Ten Year Performance of Overlays on Route 60 Over Lynnhaven Inlet and Overlay Recommendations

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INTRODUCTION

- Concrete overlays that have an established history of use and acceptance in Virginia include latex-modified concrete (LMC) (since 1969) and 7% silica fume (SF) (since 1987).
- In 1996, 16 high performance concrete overlays using thirteen different concrete mixtures were placed on two 28-span bridges on Route 60 over the Lynnhaven Inlet in Virginia Beach, Virginia.

INTRODUCTION (continued)

- **The demonstration was designed to show that many different combinations of materials can be used for overlays.**
- **The construction was funded with 20% Virginia Department of Transportation (VDOT) maintenance funds and 80% special federal funds in accordance with ISTEA, Section 6005, specifically designated to demonstrate overlay technologies.**

Purpose of Research

The purpose of the research was to:

- **evaluate the construction and initial and later age condition of the overlays.**
- **compare the overlays with respect to bond strength, permeability to chloride ion, chloride ion penetration, skid resistance and cost.**

The latest evaluation was to compare the overlays after 10 years in service.

Scope

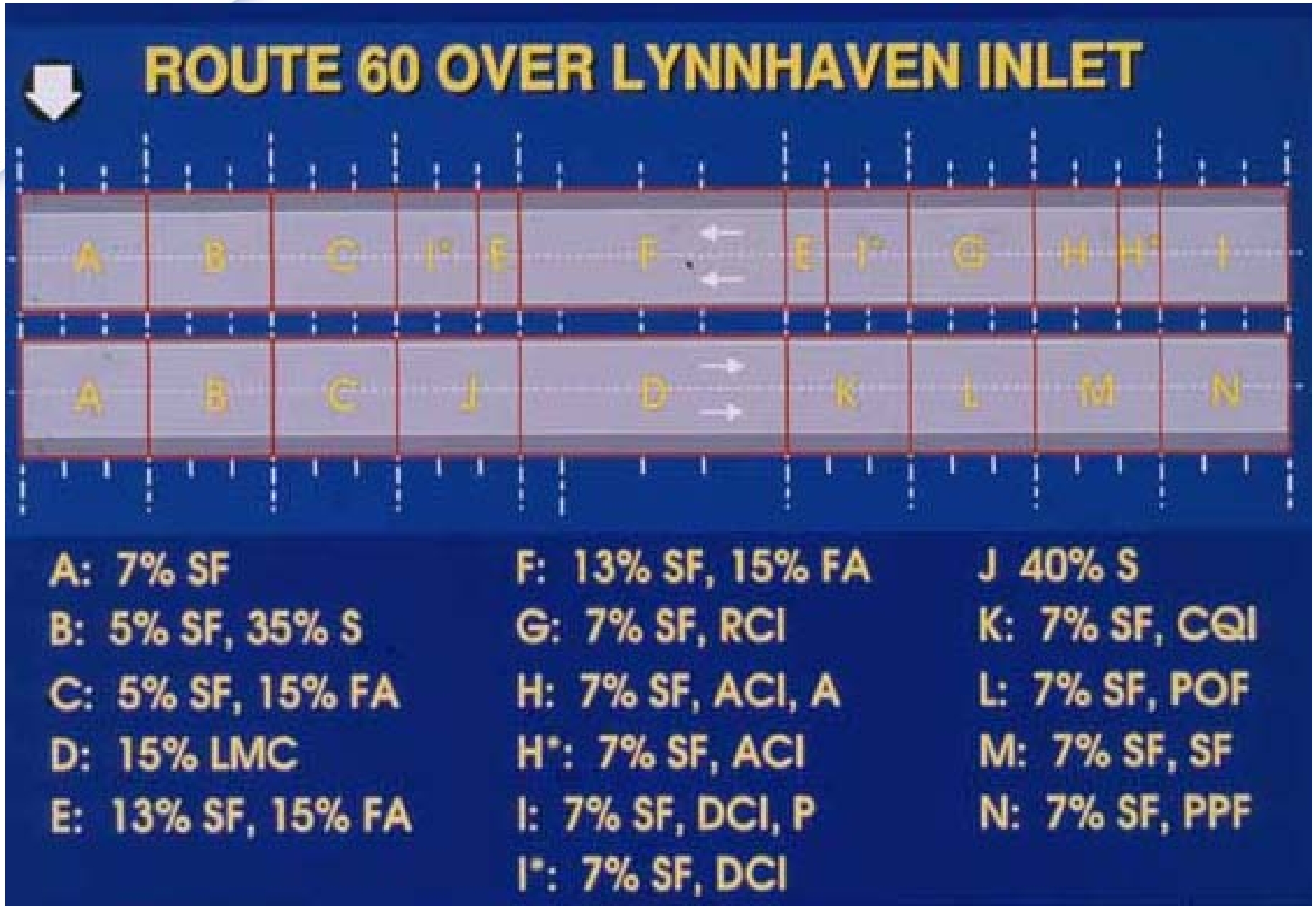
Evaluations are based on:

- **Bond tests on cores from the decks**
- **Permeability tests on cores**
- **Chloride tests on cores**
- **Diffusion constants from chloride tests**
- **Bald tire skid tests on decks**
- **Deck surveys for cracks, delaminations and spalls**
- **Estimated costs for materials**

A minimum of one lane of one span was used to evaluate each overlay system

Lynnhaven Bridges (Ref: Clark-Nexsen)

Plan View of Overlays



Results

- Bond Strength
- Permeability to chloride ion
- Diffusion constants from chloride tests
- Bald tire skid tests on decks
- Deck surveys for cracks, delaminations, spalls and scaling
- Estimated costs for materials
- Conclusions and Recommendations
- New Developments since Lynnhaven

Bond Strength (psi), WBL

Overlay	1996	1999	2006
A: 7% SF	305	275	251
B: 5% SF, 35%S	325	300	174
C: 5% SF, 15% FA	265	280	179
J: 40% S	260	300	255
D: LMC	260	310	271
K: 7% SF, CQI	280	245	263
L: 7% SF, POF	265	220	242
M: 7% SF, STF	290	250	241
N: 7% SF, PPF	315	320	239

Bond Strength (psi), EBL

Overlay	1996	1999	2006
A: 7% SF	230	255	293
B: 5% SF, 35%S	210	260	353
C: 5% SF, 15% FA	240	260	305
I*: 7% SF, DCI	230	290	291
F: 13% SF, 15% FA	240	305	300
I*: 7% SF, DCI	275	265	333
G: 7% SF, RCI	220	205	260
H: 7% SF, ACI, A	135	200	298
H*: 7% SF, ACI	215	200	222
I: 7% SF, DCI, P	145	255	211

Bond Strength Summary

- Bond strengths controlled by surface preparation shot blasting
- Most failures in surface of old concrete deck
- Bond strengths stable over 10 years

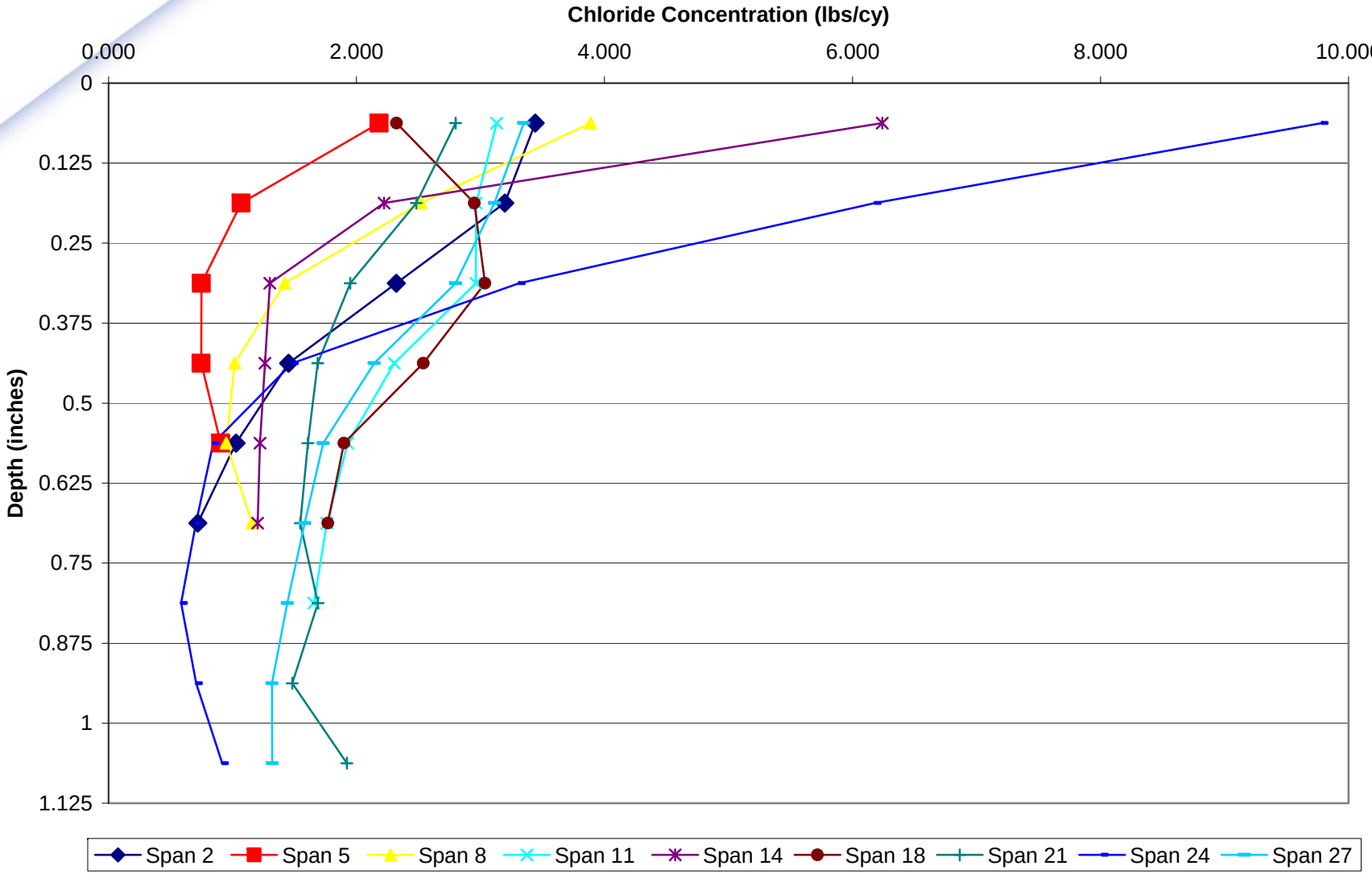
Permeability (coulombs), WBL

Overlay	1996	1999	2006
A: 7% SF	1082	1459	2222
B: 5% SF, 35%S	522	587	569
C: 5% SF, 15% FA	349	362	865
J: 40% S	1309	1887	1958
D: LMC	703	333	130
K: 7% SF, CQI	581	702	851
L: 7% SF, POF	1249	1660	1207
M: 7% SF, STF	-	-	-
N: 7% SF, PPF	923	1458	1278

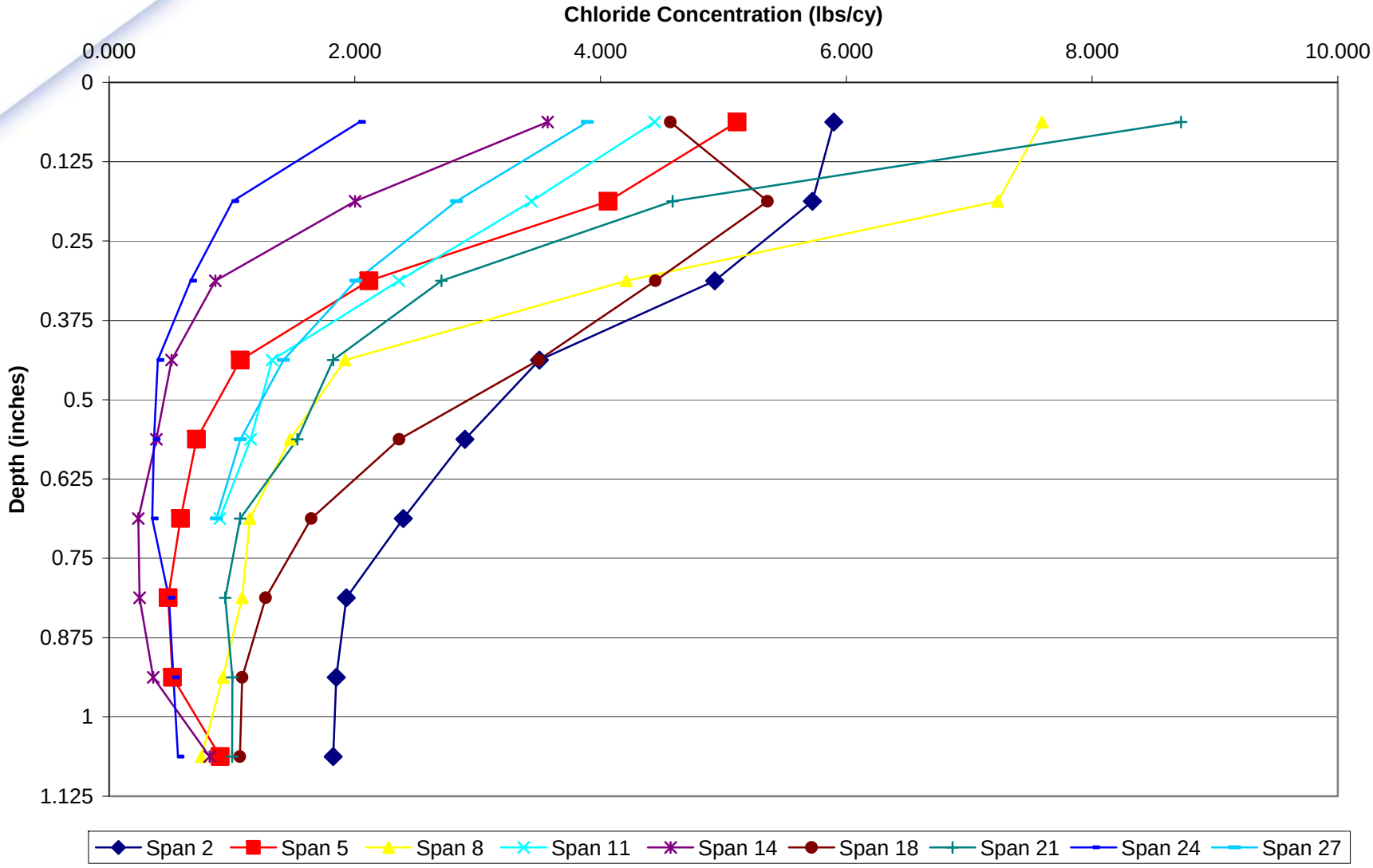
Permeability (coulombs), EBL

Overlay	1996	1999	2006
A: 7% SF	527	518	35
B: 5% SF, 35%S	422	497	516
C: 5% SF, 15% FA	369	300	262
I*: 7% SF, DCI	1418	1090	153
F: 13% SF, 15% FA	193	230	155
I*: 7% SF, DCI	1614	2347	340
G: 7% SF, RCI	1031	823	1579
H: 7% SF, ACI	393	419	308
I: 7% SF, DCI, P	1695	1395	443

Overlay Chloride Ion Profiles, EBL



Overlay Chloride Ion Profiles, WBL



Diffusion Constants (in2/yr.), WBL

Overlay	2006
A: 7% SF	0.034
B: 5% SF, 35%S	0.006
C: 5% SF, 15% FA	0.009
J: 40% S	0.009
D: LMC	0.003
K: 7% SF, CQI	0.015
L: 7% SF, POF	0.004
M: 7% SF, STF	0.004
N: 7% SF, PPF	0.009

Diffusion Constants (in2/yr.), EBL

Overlay	2006
A: 7% SF	0.013
B: 5% SF, 35%S	0.007
C: 5% SF, 15% FA	0.007
I*: 7% SF, DCI	0.067
F: 13% SF, 15% FA	0.002
I*: 7% SF, DCI	0.019
G: 7% SF, RCI	0.087
H: 7% SF, ACI	0.004
I: 7% SF, DCI, P	0.047

Bald tire skid tests, WBL

Overlay	1996	1999	2008
A: 7% SF	48	51	49
B: 5% SF, 35%S	49	51	47
C: 5% SF, 15% FA	48	52	48
J: 40% S	54	54	51
D: LMC	42	53	48
K: 7% SF, CQI	39	51	51
L: 7% SF, POF	36	48	51
M: 7% SF, STF	41	50	50
N: 7% SF, PPF	40	48	49

Bald tire skid tests, EBL

Overlay	1996	1999	2008
A: 7% SF	46	51	52
B: 5% SF, 35%S	41	49	51
C: 5% SF, 15% FA	37	49	51
I*: 7% SF, DCI	38	48	52
F: 13% SF, 15% FA	37	46	45
I*: 7% SF, DCI	43	48	50
G: 7% SF, RCI	38	49	50
H: 7% SF, ACI	33	47	49
I: 7% SF, DCI, P	45	47	47

Bald tire skid tests summary

- All numbers good
- Numbers controlled by saw cut grooved texture

Cracks

- Spans supported by concrete beams had no cracks in the decks prior to placing the overlays.
- Cracking in the overlays on the concrete beam spans was little to none except for the hair line random oriented shrinkage cracking in system K (7% SF, CQI).
- Center spans supported by steel beams had transverse cracks in the decks prior to placing the overlays.
- System F (13% SF, 15% FA) had 69 ft of crack in span 14 deck prior to placing the overlay and 76 ft of crack in the overlay in 2006. The deck cracks reflected through the overlay.
- System D (LMC) had 322 ft of crack in the span 14 deck prior to placing the overlay and 8 ft of crack in the overlay in 2006. Reflective cracking was minimal.

Delaminations, Spalls, and Patches

- The overlay delaminated up to 2 ft in width on both sides of almost all the joints shortly after construction because the contractor did not form the joints in the WBL overlays and did not remove the incompressible form material in a timely fashion in the EBL overlays.
- The contractor repaired the failed overlay in the vicinity of the joints.
- The City of Virginia Beach did additional repair along the joints over the 10 year evaluation period.
- Delaminations, Spalls, and Patches in other areas of the overlays was negligible to none over the 10 year evaluation period. The surface preparation by shot blasting provided acceptable bond strengths.

Scaling

- Heavy: L: 7% SF, POF
- Medium: J: 40% S; K: 7% SF, CQI
- Light: A: 7% SF; G: 7% SF, RCI; H: 7% SF, ACI; I: 7% SF, DCI, P
- Negligible: B: 5% SF, 35%S; C: 5% SF, 15% FA; D: LMC; F: 13% SF, 15% FA; M: 7% SF, STF; N: 7% SF, PPF

Overlay Protection Rank, Best @ Top

Permeability		Chloride Content		Diffusion Constant	
E2	7%SF	W14	LMC	E14	13%SF, 15%FA
W14	LMC	W24	7%SF, STF	W14	LMC
E11	7%SF, DCI	E5	5%SF, 35%S	E24	7%SF, ACI, A
E14	13%SF, 15%FA	W5	5%SF, 35%S	W21	7%SF, POF
E8	5%SF, 15%FA	E8	5%SF, 15%FA	W24	7%SF, STF
E24	7%SF, ACI, A	E14	13%SF, 15%FA	W5	5%SF, 35%S
E18	7%SF, DCI	E2	7%SF	E5	5%SF, 35%S
E27	7%SF, DCI, P	E24	7%SF, ACI, A	E8	5%SF, 15%FA
E5	5%SF, 35%S	W27	7%SF, PPF	W8	5%SF, 15%FA

Overlay Rank, (cont.) Worst @ Bottom

Permeability		Chloride Content		Diffusion Constant	
W5	5%SF, 35%S	W11	40% S	W11	40% S
W18	7%SF, CQI	E21	7%SF, RCI	W27	7%SF, PPF
W8	5%SF, 15%FA	W21	7%SF, POF	E2	7%SF
W21	7%SF, POF	W8	5%SF, 15%FA	W18	7%SF, CQI
W27	7%SF, PPF	E27	7%SF, DCI, P	E18	7%SF, DCI
E21	7%SF, RCI	E11	7%SF, DCI	W2	7%SF
W11	40% S	E18	7%SF, DCI	E27	7%SF, DCI, P
W2	7%SF	W18	7%SF, CQI	E11	7%SF, DCI
-	-	W2	7%SF	E21	7%SF, RCI

Relative Material Costs

Overlay	Cost	Overlay	Cost
L: 7% SF, POF	H	M: 7% SF, STF	H
D: LMC	M-H	K: 7% SF, CQI	M-H
H: 7% SF, ACI, A	M-H	I: 7% SF, DCI, P	M-H
N: 7% SF, PPF	M	I*: 7% SF, DCI	M
G: 7% SF, RCI	M	H*: 7% SF, ACI	M
F: 13% SF, 15% FA	M	A: 7% SF	L-M
B: 5% SF, 35% S	L-M	C: 5% SF, 15% FA	L-M
J: 40% S	L		

Conclusions

1. The HPC overlays evaluated had fair to excellent bond strengths and excellent skid resistance at 10 years of age. The overlays differed with respect to permeability to chloride ion.
2. In addition to the VDOT conventional overlays of LMC and 7% SF, HPC overlays that have very low to low permeability to chloride ion and good to excellent bond strength can be constructed with a variety of combinations of SF, FA, S, latex, corrosion-inhibiting admixtures, a shrinkage-reducing admixture, and fibers.

Conclusions

3. The overall best performing overlay was the LMC overlay, which had the second lowest permeability and chloride diffusion coefficient and the lowest chloride ion content.
4. Use of Overlay Systems J, K and L should be avoided in situations in which heavy scaling in not acceptable. These situations might include areas with poor drainage, sidewalks, and surfaces that need to have a pleasing appearance. The scaling can likely be avoided if a proper air-void system can be obtained in these overlay systems.

Conclusions

5. Joints in overlays must be properly formed and the forms removed in a timely fashion to prevent damage to the bond interface of the overlay adjacent to the joint and subsequent spalling in a short time.
6. Deck surface preparation by shot blasting can provide high bond strengths.
7. Milling of the top 0.5 to 1 in of the deck surface prior to shot blasting the surface can remove chloride from older decks that when not removed can migrate upward into the overlay.

Recommendations

1. *VDOT's Structure & Bridge Division should continue to extend the life of bridge decks using LMC.*
2. *VDOT's Structure & Bridge Division should consider using overlays containing combinations of SF, FA, and S as evaluated in this study when a cost-benefit analysis for a project indicates that the higher cost of LMC is not justified.* Although the other overlays evaluated can be used, the higher cost associated with adding the corrosion inhibitors, fibers, and shrinkage-reducing admixture would need to be justified.

Acknowledgements

- VTRC lab staff Michael Burton, Bill Ordel, Andy Mills and Linda DeGrasse conducted the material tests.
- Materials NDE lab staff conducted the skid tests.

Changes in LMC Technology

- LMC prepared with very early hardening cement (LMC-VE) was used as an overlay in 1997 so that traffic could be placed on the overlay after 3 hours of curing.
- LMC prepared with Type K cement was used as an overlay in 2005 to help reduce the incidence of shrinkage cracking.
- Use of LMC-VE has become a standard overlay for situations in which lane closures cause major traffic congestion.

I64 Over Rivanna River, 2006

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