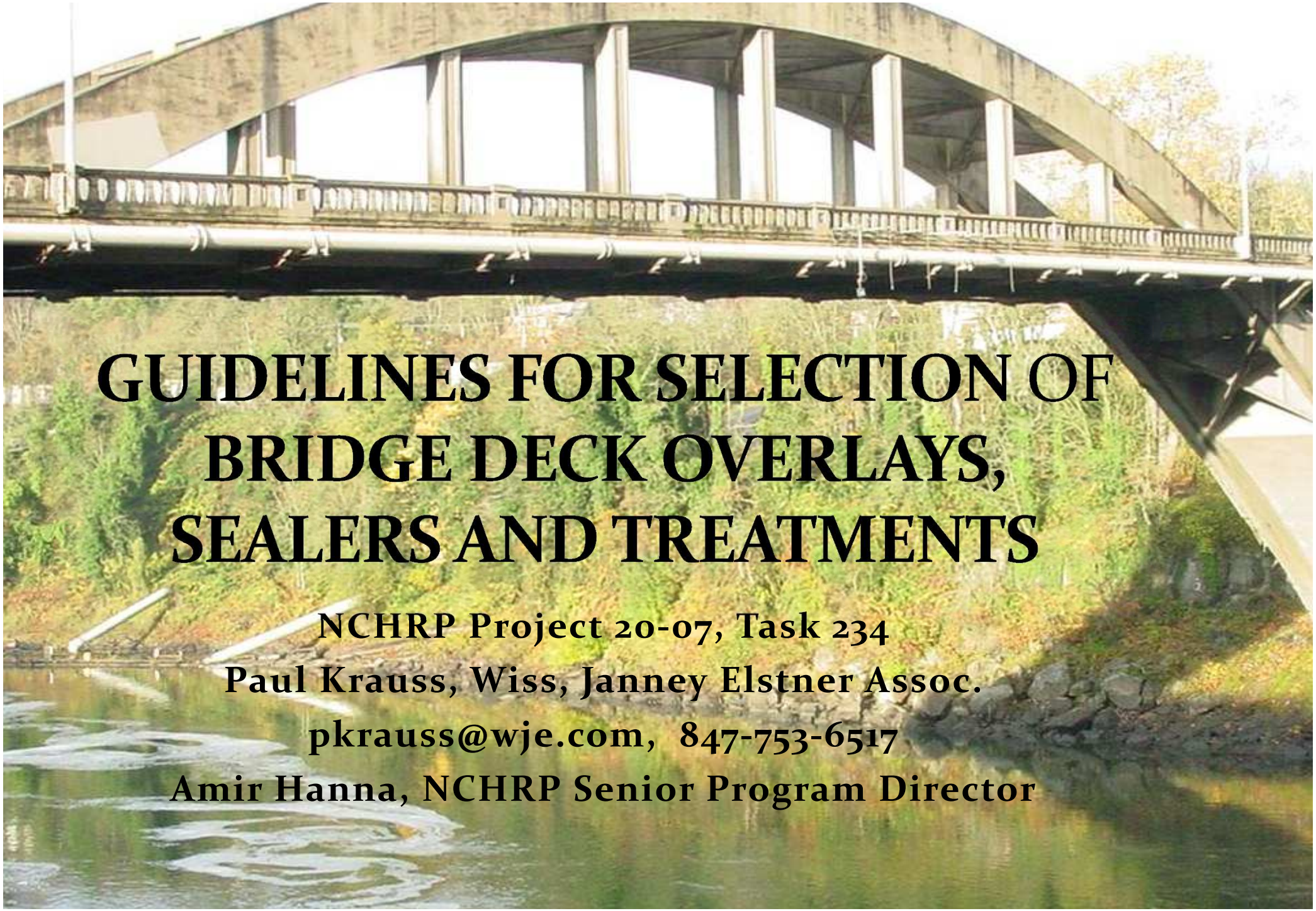

GUIDELINES FOR SELECTION OF BRIDGE DECK OVERLAYS, SEALERS AND TREATMENTS

NCHRP Project 20-07, Task 234

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Guidelines For Selection of Bridge Deck Overlays, Sealers and Treatments - Scope

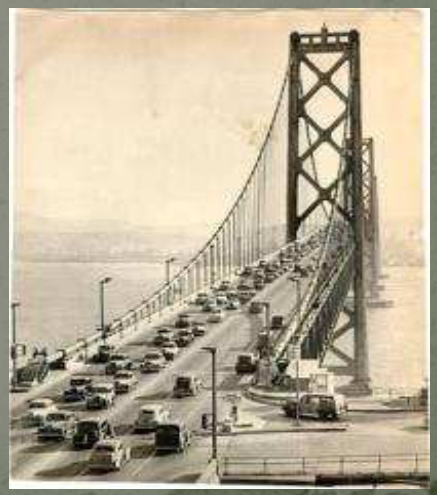
- Agency Survey of State Guidelines
- Review Literature

- <u>Results:</u>
- Deck Characterization
- Primary Repair Category Selection
- Selection of Repair Options

Agency Survey

- Extensive survey (46 agency responses)
- How are repair decisions made for decks?
  - 22 have procedures - only 10 written
- How do you characterize the deck condition and make repair decisions?
- Experience on up to 5 different repair options

- Concrete, Steel and Timber decks



Repair Methods

- Portland cement concrete overlays
- Low slump concrete overlays
- High performance concrete overlays (rigid)
- Latex-modified concrete overlays
- Asphalt concrete overlays with a waterproofing membrane
- Miscellaneous asphalt overlays
- Polymer overlay (including thin-bonded and polymer concrete)
- Deck replacement (including partial deck replacement)
- Sealers
- Crack repair

Overlay Type/Use	New or Experimental	Current Common Practice	Historic Experience (Not Current Practice)	Never
Low slump, low water-cement ratio concrete overlays	4	12	14	11
Asphalt concrete overlay with a membrane	0	30	12	3
High performance concrete overlay	9	17	2	16
Fly-ash modified concrete overlays	7	7	6	24
Silica-fume modified concrete overlays	8	6	6	23
Polymer concrete overlays	12	16	7	9
Latex-modified concrete*	2	4	3	-

Sealer Type/Use	New or Experimental	Current Common Practice	Historic Experience (Not Current Practice)	Never
Silane sealers	4	15	9	12
Siloxane sealers	7	5	13	13
Epoxy sealers	11	13	5	13
Methacrylate sealers	10	11	9	10
Polyurethane sealers	8	4	8	18

Rehabilitation Method/Use	New or Experimental	Current Common Practice	Historic Experience (Not Current Practice)	Never
Epoxy Injection Crack Repair	4	22	8	9
Polyurethane crack repair	5	4	2	26
Methacrylate (HMWM) crack repair	7	15	9	10
Lithium salts	4	1	1	34
Cathodic protection	10	6	16	10
Corrosion inhibitors	14	6	8	14

Agency Survey

- Service Life
  - Rigid overlays — 15 to 30 years
  - AC overlays — 10 to 15 years
  - Polymer overlays — 10 to 20 years
  - Crack repair — 20 to 30 years
  - Sealers — 5 to 10 years
  - Deck replacement — +/- 30 years

Steel Bridge Decks (29 agencies)

Rehabilitation Method/Use	New	Current Common Practice	Historic Experience (Not Current Practice)	Never
Replacement of asphalt concrete overlay	0	10	4	12
Replacement of polymer concrete overlay	0	5	4	15
Coating with zinc-rich primer	0	6	2	18
Applying other coatings	0	1	1	19

Timber Bridge Decks (35 agencies)

Rehabilitation Method/Use	New or Experimental	Current Common Practice	Historic Experience (Not Current Practice)	Never
Replacement the wearing surface with an asphalt concrete overlay	0	19	5	8
Replacement of the wearing surface with a polymer concrete overlay	3	0	1	26
Apply creosote wood preservatives	0	0	3	27
Apply pentachlorophenol wood preservative solutions	0	1	3	26
Apply water-borne wood preservative solutions containing copper, chromium, or arsenic	0	2	4	24

Evaluation Technique/Frequency of Use	Typically	Occasionally	Never
Visual Inspection	45	0	0
Hammer or chain sounding	34	10	0
Crack mapping/width measurement	13	24	6
Core sampling and strength testing	13	25	5
Core sampling and petrographic evaluation	5	22	15
Chloride measurement	21	21	4
Half-cell potential measurement	8	20	14
Corrosion rate	2	13	24
Infrared Thermography	0	8	30
Freeze/thaw testing or air content	2	7	30
Pulse velocity-ultrasonic	0	3	35
Ground penetrating radar (GPR)	1	18	19
Impact/echo	1	11	27

Deck Repair Selection Methodology

- Characterization of Deck Condition
- Primary Repair Category Selection
- Repair Method Selection within Primary Category

Primary Repair Decision

- ***A. Do Nothing***
- ***B. Maintenance*** that may include:
  - patching
  - crack repairs
  - concrete sealer
- ***C. Protective Overlay***
- ***D. Structural Rehabilitation*** that may include:
  - partial deck replacement
  - full depth deck replacement

Deck Replacement Criteria

- California – 20% Distress
- Virginia – 25% Distress
- Illinois – 35% Distress
- CT, MA, & KS – 50% Distress

Deck Characterization

- ***1. Percent Deck Deterioration / NBI Ratings*** - percent of non-overlapping area of patches, spalls, delaminations, and half-cell potentials more negative than -0.35V CSE and NBI rating of the top and bottom deck surfaces
- ***2. Estimated Time-to-Corrosion*** - estimated time until sufficient chloride penetration occurs to initiate corrosion over a given percentage of the reinforcing steel
- ***3. Deck Surface Condition*** - consideration of poor drainage, surface scaling, abrasion loss, or skid resistance problems
- ***4. Concrete Quality*** - related to concrete durability (ASR/DEF/freeze-thaw) and strength issues


2009 9 3

Code	Deck Rating (NBI) Description
9	Excellent condition (Superior to present desirable criteria).
8	Very Good Condition - no problems noted (desirable criteria).
7	Good Condition - some minor problems (Better than minimum criteria).
6	Satisfactory Condition - structural elements show some minor deterioration (Equal to present minimum criteria).
5	Fair Condition - all primary structural elements are sound but may have minor section loss, cracking, spalling (tolerate being left in place as is).
4	Poor Condition - advanced section loss, deterioration, spalling or scour (Meets minimum tolerable limits to be left in place as is).
3	Serious Condition - loss of section, deterioration, spalling have seriously affected structural components. Local failures possible. (Basically intolerable requiring high priority of corrective action).
2	Critical Condition - advanced deterioration of primary structural concrete may be present… may be necessary to close the bridged until corrective action is taken (intolerable high priority of replacement).
1	Imminent Failure Condition - major deterioration or section loss present in critical structural components. Bridge is closed to traffic but with corrective action may be put back in light service.
0	Failed Condition - out of service (Bridge closed).


Exit 9
43
Elkview
55
2 MILES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2009 8 31

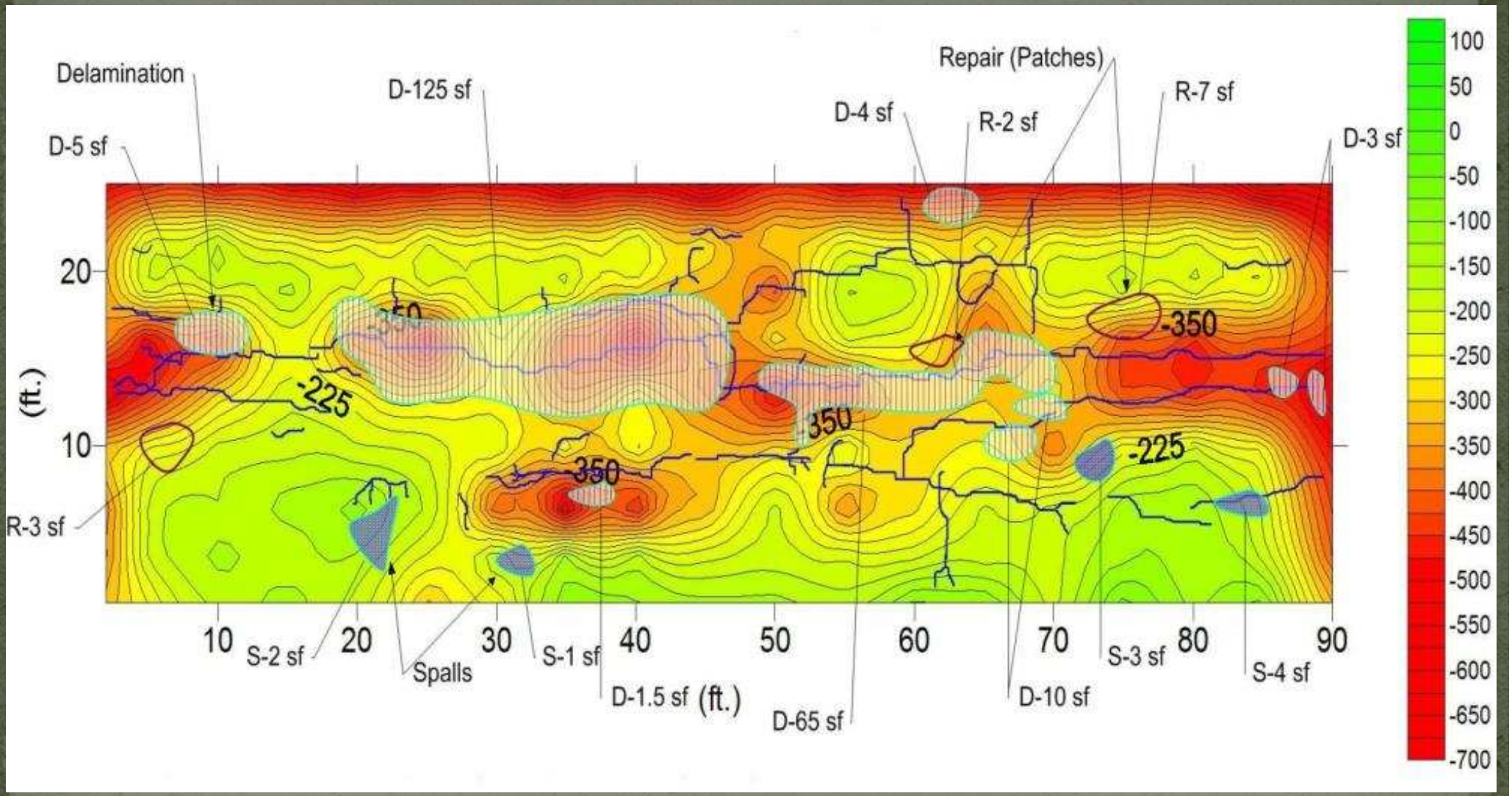

Delamination
D-125 sf
Repair (Patches)
D-4 sf
R-2 sf
R-7 sf
D-3 sf
D-5 sf
20
10
(ft.)
-225
-350
350
-225
R-3 sf
10
S-2 sf
20
Spalls
30
S-1 sf
40
D-1.5 sf
50
(ft.)
D-65 sf
60
70
D-10 sf
S-3 sf
80
S-4 sf
90
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600
-650
-700

TABLE 1 Primary Repair Category Selection Guidelines Based on Deck Characterization

Primary Repair Category	[1]	1. % Distress plus Half-cells < -0.35, & NBI Ratings	2.Time-to-Corrosion Initiation	3.Surface Issues	4. Concrete Quality (ASR/DEF/ F-T/Strength)
A. Do Nothing [2]	i. % Distress	< 1%	> 10 years	None	None
	ii. % Distress + 1/2 cell	< 5%			
	iii. NBI Top	7 or greater			
	iv. NBI Bottom	7 or greater			
B. Maintenance	i. % Distress	1 - 10%	> 5 years or >10 years	None [3]	None [4]
	ii. % Distress + 1/2 cell	1 - 15%			
	iii. NBI Top	5 or greater			
	iv. NBI Bottom	5 or greater			

Primary Repair Category	[1]	% Distress plus Halfcells < -0.35, & NBI Ratings	Time-to-Corrosion Initiation	Surface Issues	Concrete Quality ASR/DEF/Freeze-thaw/Strength issues
C. Overlay [7]	i. % Distress	2 to 35% [5]	Ongoing to >5 years	Yes [3]	Yes [6]
	ii. % Distress + 1/2 cell	10 to 50%			
	iii. NBI Top	4 or greater			
	iv. NBI Bottom	5 or greater			
D. Structural Rehabilitation	i. % Distress	> 35%	Ongoing	Yes [7]	Yes
	ii. % Distress + 1/2 cell	> 50%			
	iii. NBI Top	3 or less [8,9]			
	iv. NBI Bottom	4 or less [8,9]			

Table Notes:

[1] i - % Distress includes % patches, spalls, & delaminations
ii. % Distress plus 1/2 cell <-0.35 V (Cu-CuSO4)
iii. - NBI rating of top deck
iv. NBI rating of bottom of deck

[2] Select Do Nothing only if all conditions apply.

[3] If only skid resistance is a concern consider grooving or chip seal instead of overlay.

[4] If cracking due to ASR/DEF, deck life can be prolonged 2 to 5 years with HMWM treatment

[5] If deck has existing overlay, replace overlay if distress is greater than about 15 to 25 percent.

[6] Overlays may prolong deck life of decks with ASR; however, close monitoring is suggested. Compare partial and full depth replacement to cost of overlay and assess overall structure condition and the service life goals.

[7] If the deck already has been overlaid twice previously and concrete cover is a problem, consider structural rehabilitation.

[8] Partial depth replacement an option if NBI bottom is 6 or greater. Assess corrosion condition of lower mat of reinforcing steel.

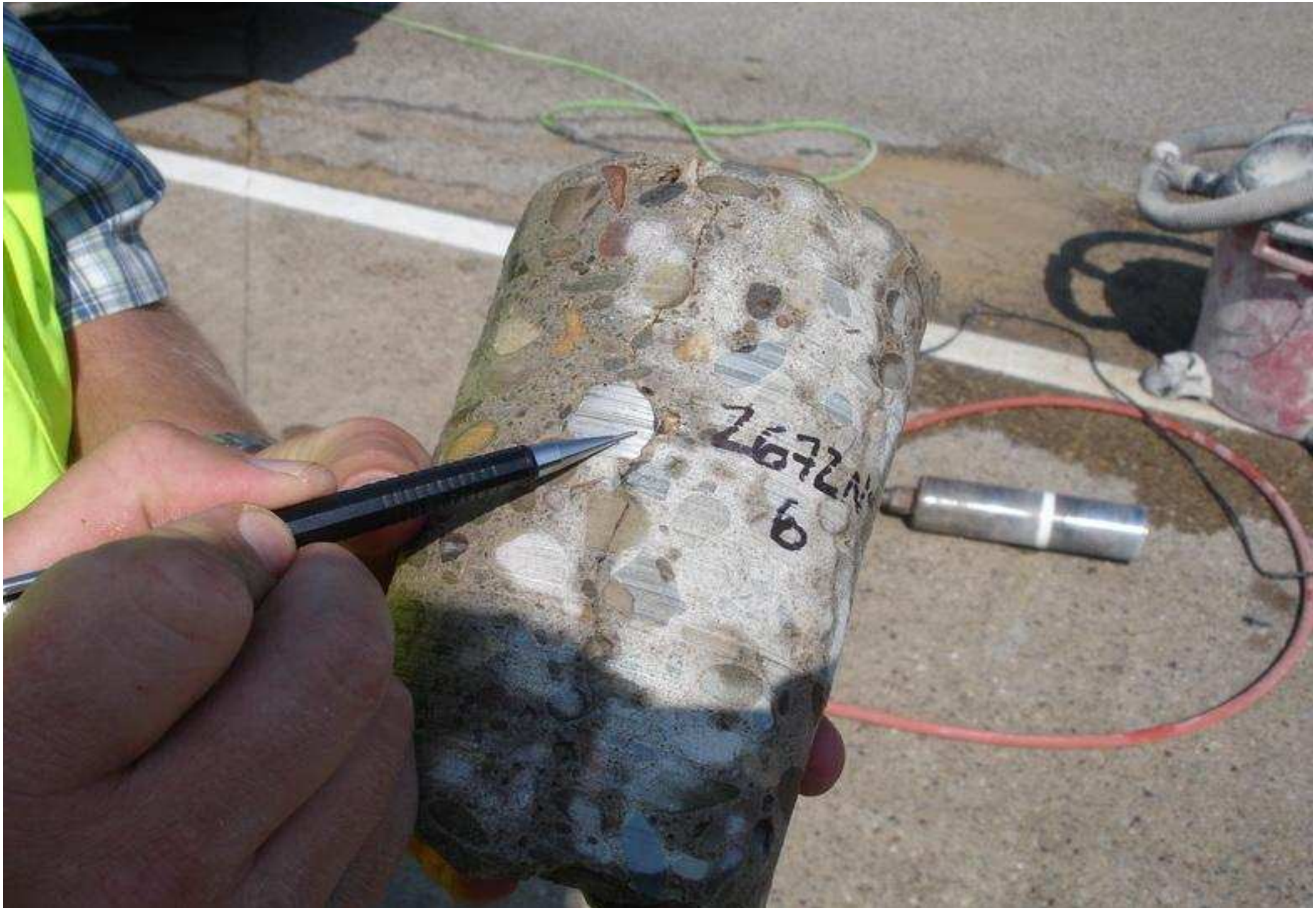
[9] Replace deck full depth

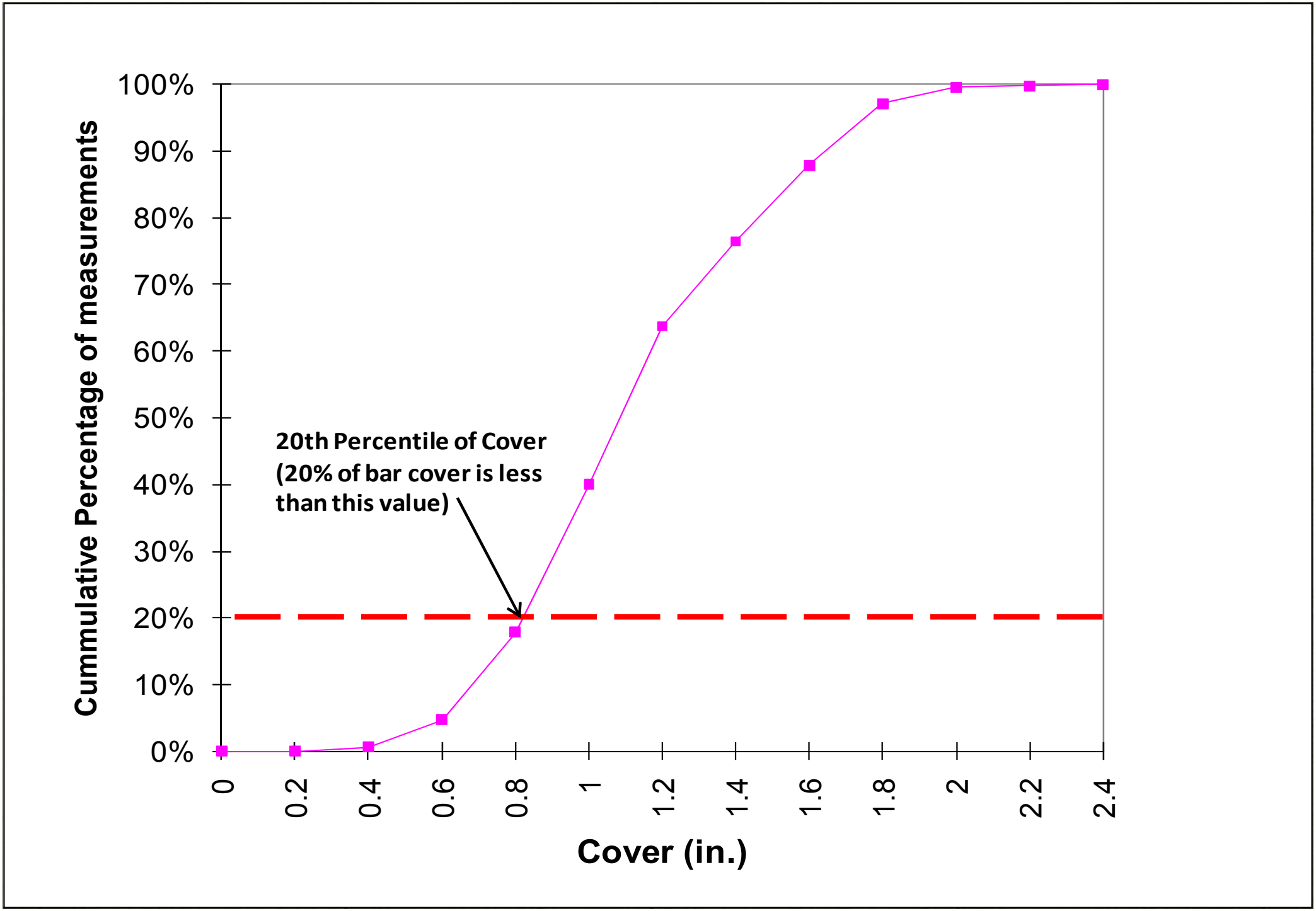
2. Estimate Time to Corrosion

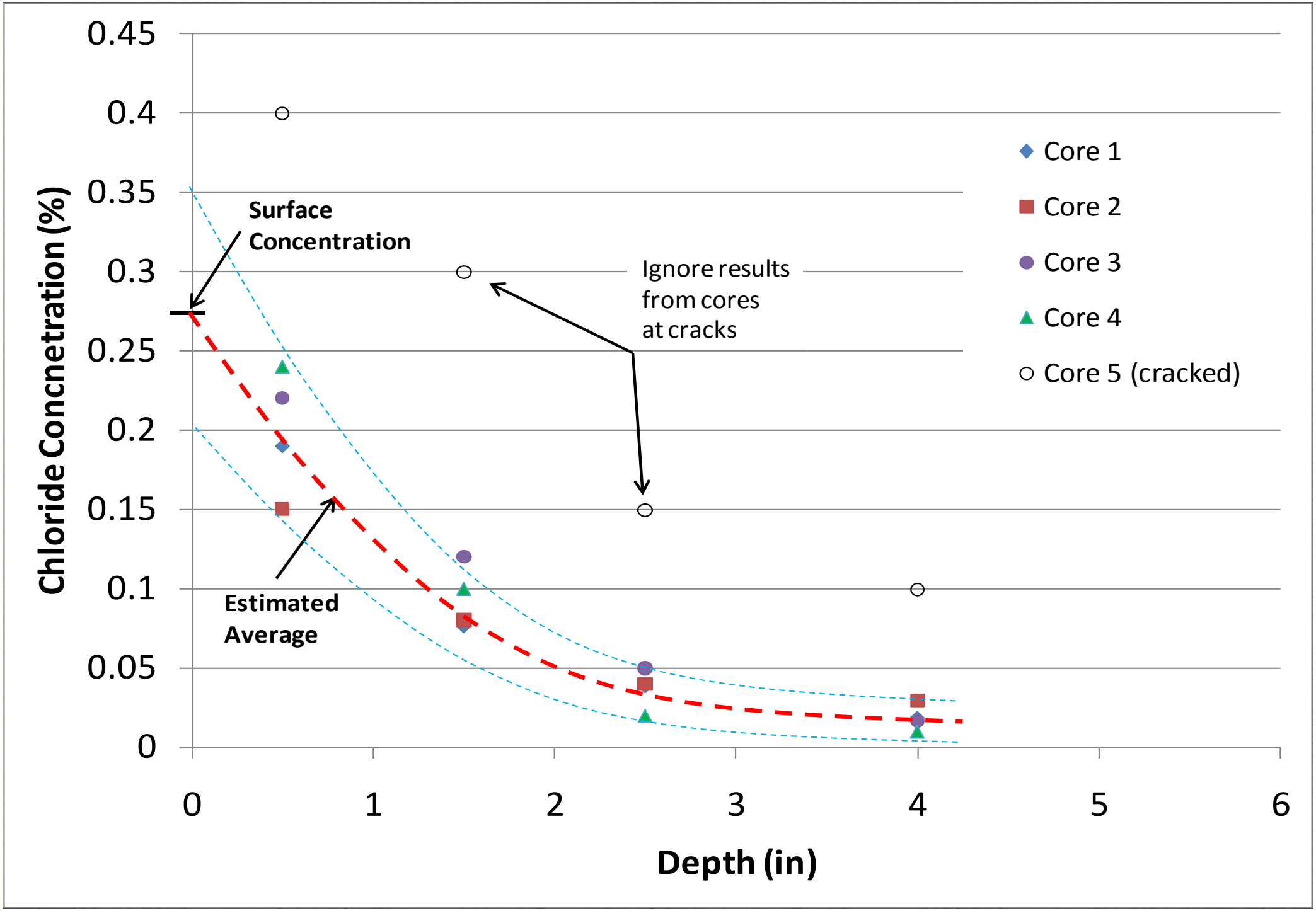
- Detailed approach using Ficks 2nd law
- Simplified approach using estimations of eff. Diff. coeff. and Cs. and charts (Appendix B) - rate of advancement.
- Determine if corrosion is occurring at 20%*of steel depth as:
  - Ongoing
  - Within 5 years
  - Within 10 years
  - Longer than 10 years

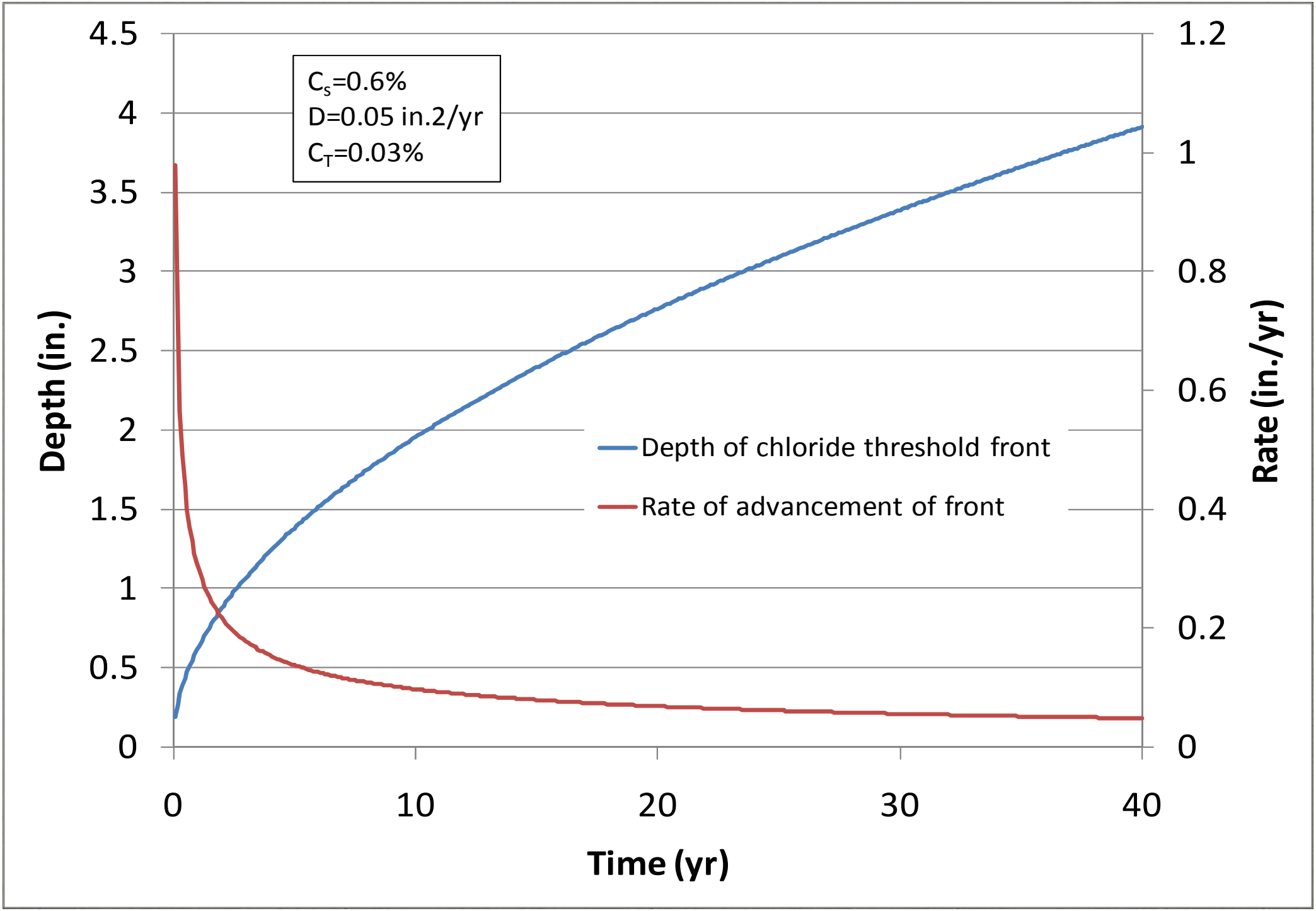
2. Estimate Time to Corrosion

- Measure concrete cover and plot cumulative distribution. Identify the 20th percentile (20% of bars have concrete cover less than this value).
- Take cores.
- Determine chloride content with depth.
- Check carbonation depth using pH indicator.
- Determine extent of characteristic full depth cracking, and estimate the average spacing of the cracks per length of deck.




Cummulative Percentage of measurements
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20th Percentile of Cover
(20% of bar cover is less
than this value)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Cover (in.)


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Chloride Concnetration (%)
0
1
2
3
4
5
6
Depth (in)
Surface Concentration
Ignore results from cores at cracks
Estimated Average
Core 1
Core 2
Core 3
Core 4
Core 5 (cracked)


C_s=0.6%
D=0.05 in.2/yr
C_T=0.03%
Depth of chloride threshold front
Rate of advancement of front
Depth (in.)
Rate (in./yr)
Time (yr)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
0.2
0.4
0.6
0.8
1
1.2
0
10
20
30
40

THRESHOLD = 0.03% (Black Steel)

TABLE. Rate of advancement of chloride threshold front (in./yr)

Bridge age = 10 years, Chloride threshold = 0.03% by wt. of concrete (black steel).

			Diffusion Coefficient					
			0.05 $in.^2/yr$ ($1.0x10^{-12}$ m^2/s)	0.1 $in.^2/yr$ ($2.0x10^{-12}$ m^2/s)	0.15 $in.^2/yr$ ($3.1x10^{-12}$ m^2/s)	0.2 $in.^2/yr$ ($4.1x10^{-12}$ m^2/s)	0.25 $in.^2/yr$ ($5.1x10^{-12}$ m^2/s)	0.3 $in.^2/yr$ ($6.1x10^{-12}$ m^2/s)
Surface Concentration (% by weight of concrete)	Mild	0.1	0.052	0.073	0.090	0.104	0.116	0.127
		0.2	0.072	0.102	0.125	0.144	0.161	0.176
	Moderate	0.3	0.082	0.116	0.142	0.164	0.184	0.201
		0.4	0.089	0.126	0.154	0.178	0.199	0.218
	Severe	0.5	0.094	0.133	0.163	0.188	0.210	0.230
		0.6	0.098	0.138	0.169	0.196	0.219	0.240
		0.7	0.101	0.143	0.175	0.202	0.226	0.248

Simplified Approach

Determine the expected depth of the chloride threshold front in 5 and 10 years.

1. Ongoing
2. If this depth exceeds the 20th percentile cover after 5 years, report “time-to-corrosion < 5 years.”
3. If this depth exceeds the 20th percentile cover after 10 years, report “time-to-corrosion < 10 years.”
4. Greater than 10 years

3. Deck Surface Conditions

- Rate deck scaling per ASTM C672 *Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals*
  - [Rate 0 - 5]
- Visually assess deck texture and assess abrasion loss.
- Measure skid resistance per AASHTO T242 *Full-Scale Tire* or T278 *British Pendulum*
- Visually assess deck drainage (flood deck)
- Examine joint conditions, including grade, slope and transitions

4. Concrete Quality

- Examine concrete for pattern cracking, excessive crazing, scaling, spalling unrelated to reinforcing corrosion, and other signs of concrete disintegration.
  - Remove cores and examine petrographically per ASTM C856
- Test multiple cores for compressive strength or (wet) static modulus if ASR or DEF is suspected.
- Determine cause of concrete distress and risk of future deterioration. [ASR/DEF/F-T/Low Strength]

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	iv. NBI Bottom	4 or less [8,9]			

Section Within Primary Repair Categories

- A. Do Nothing
  - All criteria in Table must be meet.

- B. Maintenance
  - Patching
  - Crack Repair
  - Sealers – based on chloride profiles

C. Overlay Considerations

- Traffic constraints on construction closures
- Previous deck overlays and repairs
- Dead load/clearance restrictions and drainage and slope corrections needed
- Costs and Service Life
- Contractor and DOT experience
- Special objectives, such as cathodic protection, deck strengthening, deicer systems, etc.

C. Overlays – its about speed

- Conventional Rigid Overlays (HPC, LMC, Low-slump, Fiber-reinforced)
- Waterproofing Membrane/AC Overlay
- Fast Curing Overlays -Weekend closures (VHE-LMC, polymer)
- Very Rapid Curing Overlays- Less than 24 hours, night closures (polymer overlays)

D. Deck Replacement (Partial or Full Depth)

- Partial Depth Repair
  - Below top mat level of steel
- Full Depth Replacement

Other Factors

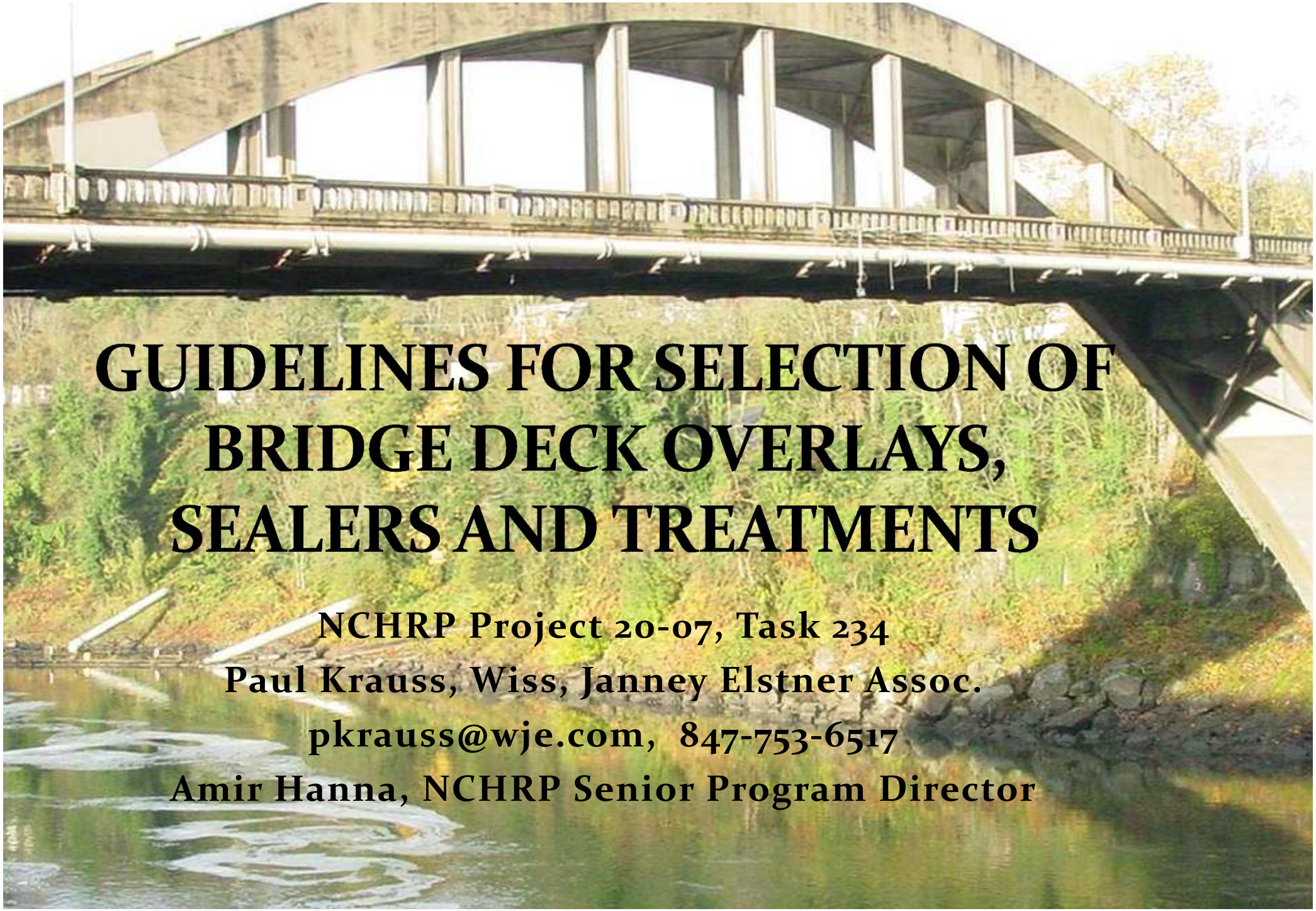
- Structural adequacy
- Functionality
- Traffic volume
- Historical significance
- User costs
- Length of detour
- Environmental considerations
- Traffic control
- Funding

Report Contents

- Survey Results and Literature Review
  - Agency Bridge Deck Maintenance and Repair Selection Processes
- Deck Characterization Evaluation Testing Methods (how to do the survey & what data to collect)
- Repair Selection Guidelines

Appendices

- Dot Survey Responses for Repair Methods
  - Agency Responded
  - Advantages/Disadvantages
  - Use History
  - Why system is selected & Conditions addressed
  - Anticipated Lifespan
  - Cost
  - Installation Procedures & Thickness
  - General Recommendations for Peers
- Tables of Rates of Advancement of Chloride Threshold Front
- Discussion of Repair Techniques



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