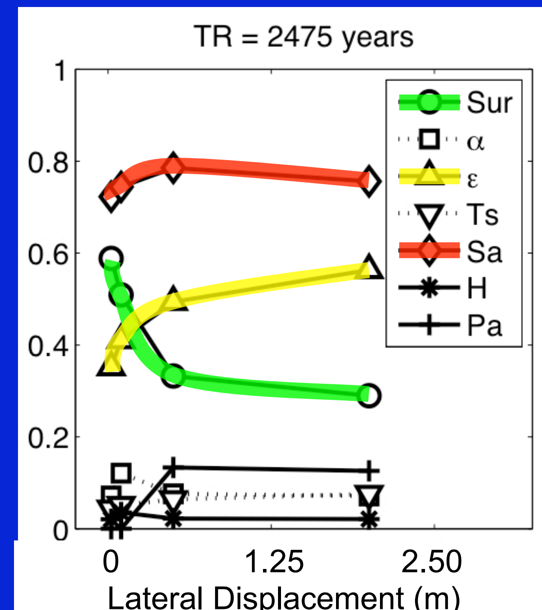
- Spectral acceleration at degraded period, $S_a(1.5T_s)$
- Fundamental period of sliding mass, T_s
- Thickness of liquefiable material, H
- Distance to point of pile fixity, a
- Passive reaction against abutment backwall, P_a
- Error term in estimating Newmark-type displacement, e
- Residual undrained shear strength, S_{ur}

Relative Importance of Random Variables at different hazard and displacement levels

Right Abutment

$\hat{\gamma}_i$





Most important factors:

1. S_a
2. e
3. S_{ur}

Outcomes

- Probabilistic procedure for evaluating the seismic performance of bridges affected by lateral spreading has been developed
- Calibrated against available case histories and model studies
- Uncertainty in key parameters has been incorporated
- Can be used to estimate impact on seismic performance in terms of death, dollars, and downtime
- Simplified user guide provided (10 pp)

Uses

- Methodology can be used to identify likely damage state and repairs required
- Methodology can be used to evaluate the relative importance of key parameters:
  - Intensity of the ground motion, $S_a(1.5T_s)$
  - Error term in estimating lateral displacement, e
  - Residual undrained shear strength of liquefied material, S_{ur}
- Identify what matters most to impact on death, dollars, and downtime.

Limitations & Opportunities

- Key limitation in PEER methodology is relating death and downtime to damage and then to seismic displacement.
- Opportunity to capitalize on this effort and develop a simplified deterministic procedure to use for standard designs.