

Bridge Repair Modeling



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Introduction

- ◆ Network simulation inputs
 - Repair times
 - Return to functionality
 - Repair costs
- ◆ Repair cost modeling currently crude
 - Not bridge/configuration specific
 - Difficult to quantify uncertainty
- ◆ Some progress for buildings that can be applied to bridges

Previously

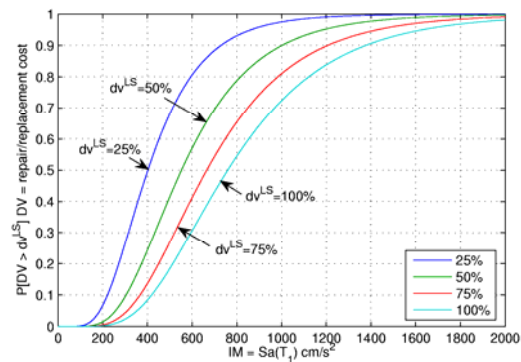
- ◆ Assumed column damage states correspond to HAZUS bridge damage states
 - Spalling -> ds2
 - Bar buckling -> ds4
 - Failure -> ds5
- ◆ Repair cost ratio (RCR) determined for whole bridge from HAZUS
- ◆ Final result is a series of decision fragility curves - probability of RCR exceeding a value, given intensity

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Previously

- ◆ Fragilities can be obtained using:
 - Fourway - graphical moment analysis
 - PEER_PBEE - Matlab script for closed-form analysis
 - Simulation - ala ATC-58 and PEER SRB study

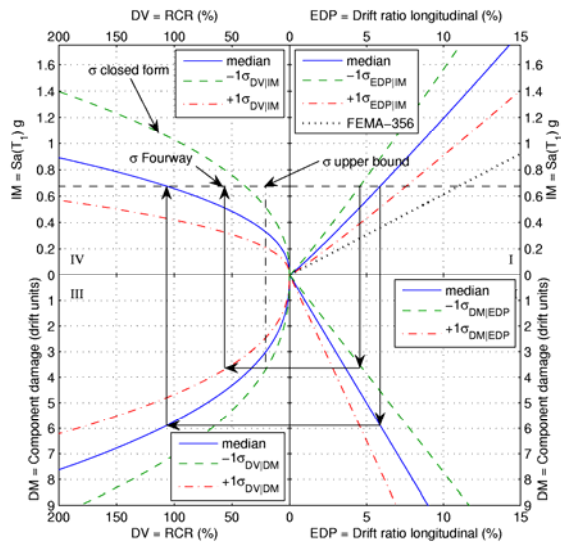


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Previously

- ◆ Fourway and closed-form solution shown

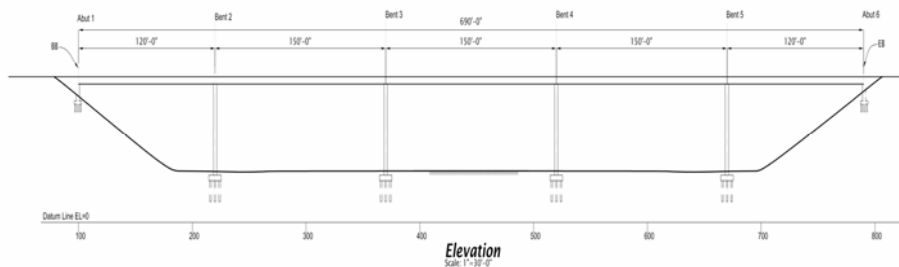


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Next Step

- ◆ Assembly-based repair implementation (Porter, etc)
- ◆ Look at bridge components individually
- ◆ Applied to specific testbed bridge



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Next Step

- ◆ Create performance groups
 - Columns
 - Abutments and embankment
 - Deck
 - Foundations
 - Soil



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Next Step - Damage Fragilities

Performance Group Summary		Damage			
		\geq DS2	\geq DS3	\geq DS4	
	Columns: lateral load resisting system; damage oriented fragilities				
		Damage states	spalling	buckling	failure
col 1 drift		Median EDP	2.5	7	10
		Beta	0.33	0.26	0.35
col 2 drift		Median EDP	2.5	7	10
		Beta	0.33	0.26	0.35
col 3 drift		Median EDP	2.5	7	10
		Beta	0.33	0.26	0.35
col 4 drift		Median EDP	2.5	7	10
		Beta	0.33	0.26	0.35
	Expansion joints: superstructure pounding, transverse shear keys, cover plates				
		Damage states	fail s.k.	impact long.	unseating
abut 1 disp		Median EDP	0.5	4	10
		Beta	0.097	0.12	0.3
abut 2 disp		Median EDP	0.5	4	10
		Beta	0.097	0.12	0.3
	Bearings: neoprene bearing pads				
		Damage states	yield	tear	slide
bp 1 disp		Median EDP	1.5	6	f(N)
		Beta	0.2	0.3	0.3
bp 2 disp		Median EDP	1.5	6	f(N)
		Beta	0.2	0.3	0.3
	Abutments: wing walls, back wall, embankment fill, approach slab, piles				
		Damage states	yield backwall	yield w.w.	slumping
abut 1 disp		Median EDP	8	3	12
		Beta	0.4	0.23	0.4
abut 2 disp		Median EDP	8	3	12
		Beta	0.4	0.23	0.4

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Next Step - Damage Fragilities

		Damage states	pile cap dmg	pile yield	soil failure
footing 1 MMn	Footings and foundations: pile caps, piles, soil gapping, soil failures	Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
		Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
footing 2 MMn	Footings and foundations: pile caps, piles, soil gapping, soil failures	Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
		Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
footing 3 MMn	Footings and foundations: pile caps, piles, soil gapping, soil failures	Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
		Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
footing 4 MMn	Footings and foundations: pile caps, piles, soil gapping, soil failures	Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
		Median EDP	1	1.5	2
		Beta	0.15	0.2	0.2
span 1 ϵ , ϕ span 2 ϵ , ϕ span 3 ϵ , ϕ span 4 ϵ , ϕ span 5 ϵ , ϕ	Superstructure: deck damage, post-tensioning system	Damage states	spalling	yield rebar	fracture PT
		Median EDP	0.6	0.2	15
		Beta	0.1	0.1	0.25
		Median EDP	0.6	0.2	15
		Beta	0.1	0.1	0.25
		Median EDP	0.6	0.2	15
		Beta	0.1	0.1	0.25
		Median EDP	0.6	0.2	15
		Beta	0.1	0.1	0.25
		Median EDP	0.6	0.2	15
		Beta	0.1	0.1	0.25
		relative u, a	Non-structural: highway barriers, light poles	Damage states	crack HB
Median EDP	1			2	1
Beta	0.15			0.2	0.2

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Next Step - Repair Quantities

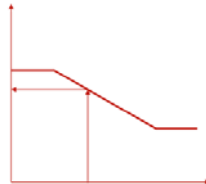
Repair quantities	unit	Repair in place	Remove and replace	site excavation	backfill	prestressing CIP concrete	footing concrete	structural concrete	joint steel	reinforcing bar	concrete barrier	light pole
		SF	SF	CY	CY	LB	CY	CY	FT	LB	FT	-
Columns												
1	DS1	inject cracks										
1	DS2	replace shell concrete in hinge zones (about 3 diameters)										
1	DS3											
1	DS4	replace the column; but has vertical capacity to hold										
2	DS1											
2	DS2											
2	DS3											
2	DS4											
3	DS1											
3	DS2											
3	DS3											
3	DS4											
4	DS1											
4	DS2											
4	DS3											
4	DS4											
Expansion joints												
left abutment	DS1	once the back wall breaks, the expansion joint is toast; replace expansion joint after impact about 100k. Neoprene bearings are pret										
left abutment	DS2											
left abutment	DS3											
left abutment	DS4											
right abutment	DS1											
right abutment	DS2											
right abutment	DS3											
right abutment	DS4											
Finish protection	SF	Shore beams below remove	Remove portion of damaged beam col	epoxy injection	carbon fiber wrapping	steel jacket	Remove casework	Replace casework	Erect scaffolding	Miscellaneous access	Miscellaneous put back	Site clean up
		FT	FT	CY	SF	SF	-	-	FT	-	-	-

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Next Steps - Costs

Item Name	Unit	Min.Qty.	Max.Qty.	Max. cost	Min. cost
Repair in place	SF	1	2	10000	10000
Remove and replace	SF	1	2	200000	200000
site excavation	CY			50	
backfill	CY			65	
prestressing CIP concrete	LB			1.05	
footing concrete	CY			310	
structural concrete	CY			445	
joint steel	FT			50	
reinforcing bar	LB			0.65	
concrete barrier	FT			75	
Finish protection	SF	1000	40000	0.3	0.15
Shore beams below remove	FT	6	24	2100	1600
Remove portion of damaged beam col	FT	100	2000	80	50
Epoxy injection	CY				
Carbon fiber wrapping	SF				
Steel jacket	SF				
Remove casework	-	100	1000	20	15
Replace casework	-	100	1000	70	50
Erect scaffolding	FT	1000	10000	2.5	2
Miscellaneous access	-	100	1000	20	15
Miscellaneous put back	-	100	1000	10	7
Site clean up	-	1000	10000	1.5	0.75



◆ Quantity dependent variable unit cost

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Next Step

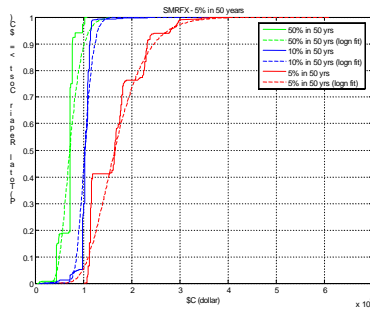
- ◆ Solution methods: Simulation
 - Fit joint-lognormal distribution to response data
 - Simulate
 - E.g., PEER SRB study, ATC-58
- ◆ Solution methods: Fourway
 - Fourway or CF analysis for each PG-EDP-Q combination
 - Moment analysis for expected costs and variance - correlation reintroduced

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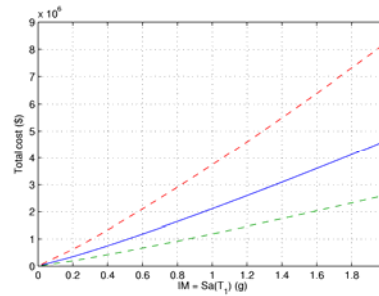


Next Step - Results

◆ For example using SRB study



Simulation: Moehle, Yang,
Stojadinovic, Der Kiureghian



Fourway/CF: Mackie

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Conclusion

- ◆ Methods already in place to ascertain repair costs
 - Simulation
 - Fourway/CF
- ◆ Huge bridge need: DATA!!!
 - Fragilities for non-column components
 - Repair quantities/costs
- ◆ Applied to repair cost, still need consideration of repair time

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Thank You!

- ◆ Questions?
- ◆ For more information contact:
 - Kevin Mackie: mackie@ce.berkeley.edu
 - Boza Stojadinovic: boza@ce.berkeley.edu

- ◆ Fourway: *JSE* soon.....
- ◆ Matlab tool: Submitted to *Spectra*,
<http://www.ce.berkeley.edu/~boza/PEER-PBEE>



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