Current and Future Condition Based Preservation Options

by

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In This Presentation

- Selecting Preservation Option
- Service Life Model
- Life-Cycle Cost Analysis
- Case Studies (Reinforced Concrete Structures)
- Conclusion

Current Status

- Average age of bridges is 42, close to design life.
- Majority of them require repair/replacement.
- More capacity is required in many routes.
- Investment for new and existing structure.
- All happening at the same time.
- Funding is scarce.
- Staggering replacement is necessary.
- Preservation is a inevitable.

FHWA Preservation Guide

Bridge preservation is defined as actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life. Preservation actions may be preventive or condition-driven. ***Source: FHWA Bridge Preservation Expert Task Group, May 2011.***

Bridge Preservation

- When a bridge experiences corrosion, we want to answer the questions:
  - What is the current condition? How bad is bad?
  - What is the rate of deterioration?
  - How do we cost-effectively extend the life?
- Average preservation cost savings for owners: **75-80%** compared to replacement.

Decision Process

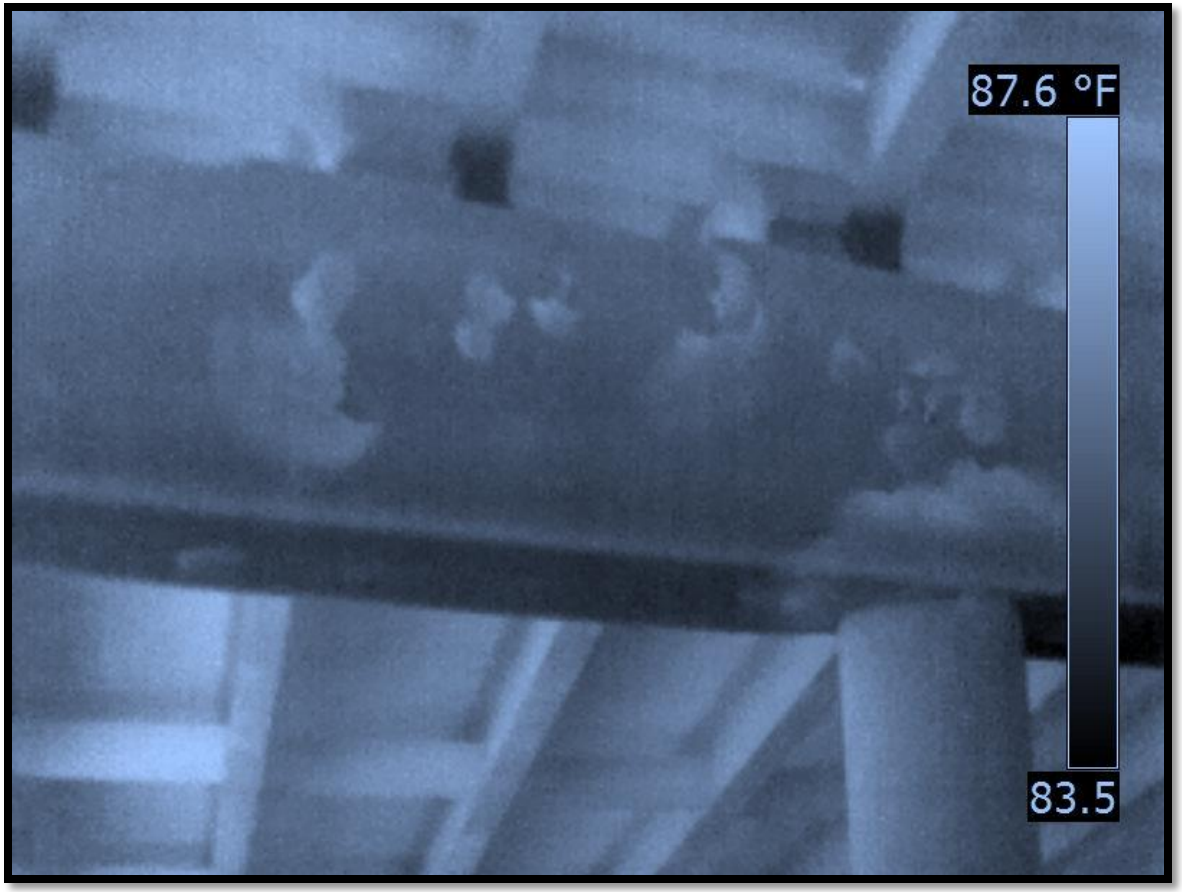
- Determine Current Condition
- Identify cause of deterioration
- Quantify the rate of deterioration
- Estimate Future Condition (Service Life Modeling)
- Identify viable Preservation Options
- Select cost-effective solution (LCCA)

Determine Current Condition

- Corrosion can be a hidden process

Determine Current Condition

- Corrosion can be a hidden process



Determine Current Condition

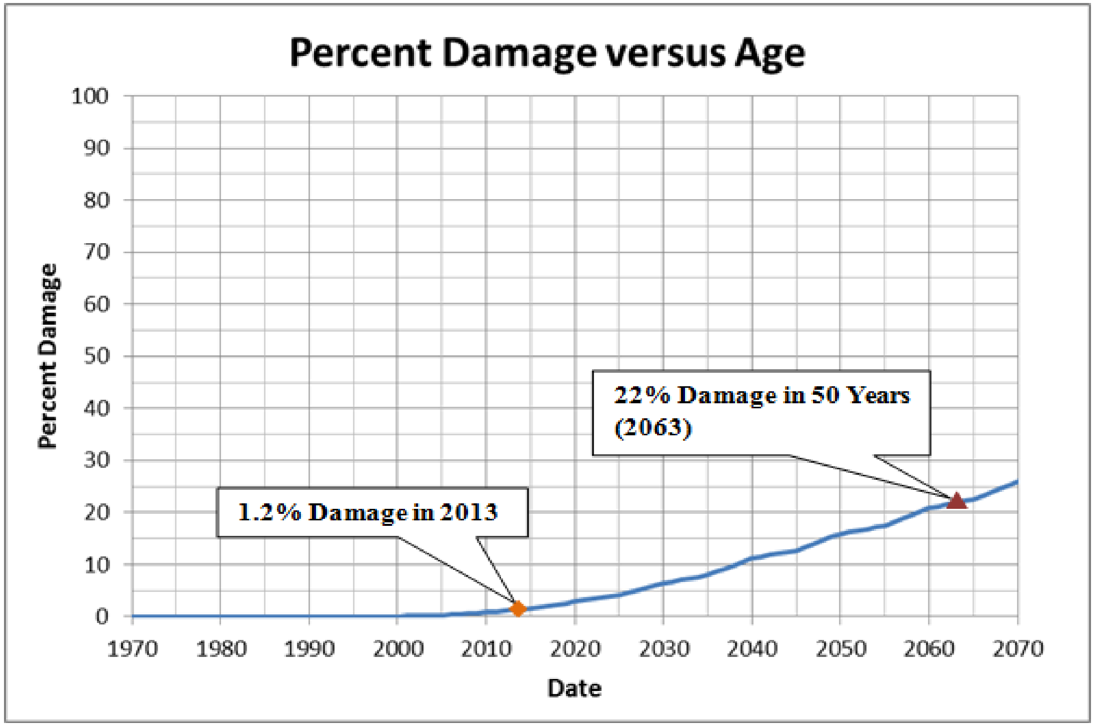
- Inspection necessary to quantify past and future deterioration
- Inspection tools:
  - Past Reports
  - Visual
  - NDT
  - Select Laboratory Testing

Quantify Rate of Deterioration

- Key Factors:
  - Existing concrete damage
  - Existing prestressing section loss
  - Chloride profile
  - Reinforcement Cover
  - Materials degradation (freeze-thaw, ASR)

Service Life Modeling

- Based on past damage and rate of deterioration, estimate future performance



Service Life Modeling

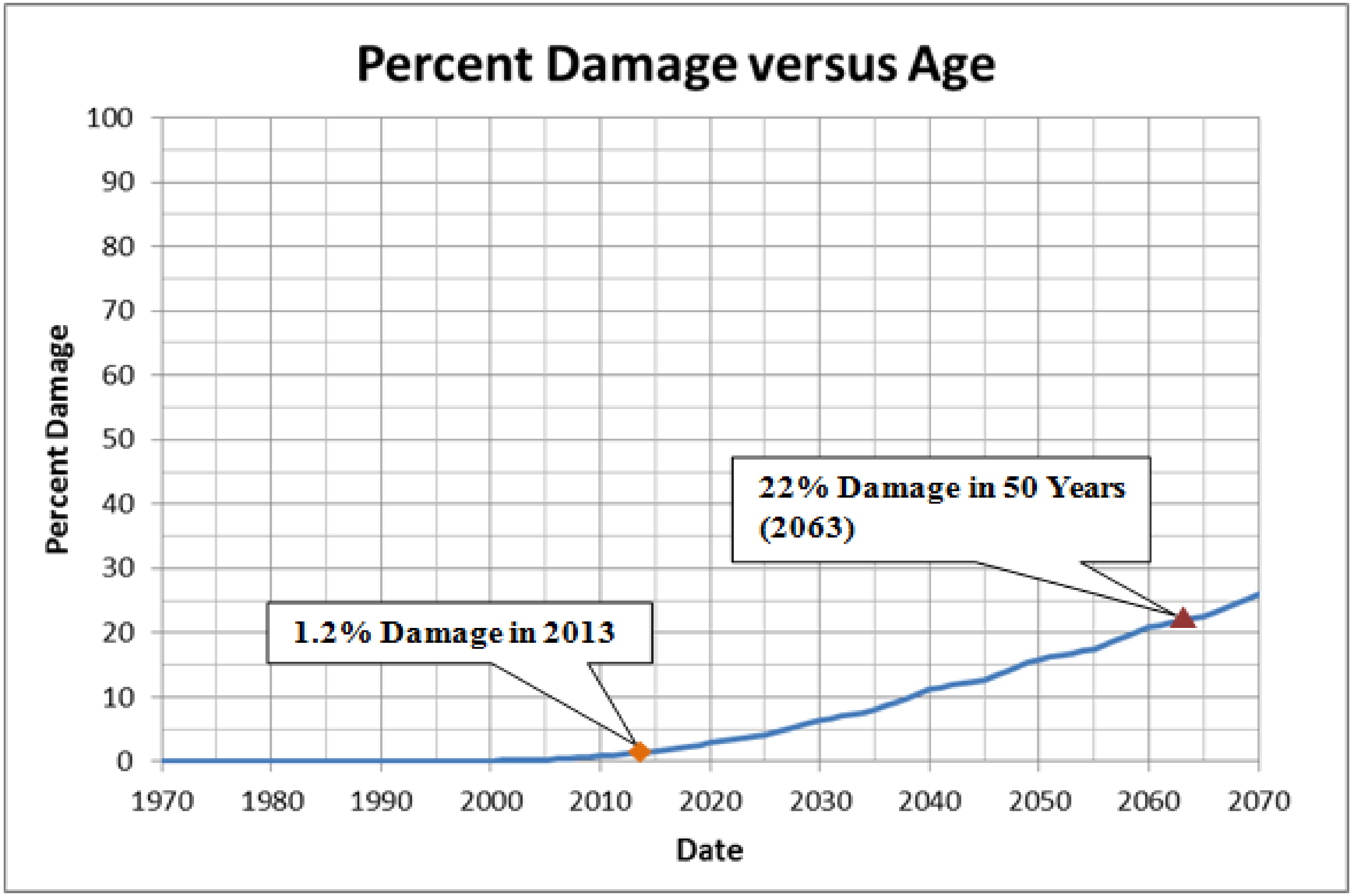
- Understand factors contributing to corrosion
- Select model
  - NCHRP 558
  - Stadium
  - Life 365
- Engineering judgment still required

NCHRP 558

Manual on Service Life of Corrosion-Damaged Reinforced Concrete Bridge Superstructure Elements

- Input:
  - Age
  - Concrete damage
  - Chloride profile
  - Rebar cover
- Output:
  - Determines apparent diffusion coefficient and threshold for corrosion
  - Estimates future concrete damage

NCHRP 558



Percent Damage versus Age
Percent Damage
100
90
80
70
60
50
40
30
20
10
0
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
Date
22% Damage in 50 Years (2063)
1.2% Damage in 2013

Identify Viable Repair Options

- Based on present and future damage, select appropriate repair/rehabilitation options
- Repair option must:
  - Rectify structural issues (in concert with structural firms)
  - Address corrosion/material degradation
  - Achieve desired service life

Identify Viable Repair Options

- Patching (with/without corrosion protection)
- Sealers and Membranes
- Overlay (with milling or hydrodemo)
  - Thin Epoxy
  - Rigid (LMC, LPC)
- Fiber Wrap with Corrosion Mitigation
- Electrochemical
  - ECE (Electrochemical Chloride Extraction)
  - GCP (Galvanic Cathodic Protection)
  - ICCP (Impressed Current Cathodic Protection)
- Combination of two or three of the above

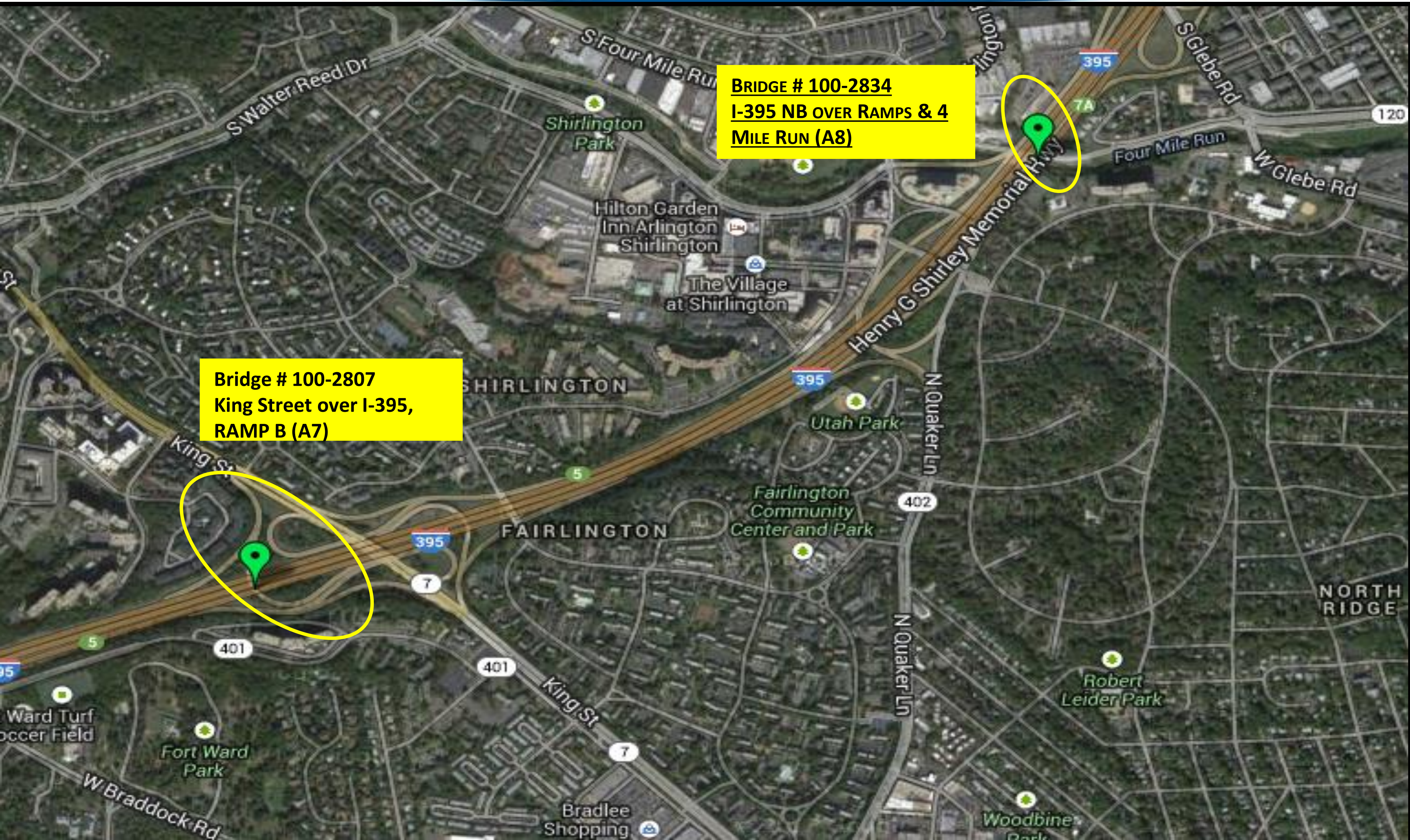
Unit Cost

Activity	Life, Years	Unit	Unit Cost ($)	Presumed Maintenance during Usable Life	MOT for Repairs
Deck Activity					
Air/Grit Blasting	N/A	Sq. ft.	$0.33	N/A	
Type A Milling (1" typical)	N/A	Sq. ft.	$2.00	N/A	
Hydrodemolition	N/A	Sq. ft.	$6.89	N/A	
Type B Top Deck Patch Repair	5	Sq. ft.	$33.33	Repair every 2 years based on the results of the service life model quantity times 2.	2 days/closure
Type C Deck Patch Repair	5	Sq. ft.	$44.44	Only at initial repair	Included in Type B MOT
Thin Epoxy Overlay	15	Sq. ft.	$5.22	Replace overlay every 15 years. Perform 5% Type B Repair at time of replacement.	2 days/closure
Rigid Concrete Overlay	25	Sq. ft.	$11.11	2% at 10 years and 2% patching every 2 years thereafter until 20 years. Replace at 25 years.	11 days/closure (7 days of curing), barrier closure

LCCA

- Past performance to model performance of various repair options
- Compare performance and cost
  - Service life
  - Initial cost
  - Life-cycle cost
  - Compare yearly life-cycle cost of each option
  - Practicality/schedule to make final decision

Case Study #1
2807- Alexandria, VA



Problem

- Ongoing corrosion in Bridges 2807 & 2834 along I-395 in Alexandria, VA.
- Corrosion related concrete damage and reinforcement section losses.
- Desired additional life - 50 years.
- Is it possible? What is the cost?

2807 Deck - Discussion

Built in 1970, LMC overlay placed in 1995

Five Span Bridge

SCS Approach

SCS performed the following tests to determine the condition of the Deck & Substructure and to calculate the remaining life:

- Delam/Spall Survey
- Continuity
- Cover Survey
- Impact Echo
- Chloride Analysis
- Carbonation
- Service Life & Life Cycle Cost

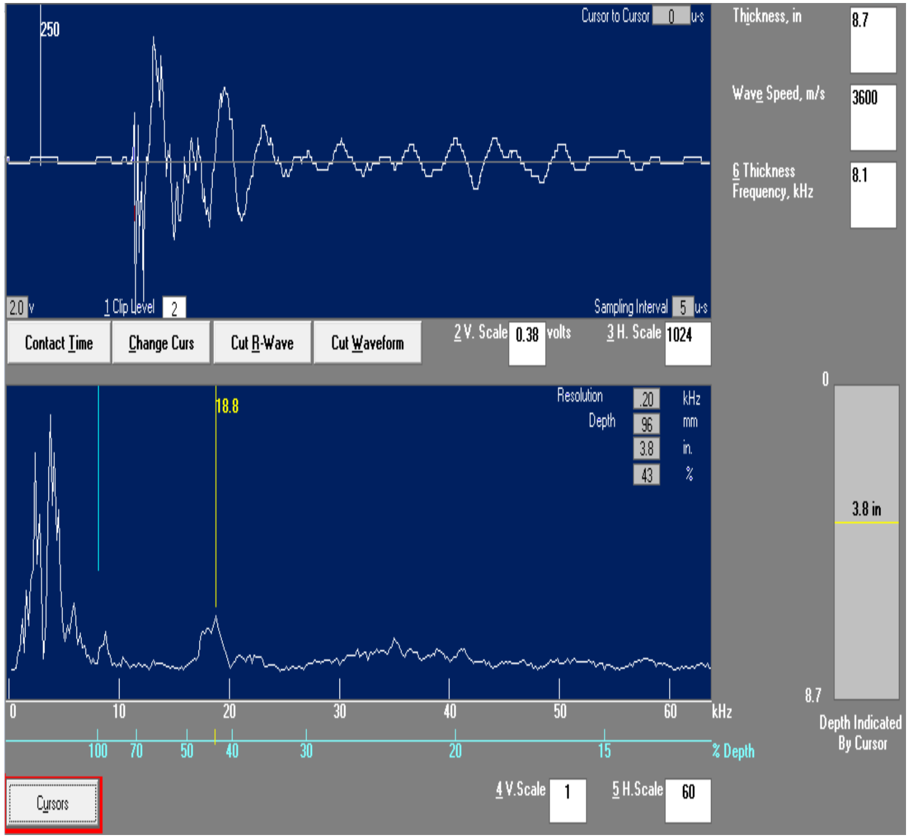
2807- Delam Survey

- 5.4% total damage observed

Location	Total Area (ft^2)	Delam/Debond Area (ft^2)	Percent Damage
Unit 1	1234.3	65.3	5.3
Unit 2	1444.8	24.9	1.7
Unit 3	1421.3	75.9	5.3
Unit 4	1510.3	114.7	7.6
Unit 5	1187.3	87.2	7.3
Total	6798.0	368.0	5.4

- Used Impact-Echo (IE) - to identify debonding at overlay or at rebar level.
- Cores - at IE locations to confirm IE result

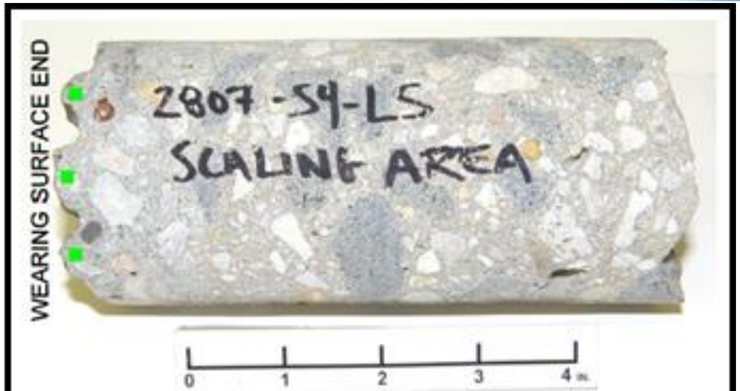
2807 – Impact Echo (IE)



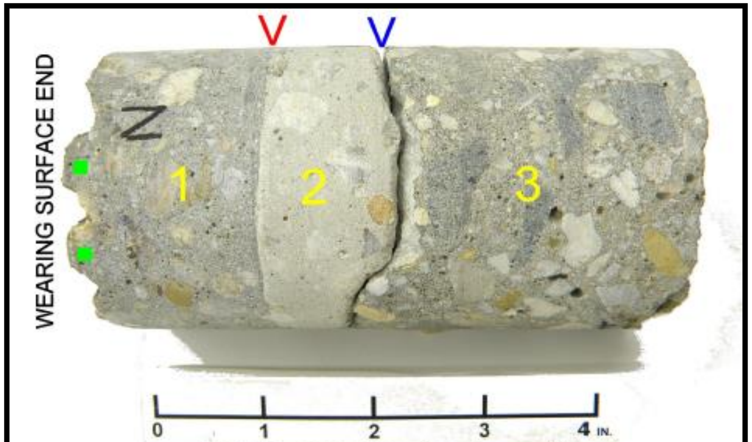
Frequency Response of Debonded Overlay in Span 5

Extracted core confirming debonding

2807 Deck - Petrographics



2807-S4-LS (Scaling Area)
(LML ID 2807-S4)



2807-S5-LS (Debond)
LML ID 2807-S5

- Water/cement ratio range was 0.40 to 0.45 (normal for this age and deck concrete).
- Petrographics concluded that concrete has freeze thaw resistance.
- No destructive ASR activity was observed in the cores.
- ASR will not adversely affect corrosion mitigations such as ECE, GCP, and ICCP.

2807 Deck – Service Life Estimates

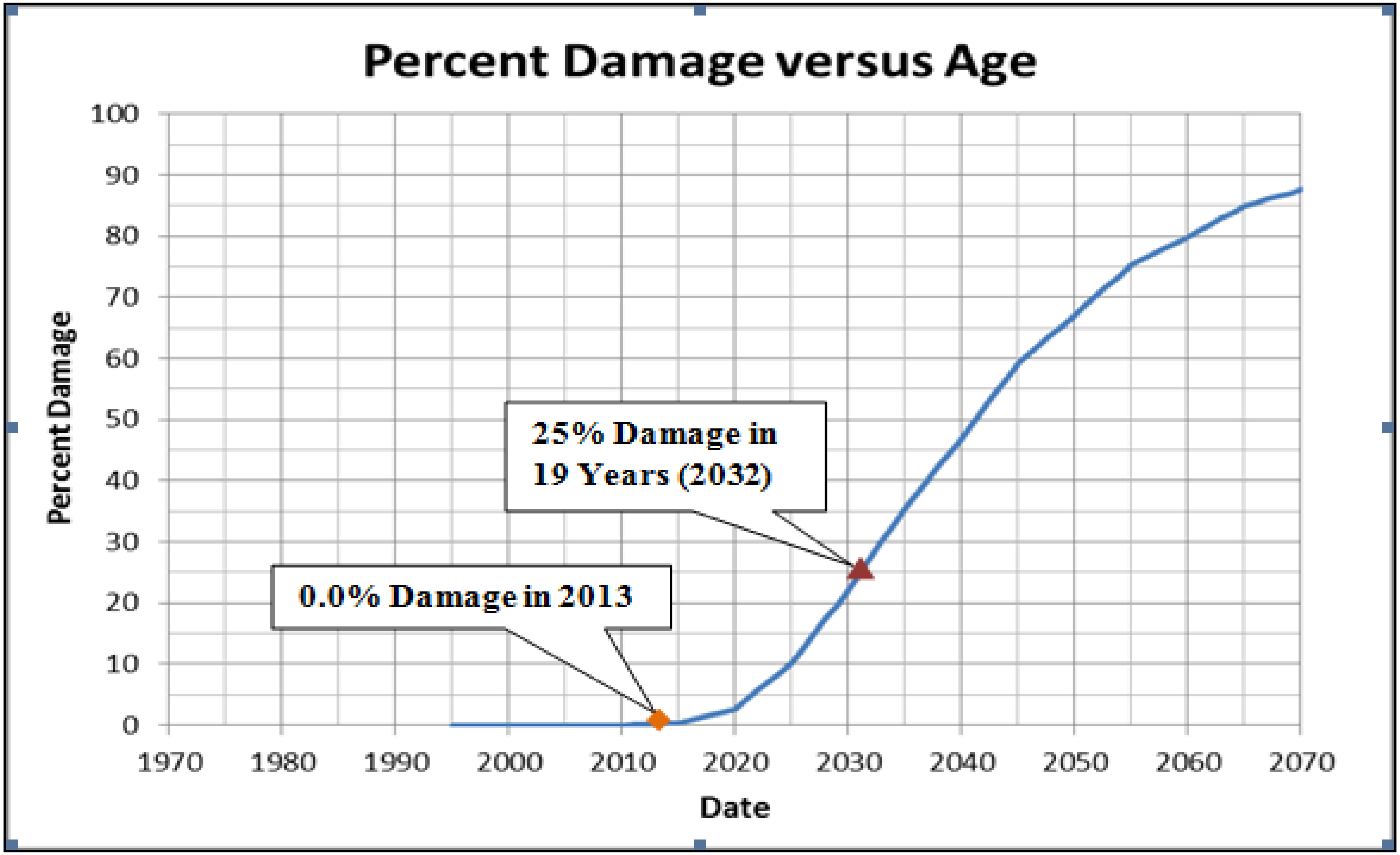


Figure 7. Projected Concrete Damage for Top Deck

2807 Substructure - Discussion

SCS performed in-depth testing on 2 Piers and 1 Abutment based on visual damage

2807 Substructure – Service Life Estimates (Open Joint)

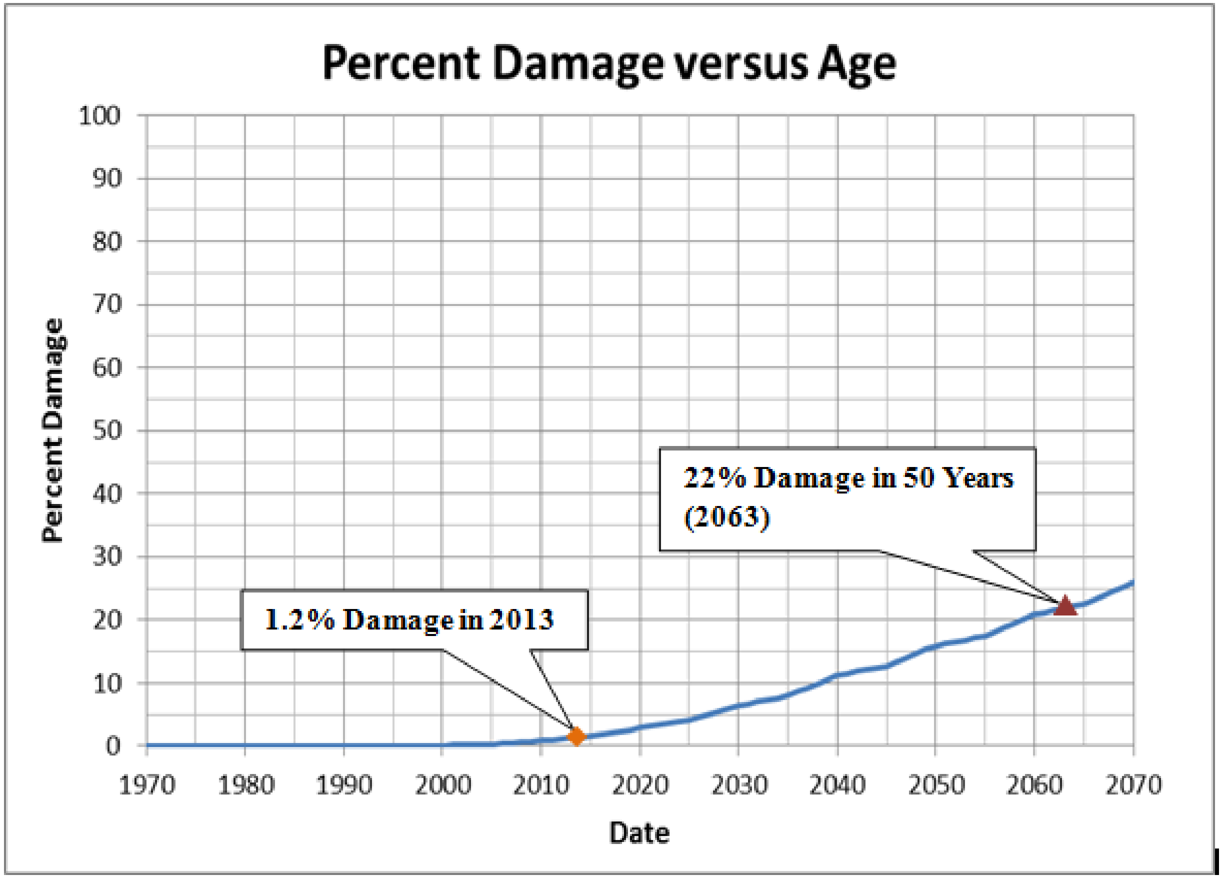


Figure 9. Projected Concrete Damage for the Pier Caps (Open Joint)

2807 Substructure – Service Life Estimates

- SCS evaluated the service life if joints were eliminated.
- If the joints are removed, less moisture and chloride will contaminate the substructure.
- At this rate, the pier cap damage would reach 12% within 50 years and the pier column damage would reach 15% within 50 years if no other corrosion mitigation is performed.

2807 Substructure – Service Life Estimates (Closed Joint)

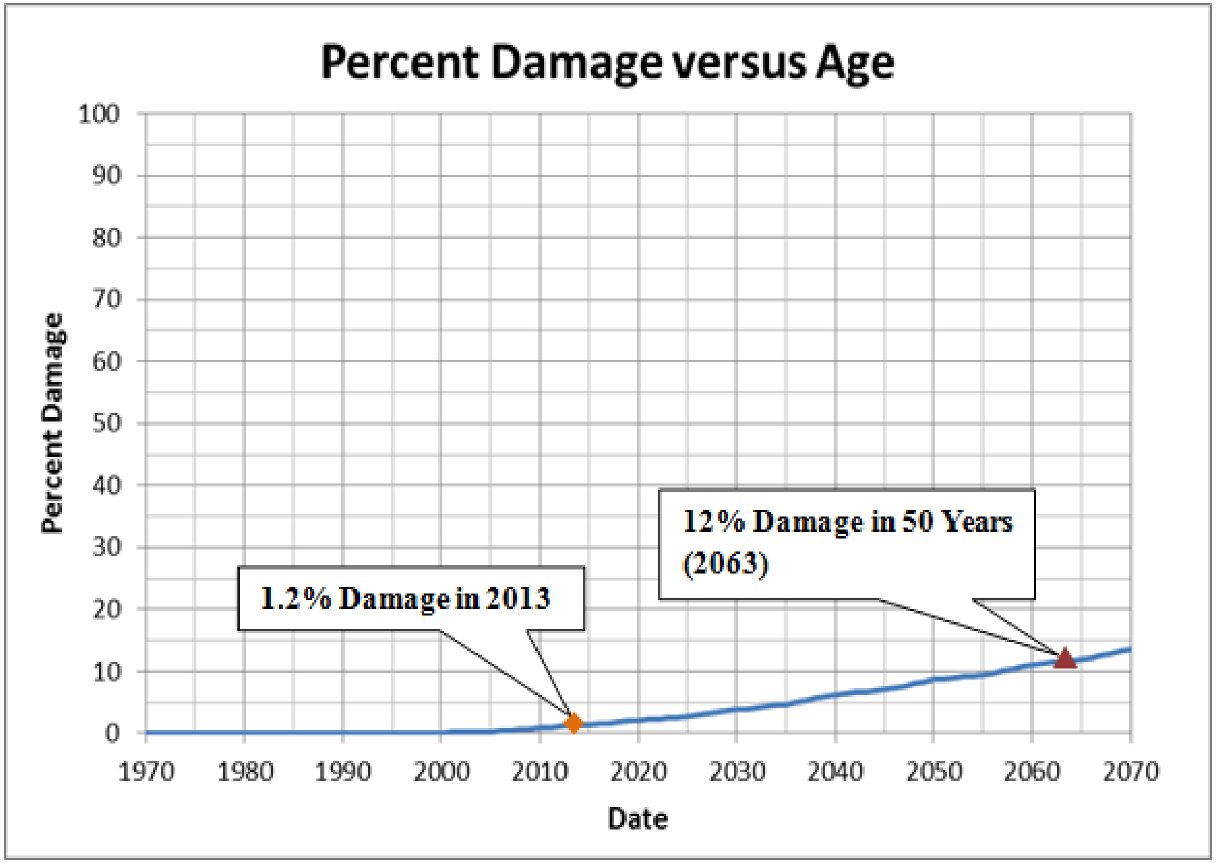


Figure 11. Projected Concrete Damage for the Pier Caps (Closed Joint)

2807 – Life Cycle Cost Estimate

Lowest Life Cycle Cost Repair Options

Bridge Element	Description	Initial Cost	Additional Life Cost (50 years)	MOT (associated w/ LCCA only)	Total
Concrete Repair/Rehabilitation					
Deck	Patch+LMC	$ 162,927	$ 103,804	$ 42,144	$ 308,875
Pier Caps (Open Joints)	Patch+ECE+Seal	$ 72,501	$ 32,591	$ 26,971	$ 132,063
Pier Caps (Closed Joints)	Patch+ECE+Seal	$ 72,501	$ 32,591	$ 26,971	$ 132,063
Pier Columns (Open Joints)	Patch+ECE+Seal	$ 95,696	$ 43,017	$ 26,971	$ 165,684
Pier Columns (Closed Joints)	Patch+ECE+Seal	$ 95,696	$ 43,017	$ 26,971	$ 165,684
Abutments	Patch+ECE+Seal	$ 16,806	$ 7,555	$ 13,486	$ 37,847

2807 – Life Cycle Cost Estimate

Lowest Initial Cost Repair Options

Bridge Element	Description	Initial Cost	Additional Life Cost (50 years)	MOT (associated w/ LCCA only)	Total
Concrete Repair/Rehabilitation					
Deck	Patch+LMC	$ 162,927	$ 103,804	$ 42,144	$ 308,875
Pier Caps (Open Joints)	Patch Repairs	$ 2,601	$ 51,006	$ 217,433	$ 271,040
Pier Caps (Closed Joints)	Patch Repairs	$ 2,601	$ 25,503	$ 217,433	$ 245,537
Pier Columns (Open Joints)	Patch Repairs	$ 3,433	$ 65,628	$ 217,433	$ 286,494
Pier Columns (Closed Joints)	Patch Repairs	$ 3,433	$ 32,814	$ 217,433	$ 253,680
Abutments	Patch Repairs	$ 1,119	$ 15,178	$ 108,716	$ 125,013

Initial vs Life Cycle Costs

Initial vs. Life-Cycle Cost Repair Options

Bridge Element	Description	Initial Total Cost	Life Cycle Total Cost
Concrete Repair/Rehabilitation			
Deck	Patch+LMC	$ 308,875	$ 308,875
Pier Caps (Open Joints)	**Initial** - Patch Repairs **Life Cycle** - Patch + ECE + Seal	$ 271,040	$ 132,063
Pier Caps (Closed Joints)	**Initial** - Patch Repairs **Life Cycle** - Patch + ECE + Seal	$ 245,537	$ 132,063
Pier Columns (Open Joints)	**Initial** - Patch Repairs **Life Cycle** - Patch + ECE + Seal	$ 286,494	$ 165,684
Pier Columns (Closed Joints)	**Initial** - Patch Repairs **Life Cycle** - Patch + ECE + Seal	$ 253,680	$ 165,684
Abutments	**Initial** - Patch Repairs **Life Cycle** - Patch + ECE + Seal	$ 125,013	$ 37,847

2807 - SCS Recommendation

Deck

Remove the existing chloride-contaminated overlay concrete (2”deep via hydrodemolition) and remove any remaining loose/deteriorated concrete underneath the overlay. Install a new LMC overlay (2” thickness).

Piers

Repair existing concrete damage, perform ECE on the piers and seal the surface.

Abutments

Repair existing concrete damage, perform ECE on the abutments and seal the surface

Structure	Deck	Piers	Abutments
100-2807 King St. over I-395, Ramp B (A7)	Patch + LMC	Patch + ECE + Seal	Patch + ECE + Seal

2834 - SCS Recommendation

Deck

Modeling indicates that the lowest cost repair is biennial patch repairs. However, due to exposed aggregate, SCS recommended installing a thin epoxy overlay. This addressed the deck condition at minimal additional cost.

Piers

Repair existing concrete damage, install ICCP on the piers and

Abutments

Repair existing concrete damage, install ICCP on the abutments

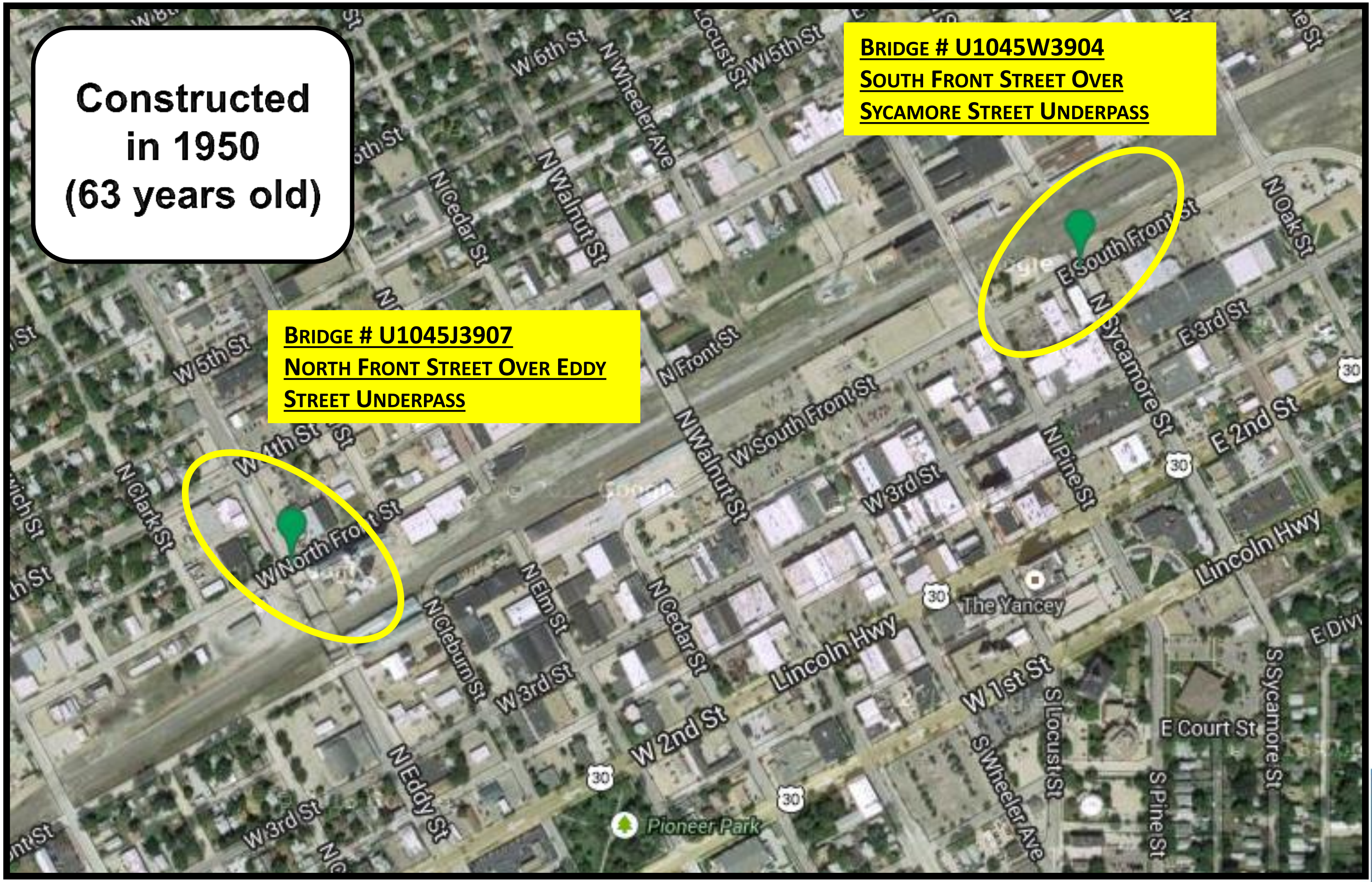
Structure	Deck	Piers	Abutments
100-2807 King St. over I-395, Ramp B (A7)	Patch + Thin Epoxy Overlay	Patch + ICCP	Patch + ICCP

Case Study #2
Grand Island, NE – 2 Bridges

Constructed in 1950 (63 years old)

<u>Bridge # U1045W3904</u>
<u>South Front Street Over Sycamore Street Underpass</u>

<u>Bridge # U1045J3907</u>
<u>North Front Street Over Eddy Street Underpass</u>



Case Study #2
Grand Island, NE – 2 Bridges

Case Study #2
Grand Island, NE – 2 Bridges

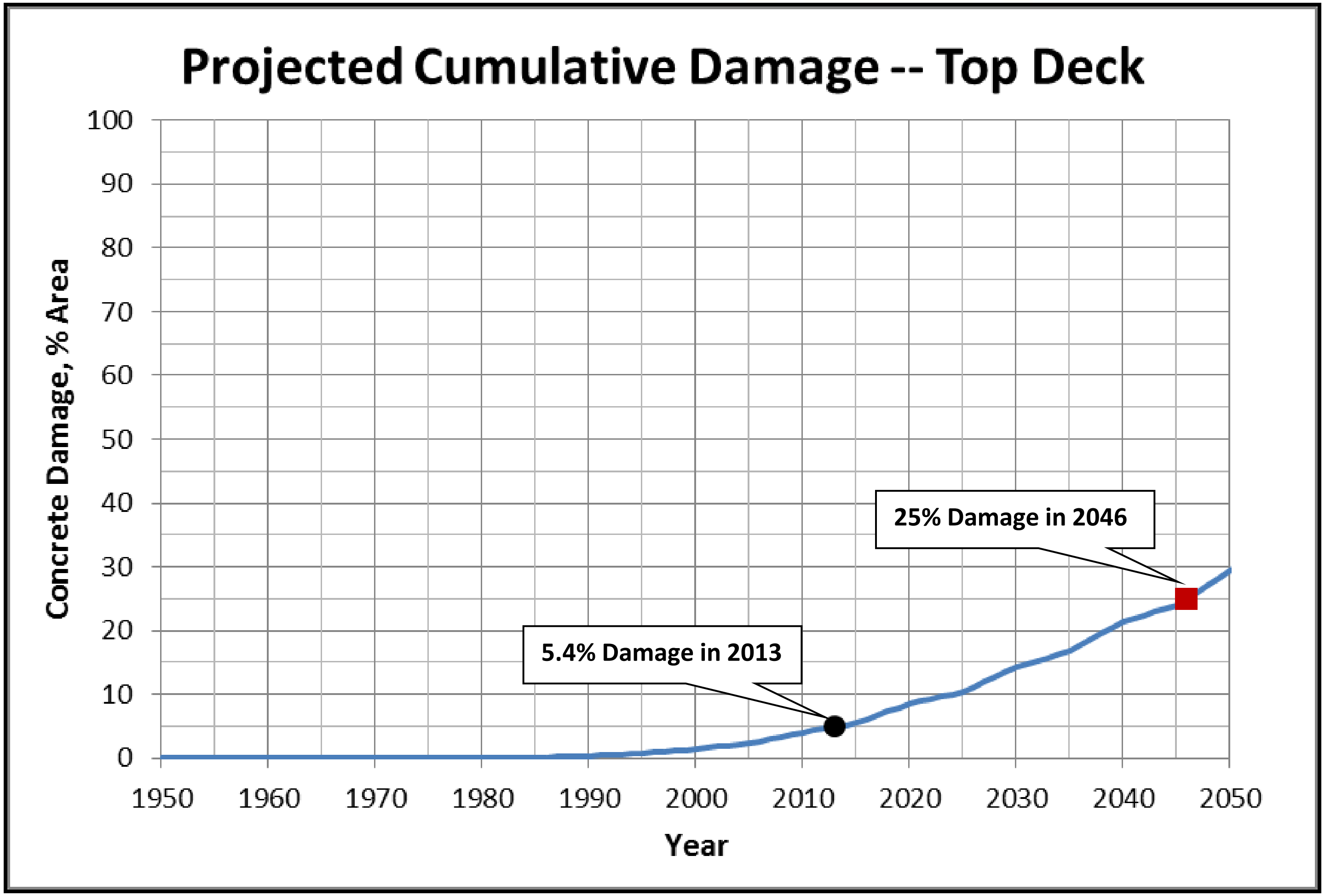
Problem

- The bridges are over 60 years old.
- Decks and substructures showed signs of corrosion-related concrete damage.
- Needed to extend the life of the bridges by 30 additional years.
- SCS was retained to quantify damage and evaluate the cost of repair vs. replacement.

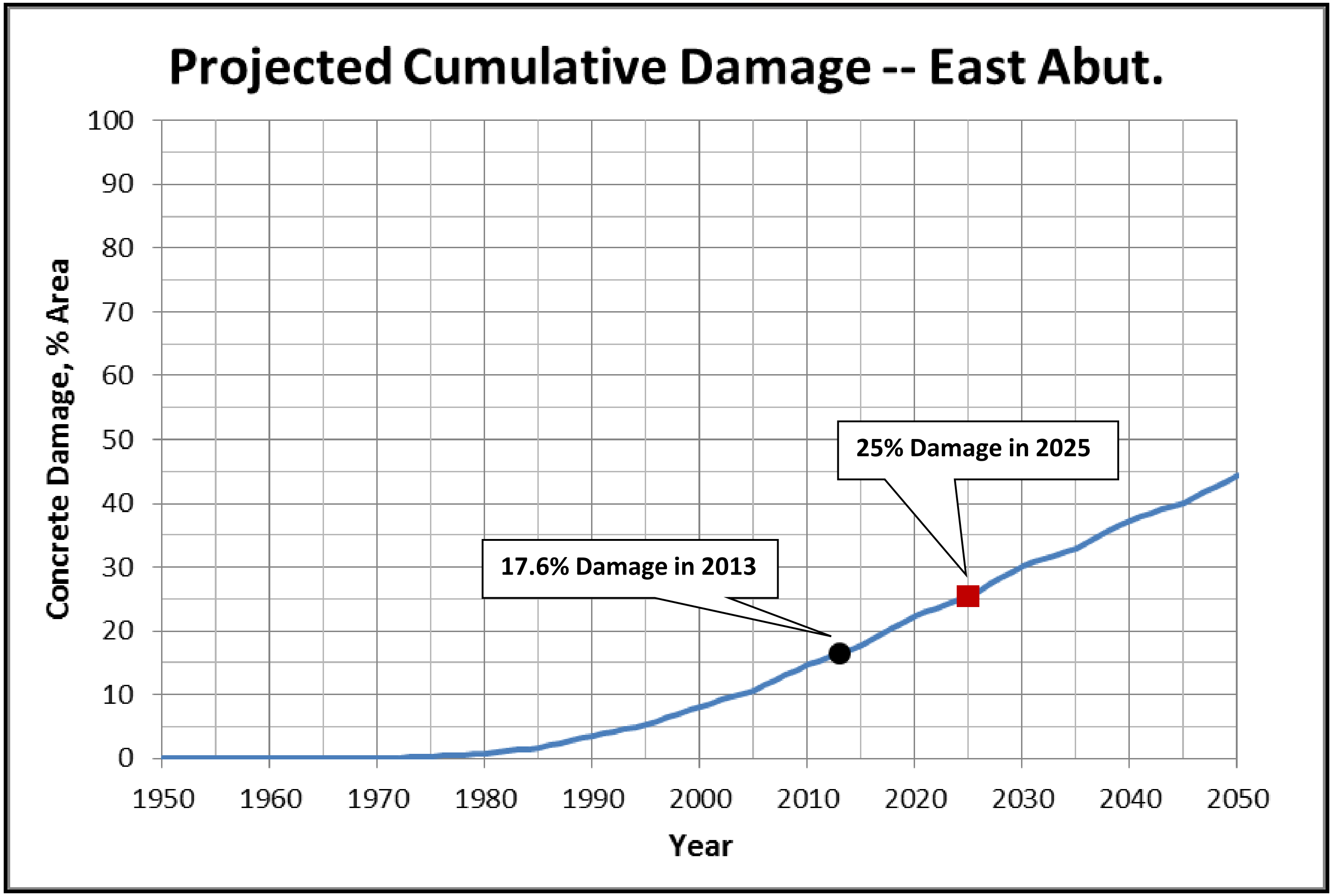
Problem

Problem

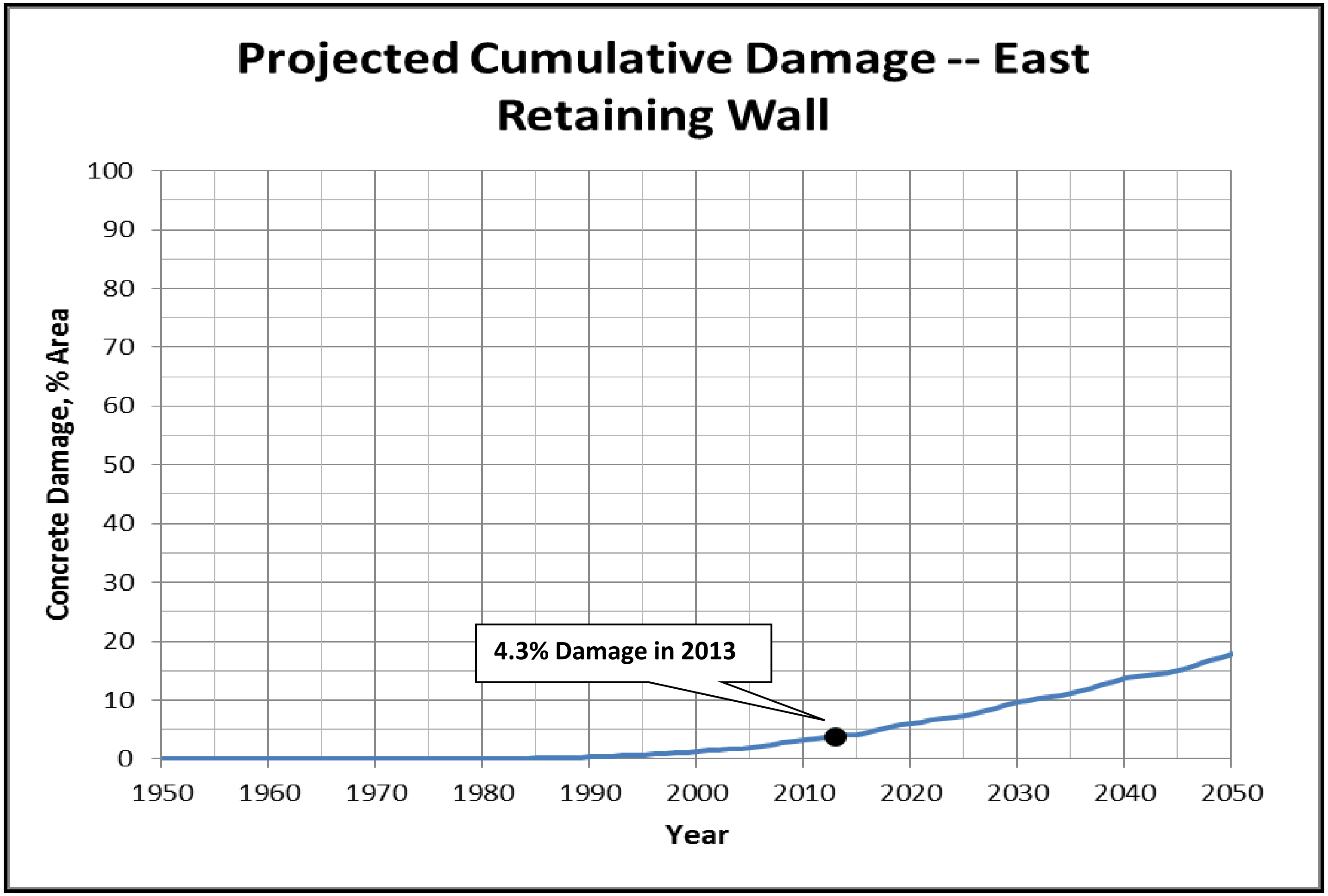
North Front - Service Life Model



North Front - Service Life Model



North Front - Service Life Model



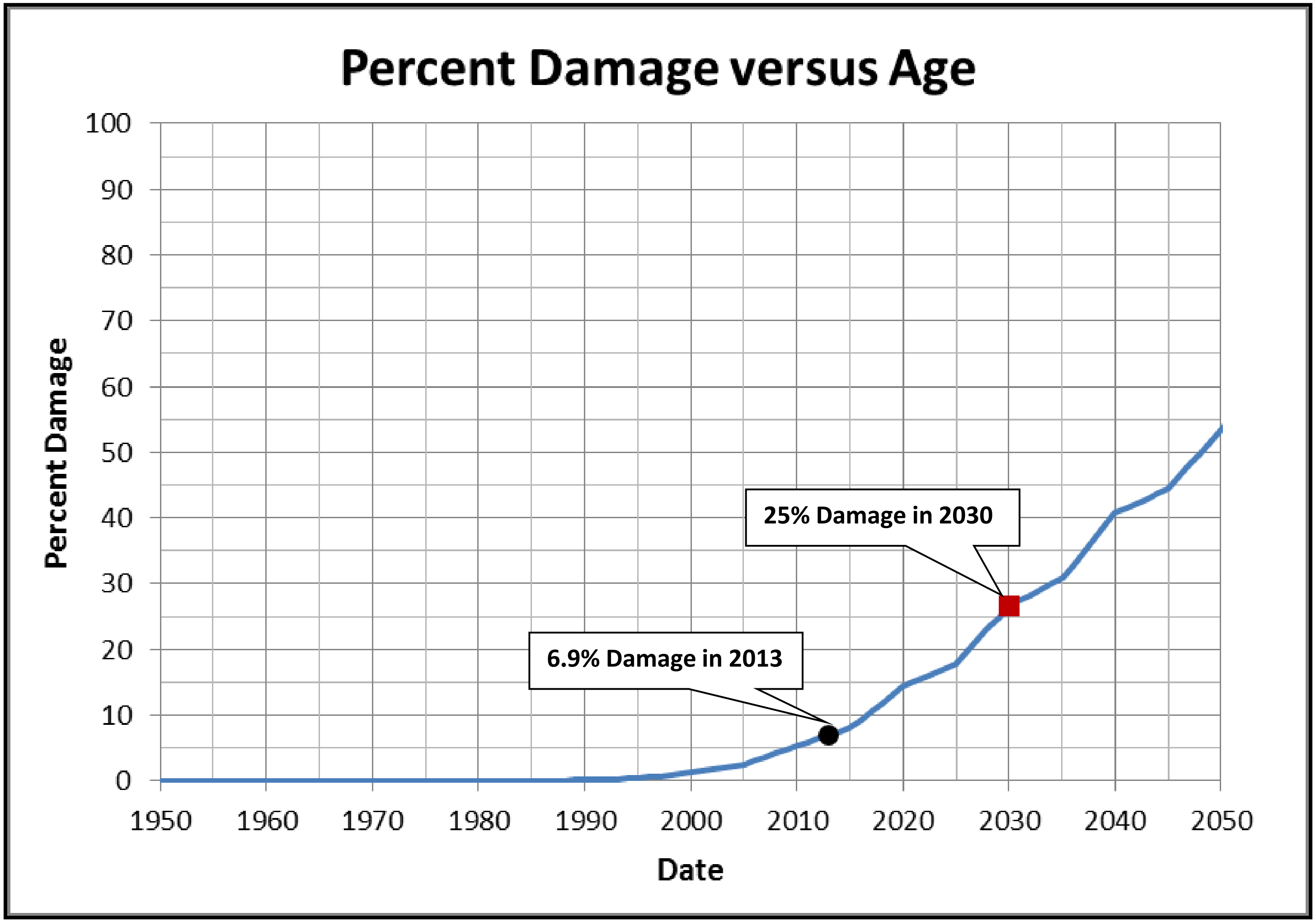
North Front - Life Cycle Cost Analysis

North Front - Summary of Lowest Life Cycle Cost Repair Options

Bridge Element	Description	Initial Cost	Additional Life Cost (30 years)	MOT (associated w/ LCCA only)	Total
Concrete Repair/Rehabilitation					
Deck	Patch + Anode	$74,885	$20,384	$38,690	$133,959
Abutment Walls	Patch + GCP Sprayed	$38,787	$22,497	$12,420	$73,705
Retaining Walls	Patch + Anode	$22,290	$49,020	$56,035	$127,345
Subtotal Concrete		**$135,962**	**$91,901**	**$107,145**	**$335,009**

South Front - Deck

South Front – Service Life Model



South Front – Life Cycle Cost Analysis

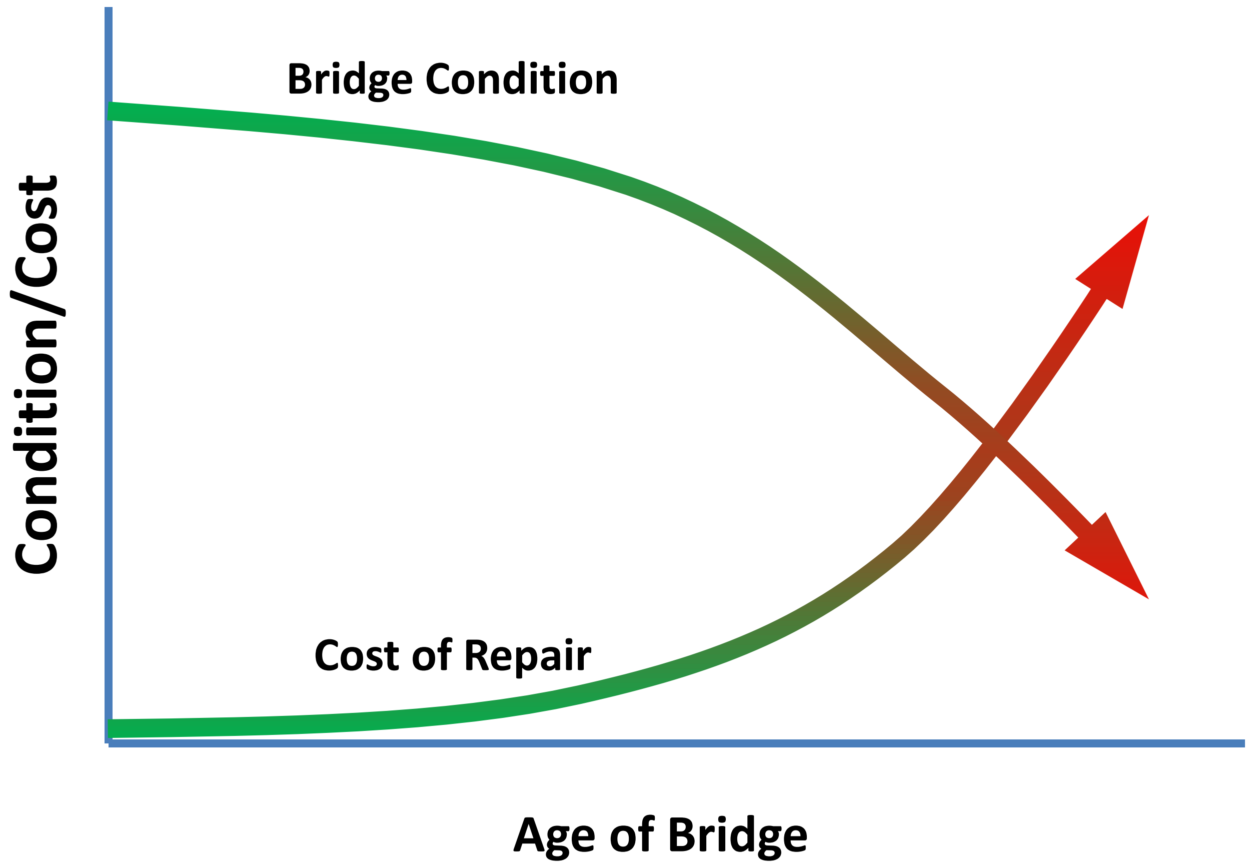
South Front - Summary of Lowest Life Cycle Cost Repair Options

Bridge Element	Description	Initial Cost	Additional Life Cost (30 years)	MOT (associated w/ LCCA only)	Total
Concrete Repair/Rehabilitation					
Deck	Replacement	$215,605	$0	$0	$215,605
Abutments	Patch Repair + Seal	$34,594	$22,880	$28,018	$85,492
Retaining Walls	Patch + Anode + Seal	$55,261	$130,461	$56,035	$241,757
Subtotal Concrete		**$305,460**	**$153,341**	**$84,053**	**$542,854**

Conclusions

- Deterioration is like cancer – typically hidden
- Use past and current damage to project future deterioration
- Good data to make sound decisions to achieve the service life that the owner requires

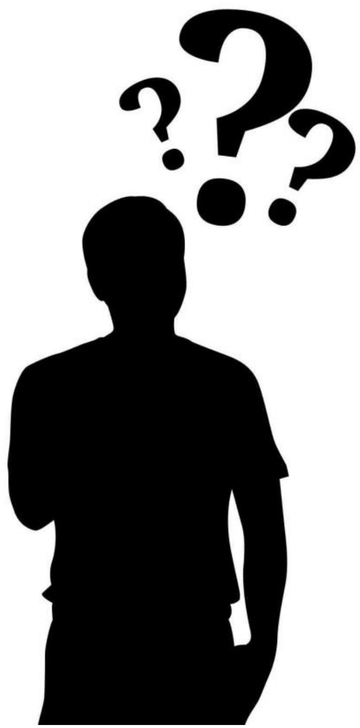
Cost of Rehabilitation



Conclusions

- Early evaluation results in lower maintenance costs and longer service lives
- Preservation is key to maximizing budgets
- Service life modeling and LCCA helps owner make data driven decisions

Questions?



Thank You!