Evaluation of Thin Polymer Overlays for Bridge Decks

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Research Objectives

- To explore waterproofing capabilities and durability of thin polymer overlays
- To assess and compare performance of selected TPOs
- To suggest appropriate bridge deck maintenance strategies

Application of TPO




Research Tasks

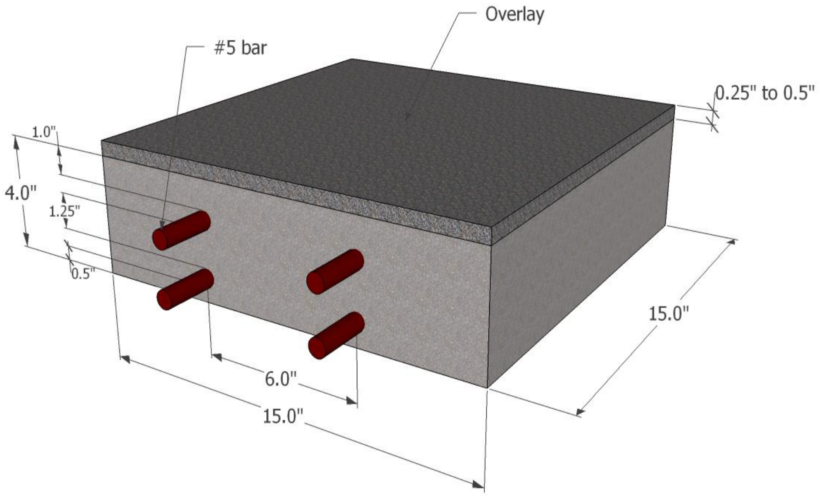
- Task 1 – Literature Review
- Task 2 – State Agency Survey
- Task 3 – Material Selection and Experimental Design
- Task 4 – Experimental Program
- Task 5 – Analysis and Reporting

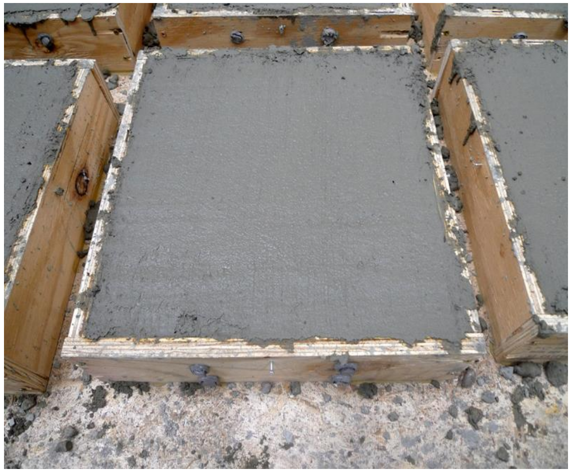
Test Products (Generic)

Specimen	Product	Broadcast Aggregate
S0	Control – no overlay system	-
S1	low-mod epoxy (2 lifts)	flint rock
S2	low-mod epoxy (2 lifts)	Wisconsin granite
S3	low-mod epoxy (2 lifts)	Calcined bauxite
S4	low-mod epoxy (1 lift) + methacrylate (1 lift)	flint rock
S5	low-mod epoxy (1 lift) + low-mod epoxy augmented with additive (1 lift)	flint rock
S6	Epoxy-urethane (2 lifts)	Calcined bauxite
S7	Polyester styrene (premix)	NA
S8	Polyester styrene (2 lifts)	flint rock
S9	Low-mod epoxy 2 (2 lifts)	Taconite

Task 4 – Laboratory Experimental Work

Construction of 84 concrete samples





Application of overlays

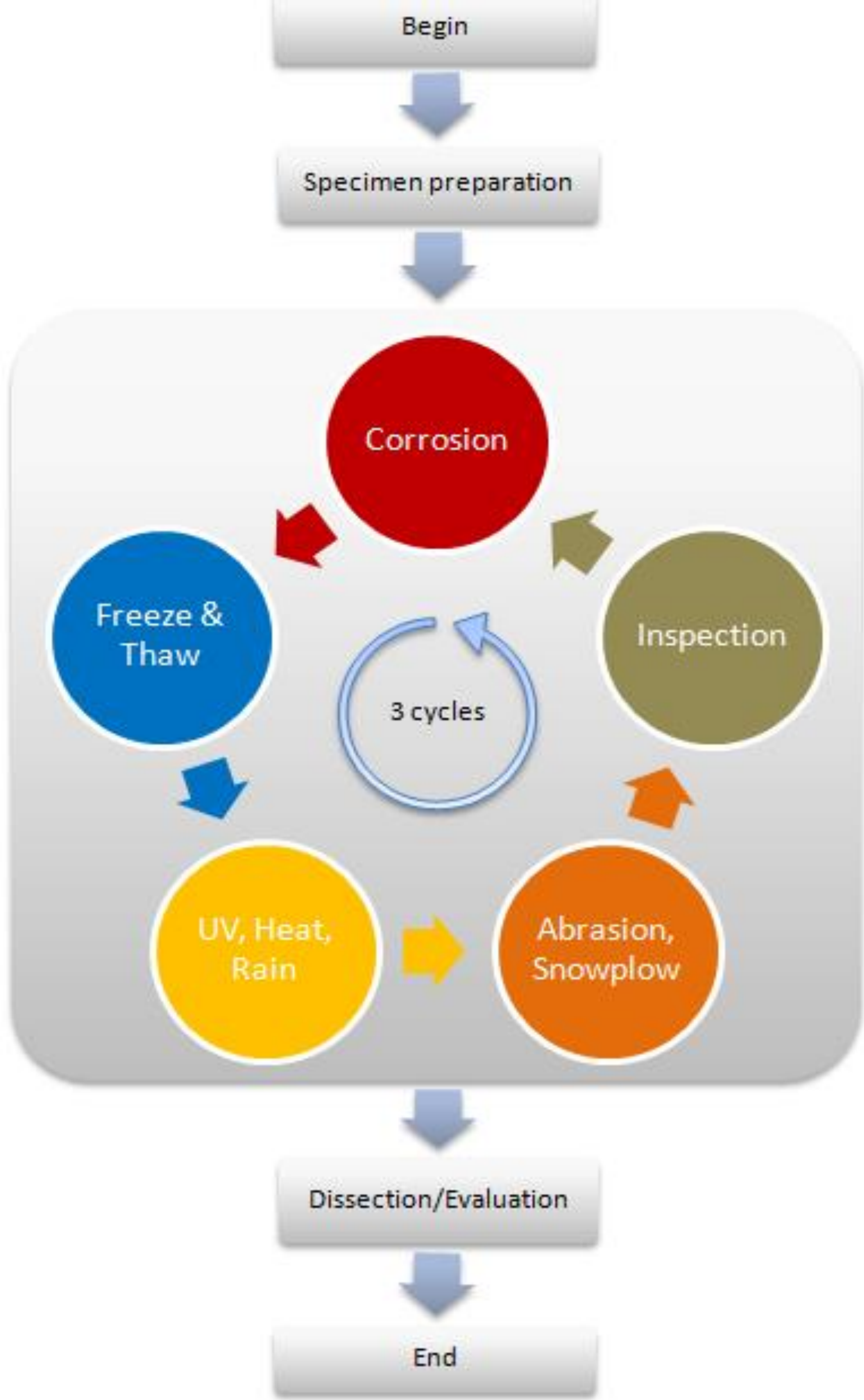
Matrix of Test Specimens

Type of treatment	Group A (no added chlorides)			Group A (moderate added chlorides)			Group A (high added chlorides)		
S0	S0-A1	S0-A2	S0-A3						
S1	S1-A1	S1-A2	S1-A3	S1-B1	S1-B2	S0-B3	S1-C1	S1-C2	S1-C3
S2	S2-A1	S2-A2	S2-A3	S2-B1	S2-B2	S2-B3	S2-C1	S2-C2	S2-C3
S3	S3-A1	S3-A2	S3-A3	S3-B1	S3-B2	S3-B3	S3-C1	S3-C2	S3-C3
S4	S4-A1	S4-A2	S4-A3	S4-B1	S4-B2	S4-B3	S4-C1	S4-C2	S4-C3
S5	S5-A1	S5-A2	S5-A3	S5-B1	S5-B2	S5-B3	S5-C1	S5-C2	S5-C3
S6	S6-A1	S6-A2	S6-A3	S6-B1	S6-B2	S6-B3	S6-C1	S6-C2	S6-C3
S7	S7-A1	S7-A2	S7-A3	S7-B1	S7-B2	S7-B3	S7-C1	S7-C2	S7-C3
S8	S8-A1	S8-A2	S8-A3	S8-B1	S8-B2	S8-B3	S8-C1	S8-C2	S8-C3
S9	S9-A1	S9-A2	S9-A3	S9-B1	S9-B2	S9-B3	S9-C1	S9-C2	S9-C3

Test Specimens

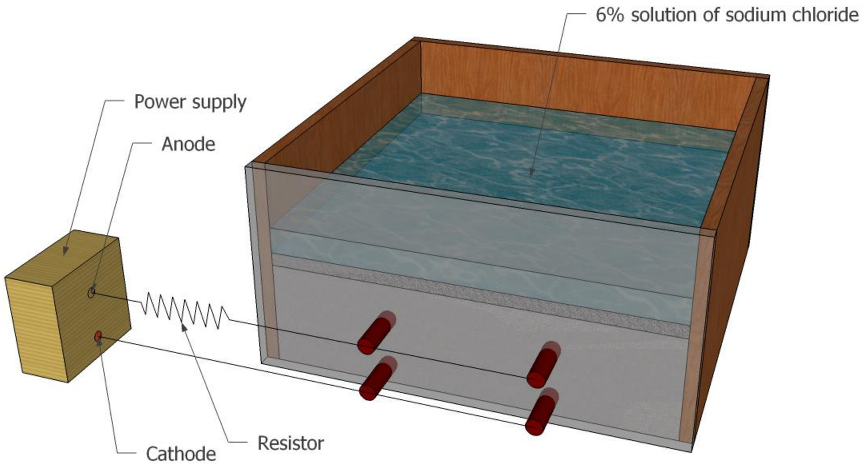
Tests/exposures cycles:

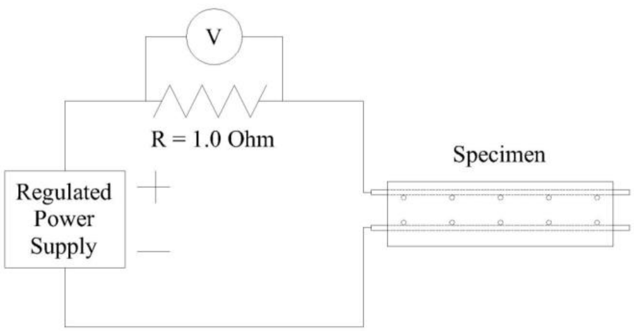
- accelerated corrosion
- freeze-thaw
- heat/UV/rain
- abrasion resistance (tire passage).

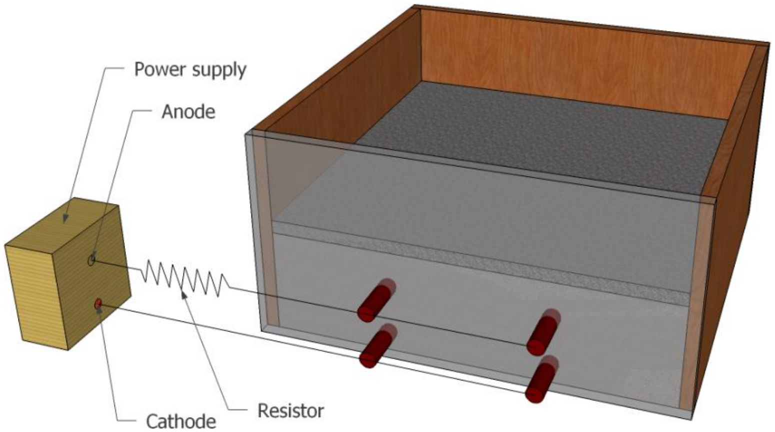


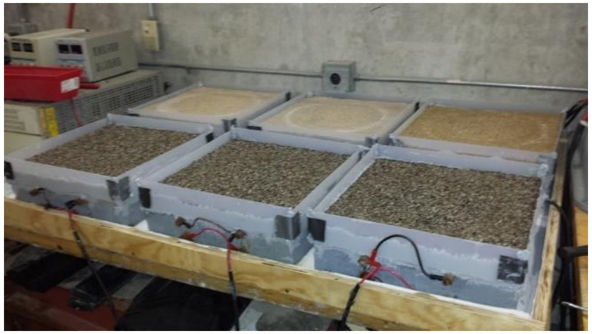
Corrosion/Chlorides Exposure

- 6% NaCl solution
- 4 days wet, 3 days dry
- Electrical potential, 2V









Corrosion mass loss measured at the end following dissection

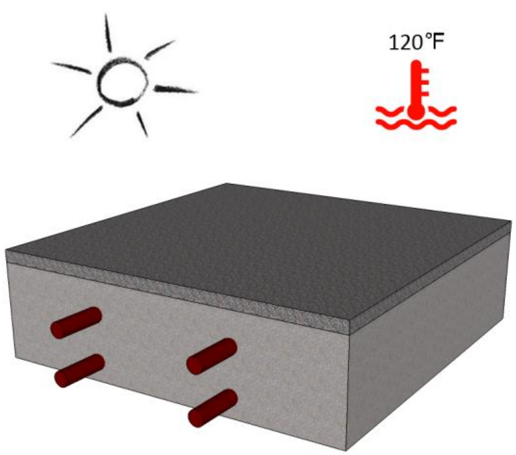
Custom test machine

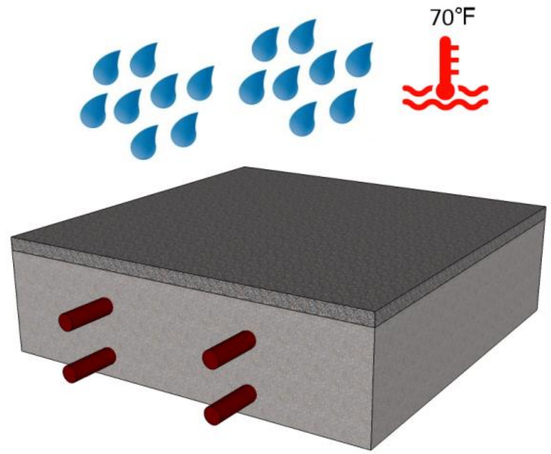
Freeze/Thaw Exposure

- Specimens subjected to freeze-thaw cycles in a chamber.
- Surface in water during F/T tests
- A total of 50 freeze-thaw cycles

High-temperature/UV/rain/ambient temperature (HURA) exposure

- Peak temperature will be 120 degrees accompanied by UV radiation with lamps, rain at 70 degrees and low temperature at 70 degrees.

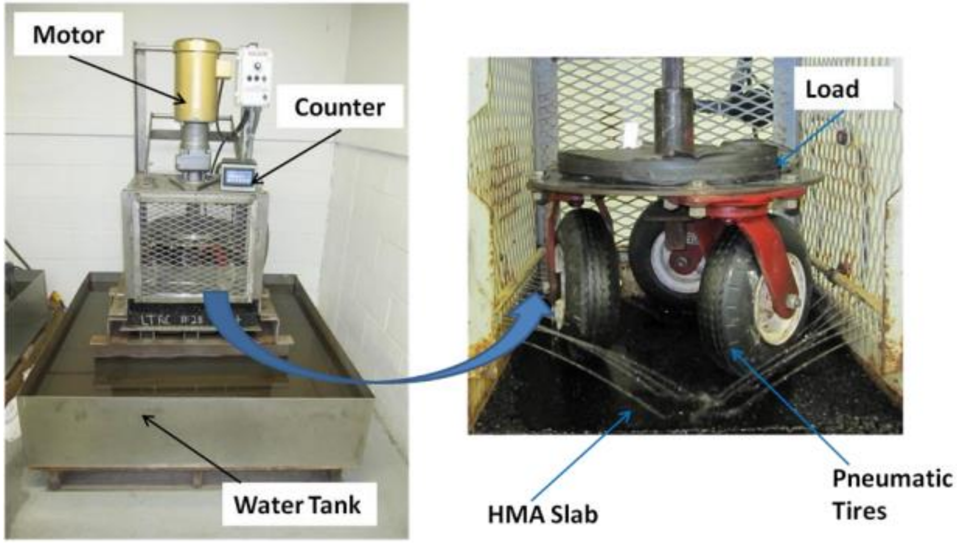




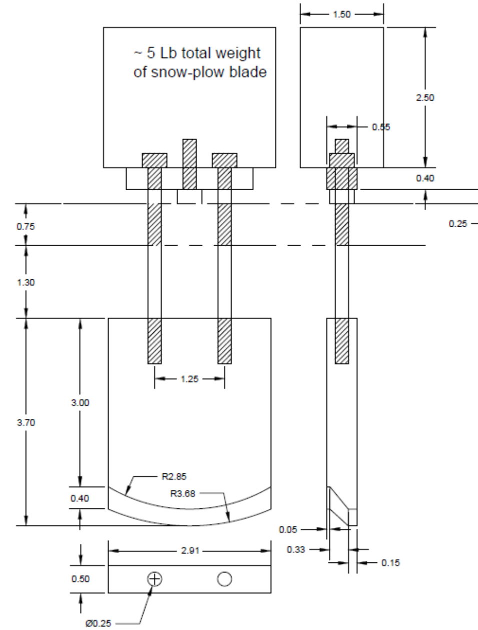
Wear Tests

- A test machine originally developed at the National Center for Asphalt Technology (NCAT) and refined at Auburn University.
- UWM-redesigned and modified NCAT test concept, and added friction measurement and snow plow feature.
- Each cycle approximately 33,000 wheel passages (11,000 turns). The total number of turns over 3 cycles was 99,000 cycles.
- A weight of approximately 115 lbs is placed over the three 10-in rubber tires.

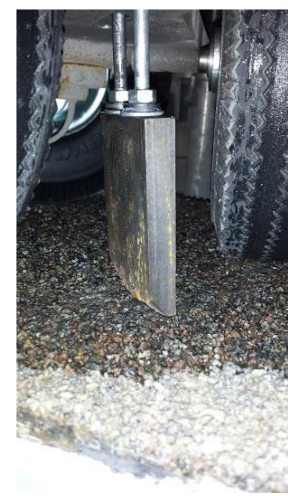
NCAT



UWM



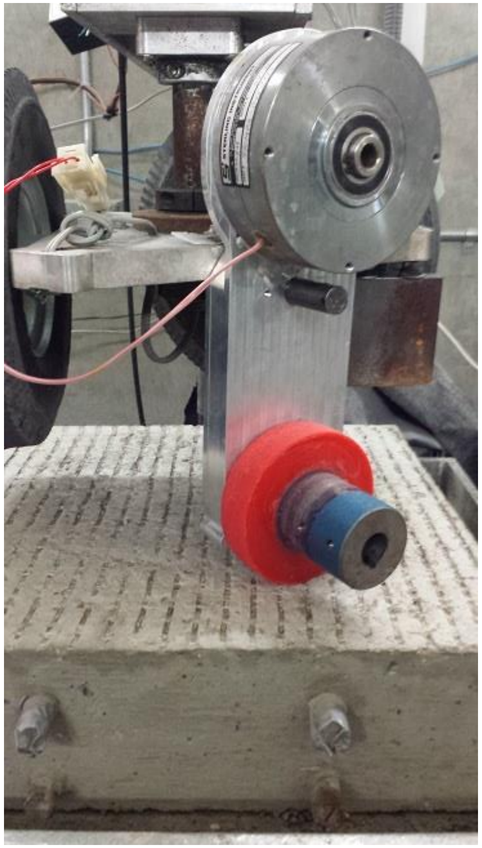
UWM "snow plow"

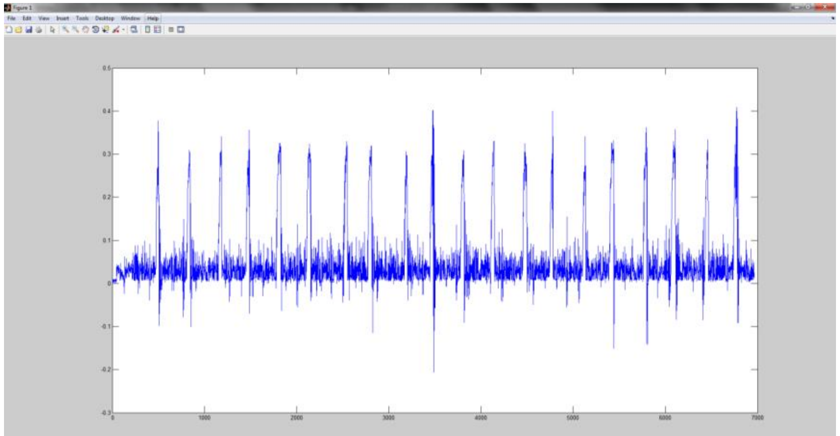


Measurement of Wear (Rut) Depth

Friction Measurements

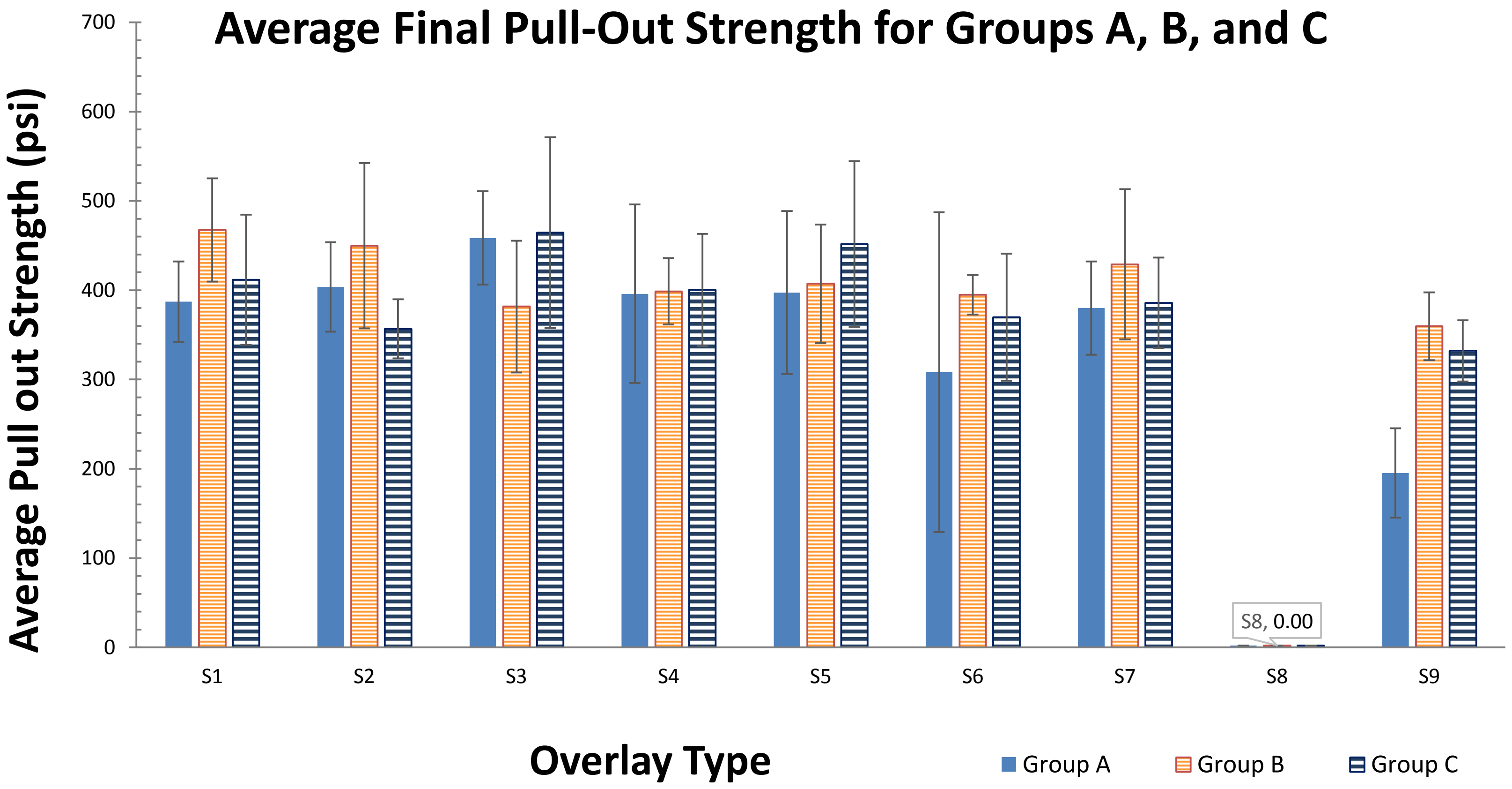
- One tire is replaced with a rubber wheel that has an electronic breaking system, allowing that wheel to be stopped and slip.
- We record the torque on the frame, which is proportional to friction force.





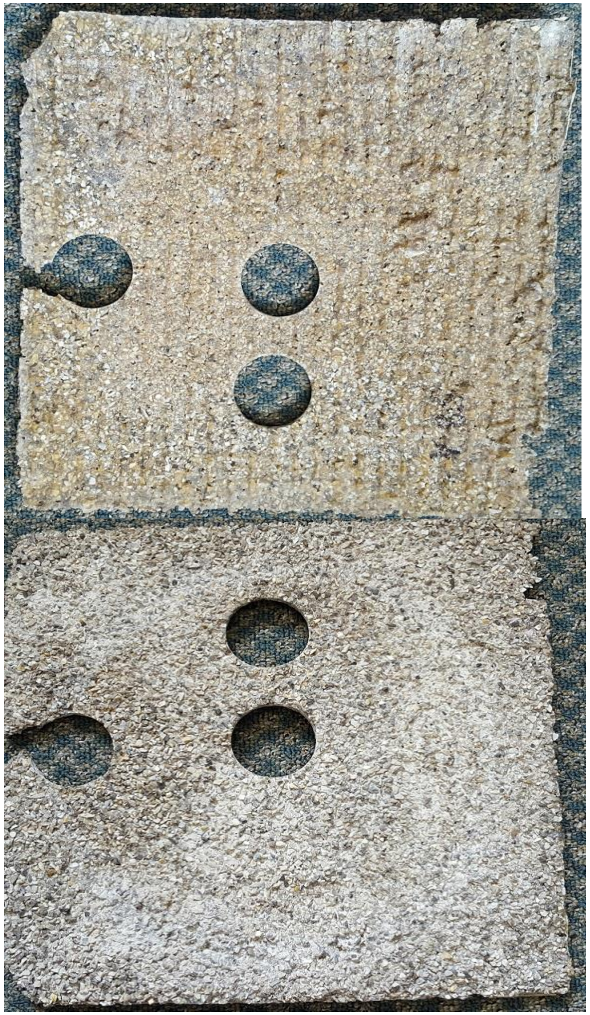
Coring and Pull out Tests

1. Pull-Out Test Results



1. Pull-Out Test Results, cont.

- The 2-lift polyester overlay system delaminated from the concrete surface
- Type of aggregate does not seem to influence the pull-out strength results significantly
- Higher chlorides (Groups B and C) does not have a significant influence on pull-out strengths



Delaminated overlay from a S8 specimen

Pull-Out Test

Specimen	Average All Groups (psi)	Index
S1	422.13	0.5
S2	403.39	0.4
S3	434.94	0.6
S4	398.30	0.4
S5	418.82	0.5
S6	357.68	0.1
S7	398.23	0.4
S8	2.00	-2.5
S9	295.65	-0.4
Mean (S1-S9) (μ)	347.90	
St. Dev. (S1-S9) (σ)	136.35	

Coefficient of Friction

Specimen	Average All Groups (Round 3)	Index
S1	0.641	1.6
S2	0.610	0.1
S3	0.583	-1.1
S4	0.605	-0.1
S5	0.596	-0.5
S6	0.596	-0.5
S7	0.584	-1.1
S8	0.605	-0.1
S9	0.639	1.5
S0	0.559	-2.3
Mean (S1-S9) (μ)	0.607	
St. Dev. (S1-S9) (σ)	0.021	

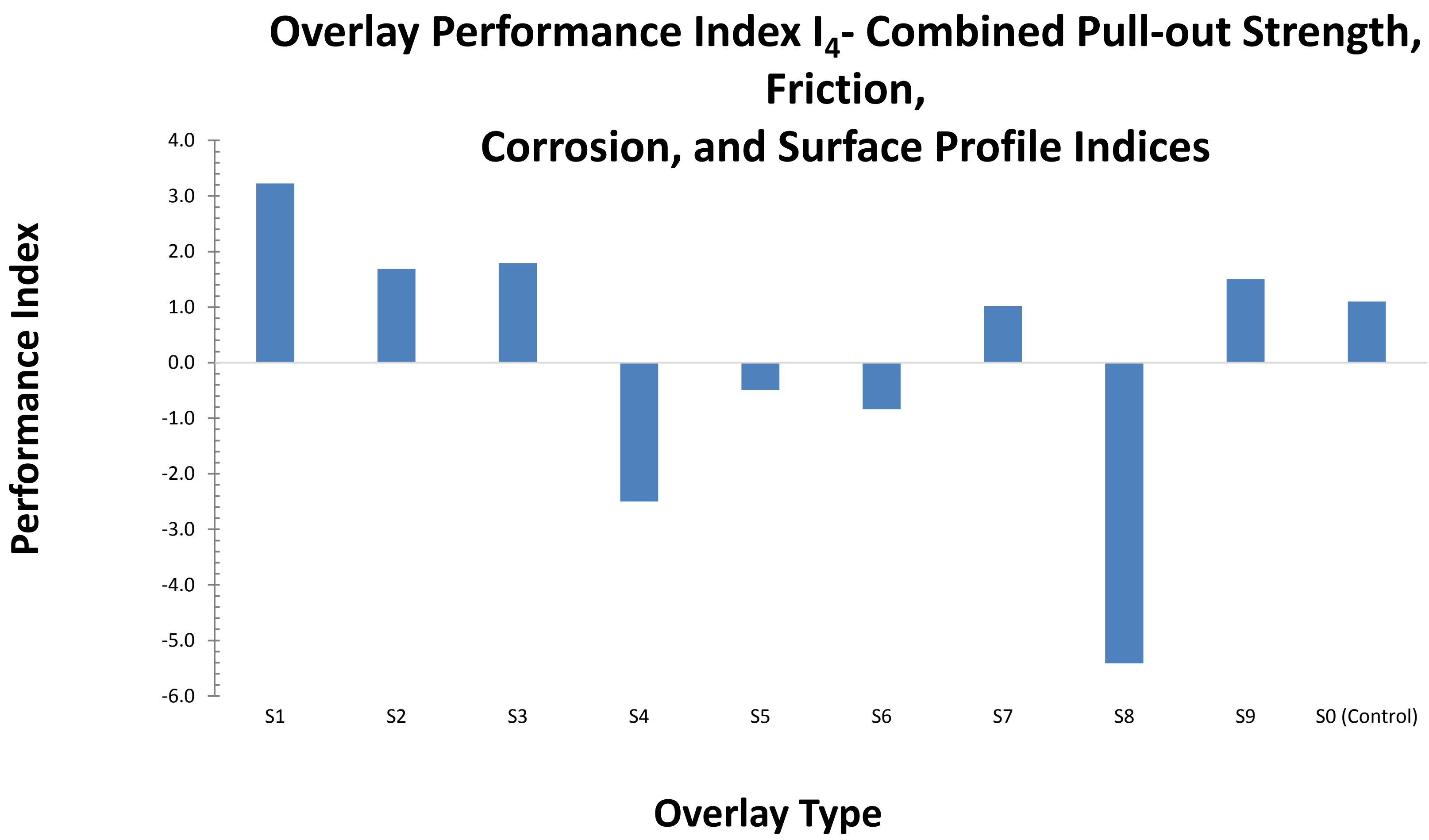
Corrosion Mass Loss Analysis

Specimen	Aver. All. Groups % Change	Index
S1	2.96	0.8
S2	3.06	0.6
S3	2.74	1.3
S4	3.70	-1.0
S5	3.74	-1.1
S6	3.56	-0.6
S7	2.99	0.7
S8	3.84	-1.3
S9	3.05	0.6
S0	2.87	1.0
Mean (S1-S9) (μ)	3.29	
St. Dev. (S1-S9) (σ)	0.41	

Surface profile

Specimen	Avg. Rut Depth (in)	Index
S1	0.050	0.2
S2	0.045	0.6
S3	0.039	0.9
S4	0.084	-1.8
S5	0.045	0.6
S6	0.050	0.2
S7	0.038	1.0
S8	0.079	-1.5
S9	0.058	-0.2
S0	0.015	2.3
Mean (S1-S9) (μ)	0.054	
St. Dev. (S1-S9) (σ)	0.017	

Overall Analysis of Laboratory Results



Economics of TPOs and Sealers

- The material cost for TPOs (per square foot) is substantially higher than penetrating sealers.
- Installation costs for TPOs are similarly higher.
- TPOs are potentially susceptible to premature failure (debonding) due to improper surface preparations, insufficient mixing, moisture conditions, environmental factors, etc.
- Approx. costs (material and installation) of penetrating sealers and 2-lift TPOs are \$0.30 and \$4.6 per ft^2, respectively.
- The cost of premix overlay systems is higher. The cost for the concrete overlay would be the highest of all overlay options.
- Approx. effective life -- TPOs: 7-15 years, sealers: 4-6 years

Results

- The 2-lift polyester TPO exhibited complete delamination.
- TPOs help retain surface friction values.
- The overlay system utilizing epoxy resin with flint rock provided the highest friction, and the best overall performance indices.
- Addition of overlays does not significantly reduce corrosion mass loss when specimens are already contaminated with chlorides prior to installation of overlays.
- The main advantage of TPOs is the long-term preservation of friction coefficients relative to the concrete without overlay.
- For protection of uncontaminated deck against corrosion, TPO should be applied shortly after construction.

Recommended Guidelines

- All new bridge decks should receive their first application of penetrating sealers shortly after construction to maximize the corrosion protection benefits, and repeat at 3 to 5 year intervals.
- Applications of penetrating sealers should ideally be performed in late spring and summer so that spring rains could wash the near-surface chlorides.
- If the first application of penetrating sealer is not possible immediately after construction, such applications should be implemented while the deck rating has not dropped below 9, or within the first 5 years of service life.

Recommended Guidelines (Cont.)

- When the ADT is high, and the cost (including traffic disruptions) associated with maintenance of traffic during frequent sealer applications are considered unacceptable, the application of thin polymer overlays may be considered as an acceptable corrosion protection strategy.
- All sealer and TPO applications should be performed after existing deck cracks have been properly sealed with compatible crack sealers.

Recommended Guidelines (Cont.)

- For bridge deck rating of 7 with no previous protection measures, applications of penetrating sealer or thin polymer overlay may potentially not be beneficial and they are not recommended.
- For bridge deck rating of 6, the recommended approach is to install a latex- or microsilica-modified concrete overlay.
- For bridge deck rating of 5 or lower, the entire bridge deck should be replaced.
- The application of thin polymer overlays when the deck rating is 8 or 7 can be considered if an important objective is to achieve higher surface friction (better skid resistance) or to restore the deck surface profile (riding quality).
- Applications of thin polymer overlays must be on solid concrete surfaces that have been properly repaired. Cementitious patch repairs must be at least 28 days old.