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REDUCING SHRINKAGE CRACKS IN CONCRETE BRIDGE DECKS

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Deck Cracking Problem

-Early age transverse cracks in more than 100,000 bridges (NCHRP Study)

- By controlling early age cracking, the amount of cracking at later ages should remain low (Darwin et al.)

Classification of Cracks (TRB Circular,E-C107)

Type of Cracking	Time of Appearance
Plastic Shrinkage Cracking	30 min to 6 h
Plastic settlement	10 min to 3 h
Thermal expansion and contraction	1 day to 2–3 weeks
Drying shrinkage	Weeks to months

Deck Cracking Problem

Drying shrinkage cracks – may occur few months after pour. Often transversely oriented and full depth, exposing rebar to chlorides and water.

Deck Cracking Problem

Nimmo Parkway (Hampton Roads)

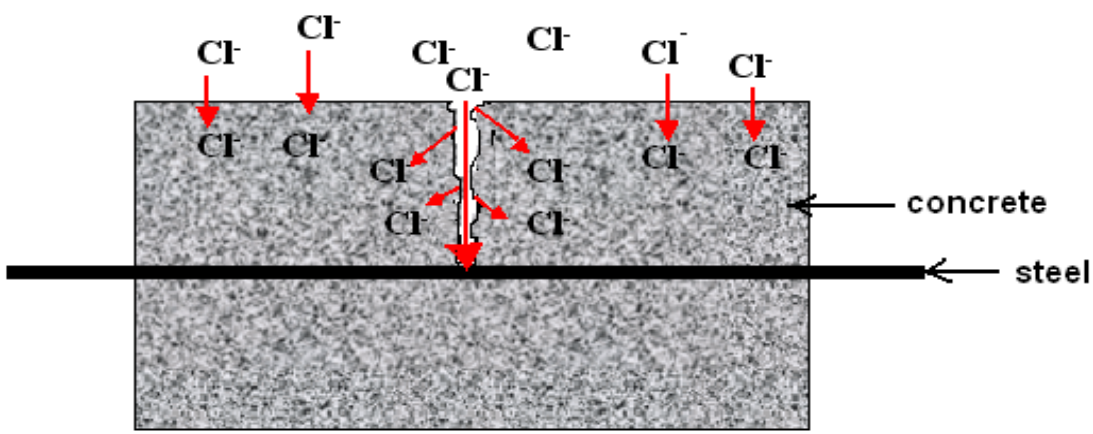
Cracks shorten service life, increase maintenance, and accelerate corrosion

Increase in the number of cracks offsets the benefits of the low-permeability concrete between the cracks.

Rte 61 over New River (Salem)

Cracks with a width over 0.20 mm should be sealed

Crack repair cost range from $35/LF - $85/LF



Chloride diffusion in cracked concrete

Corrosion Resistant Rebars

Objectives

To investigate the effectiveness of reducing drying shrinkage in VDOT concrete mixes using the following:

- Lightweight (LW) concrete with LW coarse aggregate
- Normal weight concrete with Shrinkage Reducing Admixture (SRA)
- Shrinkage compensating concrete
- Concrete with low paste content (max 600 lb/yd^3 cementitious material)
- Normal weight concrete (NWC) with LW fine aggregate

CAUTION

For the proper performance of these mixtures attention should be paid to the following:

Proper design

Proper selection of materials

Proper mixing

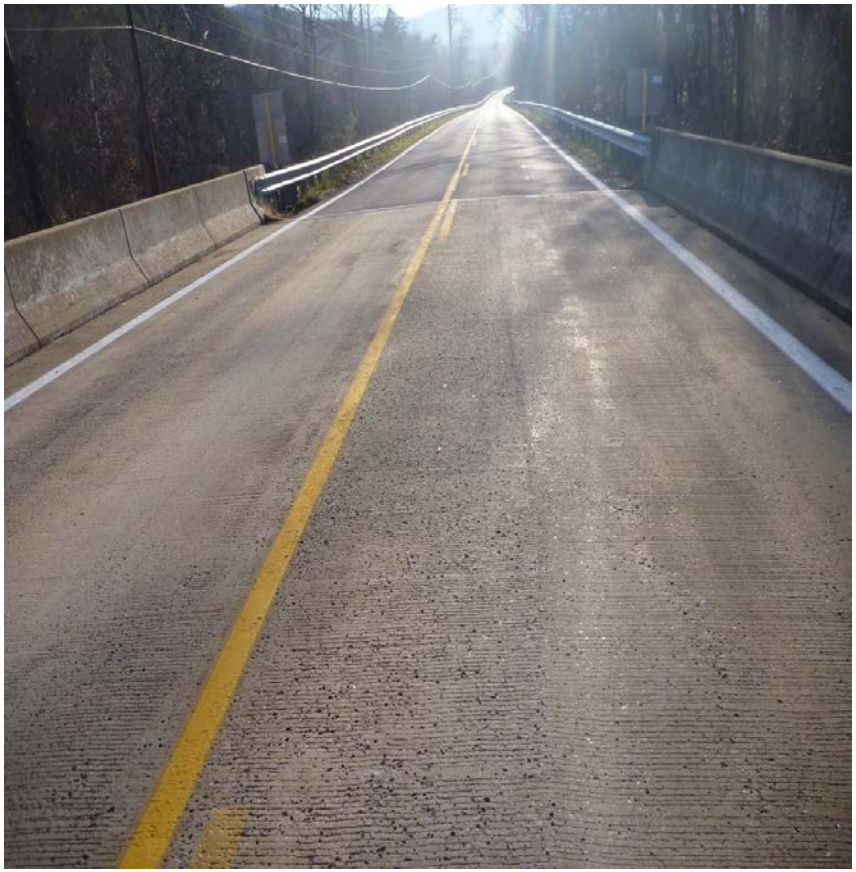
Proper placement

Proper curing

Proper sequencing

Lightweight Concrete Bridge Deck

Route 629 over Cowpasture River



After 33 Years

No Transverse Crack (Continuous two span bridge on Steel Beams)

Route 60 over Maury River

After 30 Years

Skew, no cracks

Lightweight concrete

Field Projects Completed:

2012

(i) Winchester, Staunton District

(ii) Lynchburg District

(iii) Opal, Culpeper District

2013

(iv) Nokesville, NOVA District

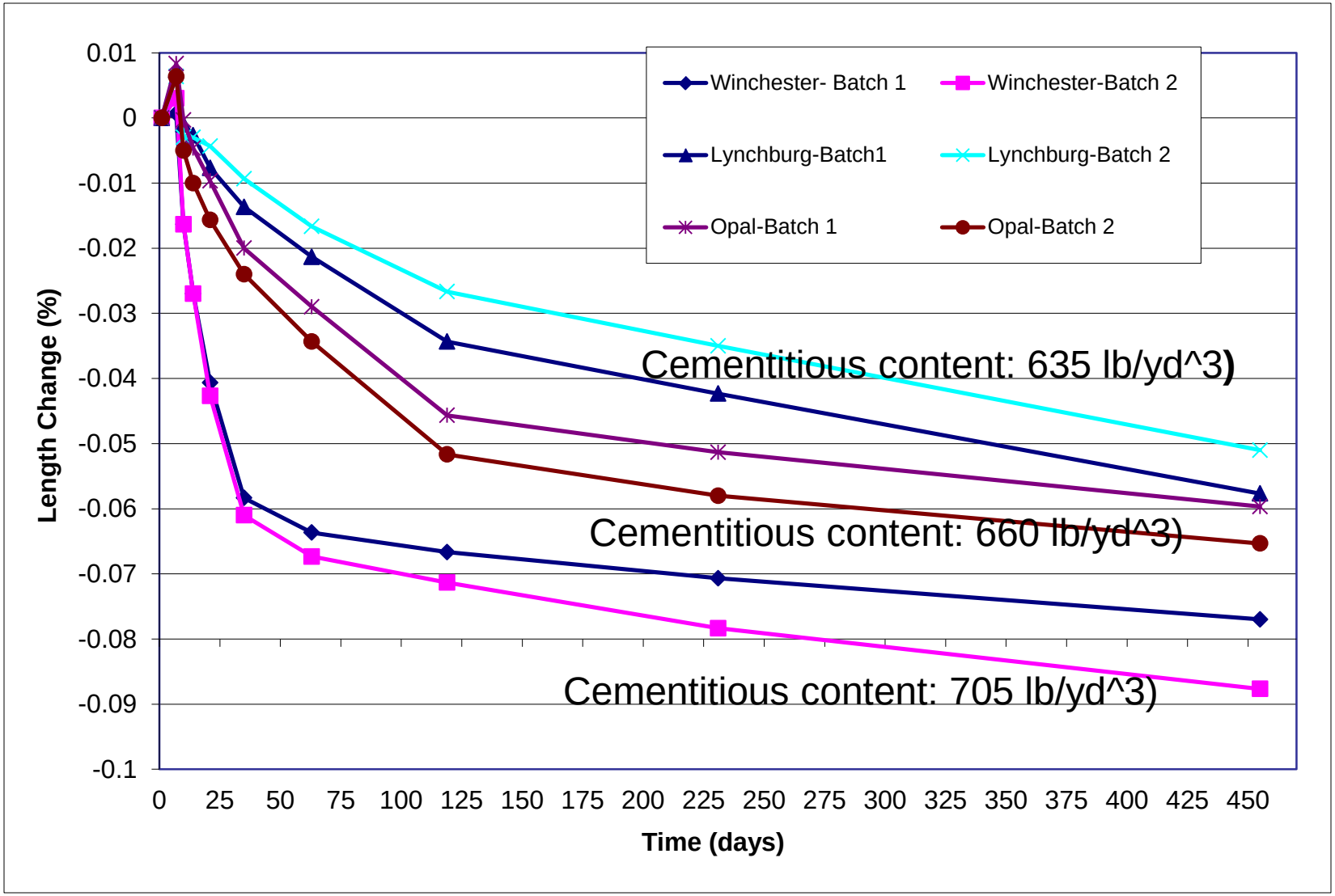
(v) Fredericksburg District

(vi) Richmond District

2014

(vii) Stafford, NOVA

Shrinkage Results –Lightweight Concrete (2012 Projects)



Crack Survey –Lightweight concrete

Winchester (2 Years)

Opal (1 ½ Years)

Lynchburg (1 ½ Years)

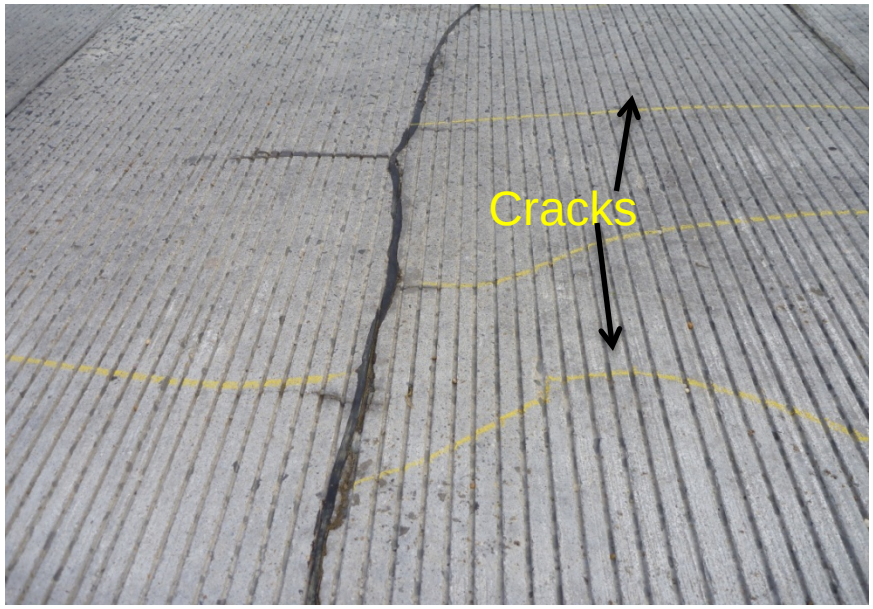
I-95 Expressway, Stafford (6 months)

Crack Survey –Lightweight concrete

Mathews County, Fredericksburg (6 Months)

Crewe, Richmond (7 Months)

Nokesville, NOVA (10 Months)



Nokesville, NOVA (10 Months)

Lightweight Concrete- Nokesville, NOVA District

Properties	Batch 1	Batch 2
compressive Strength		
3 days (psi)	**2870**	**5500**
7 Days (psi)	**3770**	**6590**
28 Days (psi)	**4870**	**8010**
Splitting Tensile Strength		
28 Days (psi)	**450**	**475**
Elastic Modulus		
28 Days (10^6 psi)	**3.09**	**3.82**
Permeability (coulomb)	**732**	**638**

Normal weight concrete with Shrinkage Reducing Admixture (SRA)

Typically shrinkage reduction achieved is between 35 – 45%

Maximum Cementitious Content : 600 lb/yd^3

Projects Completed

I-95 Express Lanes in NOVA

(i) Telegraph Road
(ii) JHS Ramp
(iii) B-601 Ramp
(iv) B-602 Ramp
(v) B-609 Ramp

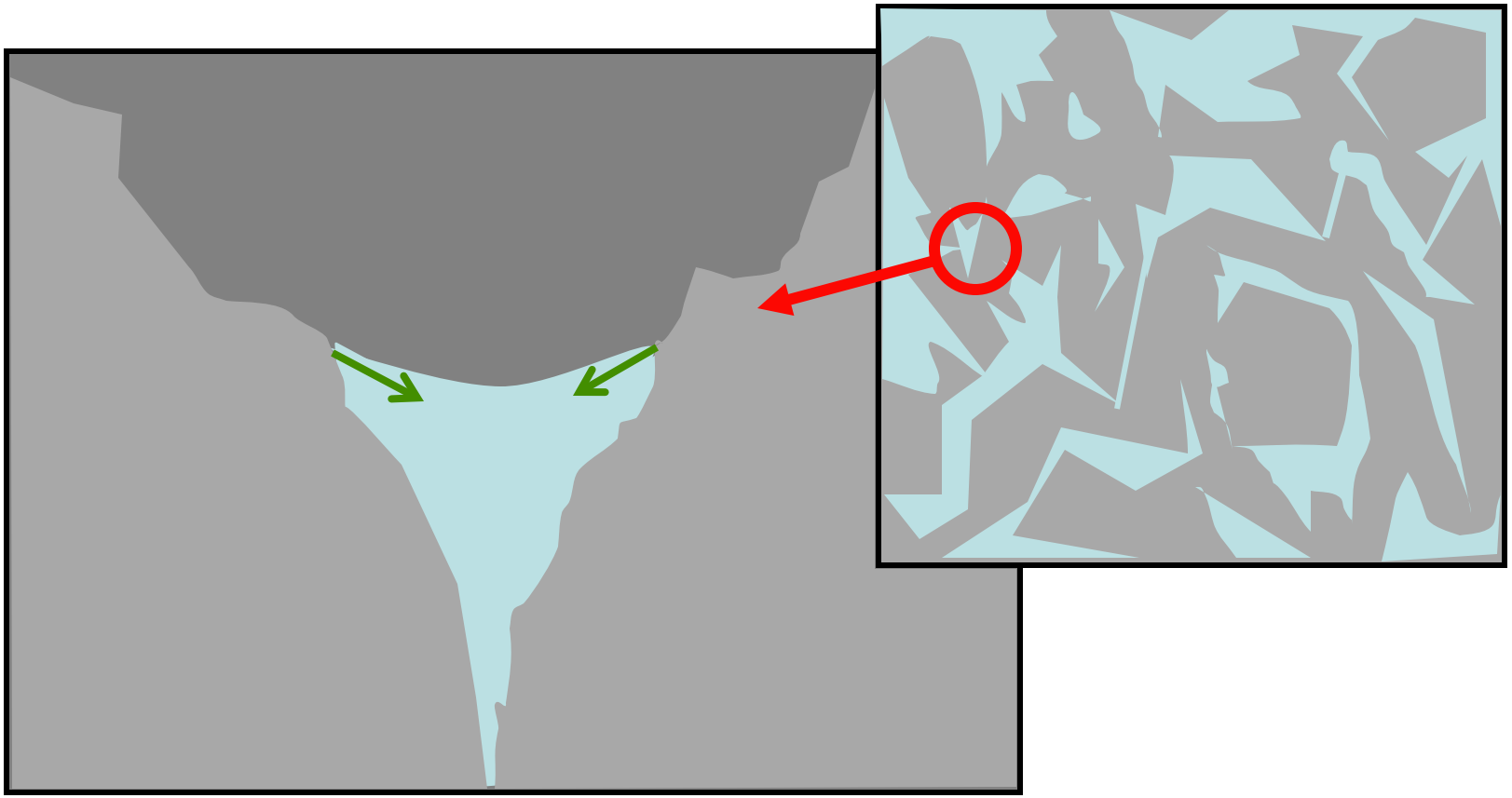
Staunton District

(i) Rte 633
(ii) Rte 1421

Fredericksburg District

(i) Rte 600 Herring Creek

SRA: How it works



SRAs function by reducing capillary tension of pore water

I-95 Express Lanes in NOVA

Mix Design

one cubic yard based on SSD condition

Cement: 300 lb
Slag: 300 lb
Total Cementitious Content: 600 lb

Coarse aggregate: 1892 lb
Fine aggregate: 1238 lbs

Water: 262 lb (31.5 gallons)

w/c =0.44

Air: 6.5 %

shrinkage reducing admixture: 1.5 gallon/yd^3

I-95 Express Lanes in NOVA

Properties	B607 8/30/13	B603 9/18/13	B602 11/19/13	B609 4/1/14	B601 6/26/14
compressive Strength					
28 Days(psi)	**4970**	**4390**	**5450**	**4670**	**5160**
Elastic Modulus					
28 Days(10^6 psi)	**4.53**	**4.44**	**5.49**	**4.90**	**5.11**
Permeability (Coulomb)	**1237**	**611**	**625**	**983**	**674**
Drying Shrinkage (28 days) %	**0.0367**	**0.0357**	**0.0373**	**0.0347**	**0.0340**

I-95 Express Lanes in NOVA

Bridge No.	Length of bridge	Number of cracks length(ft) and Width(mm)
B607 (Telegraph Rd)	313 ft	One crack (36'(0.2mm))
B609 (GHS Ramp)	448.33 ft	4 cracks 3'(0.25mm),15'(0.2mm),9'(0.3mm),1' (0.25mm)
B603 (JHS Ramp)	541.83 ft	No Cracks
B602 (ramp)	558 ft	One crack (7' (0.2mm)
B601 (ramp)	964 ft	20 short cracks (average length 4-5ft) (All cracks are in the first 150 feet length, already sealed with epoxy

Normal weight concrete with SRA

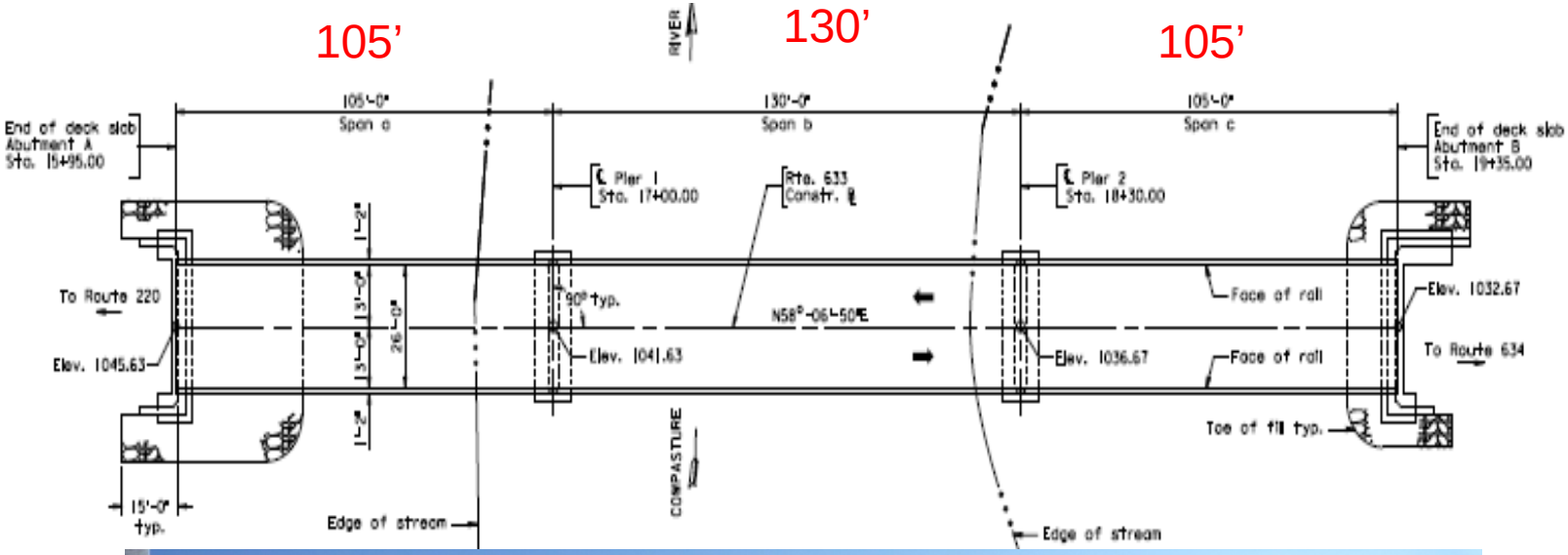
Telegraph Bridge, NOVA (9 Months)

Rte 600 Herring Creek, Fredericksburg (9 Months)

Rte 1421, Staunton (1 ½ years)

Rte. 633 Covington, Staunton District

105’ 130’ 105’



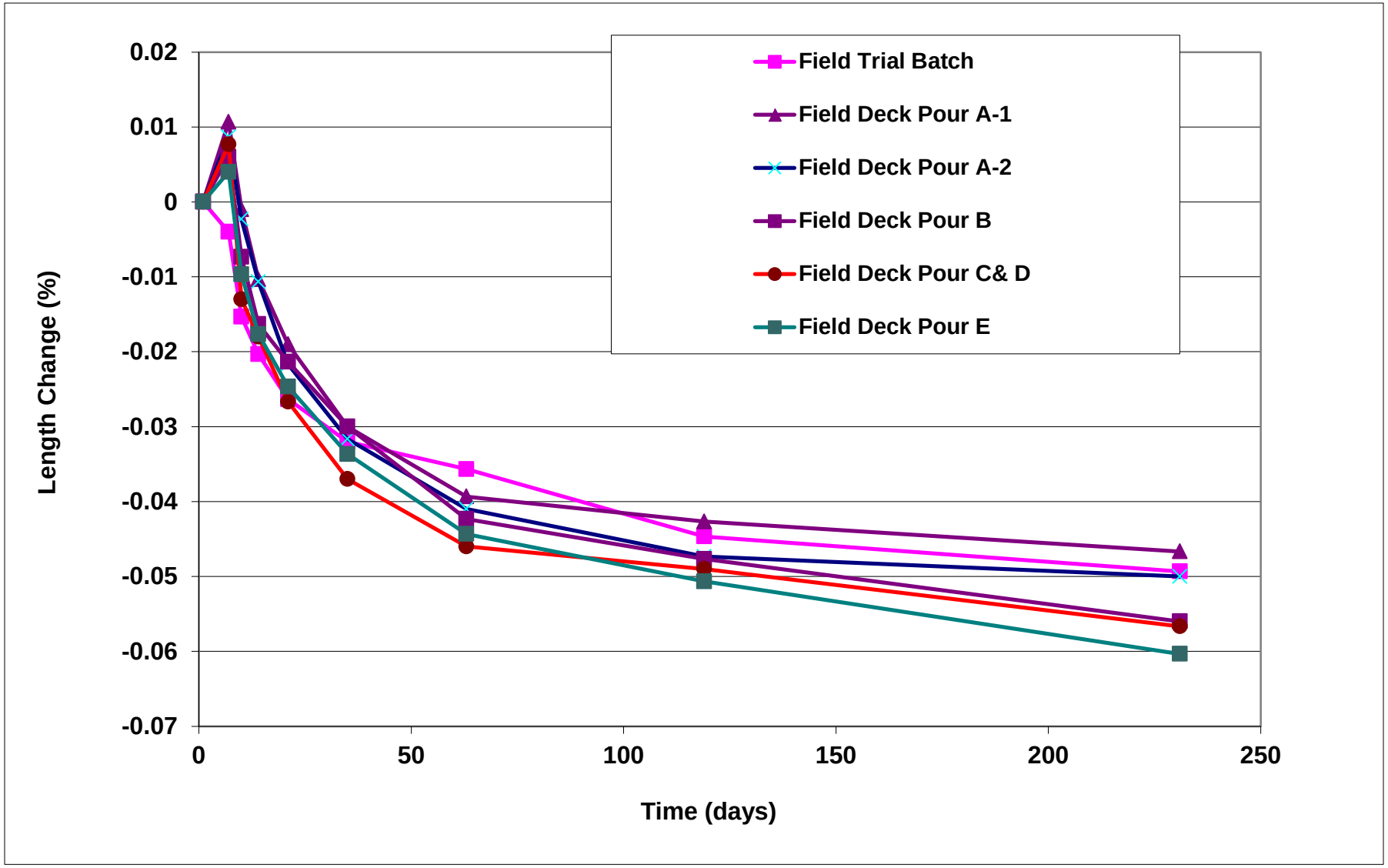
Rte. 633 Covington, Staunton District

Hardened Concrete Test Results

Properties	Field Trial Batch 1	Deck Pour A-Batch1	Deck Pour A-Batch 2	Deck Pour B	Deck Pour C &D	Deck Pour E
compressive Strength						
28 Days(psi)	**4670**	**4200**	**4640**	**4060**	**5150**	**5030**
Splitting Tensile Strength						
28 Days(psi)	**465**	**525**	**530**	**505**	**545**	**555**
Elastic Modulus						
28 Days(10^6 psi)	**3.51**	**3.46**	**3.39**	**3.60**	**3.60**	**3.58**
Permeability (Coulomb)	**791**	**1128**	**960**	**894**	**1014**	**1240**

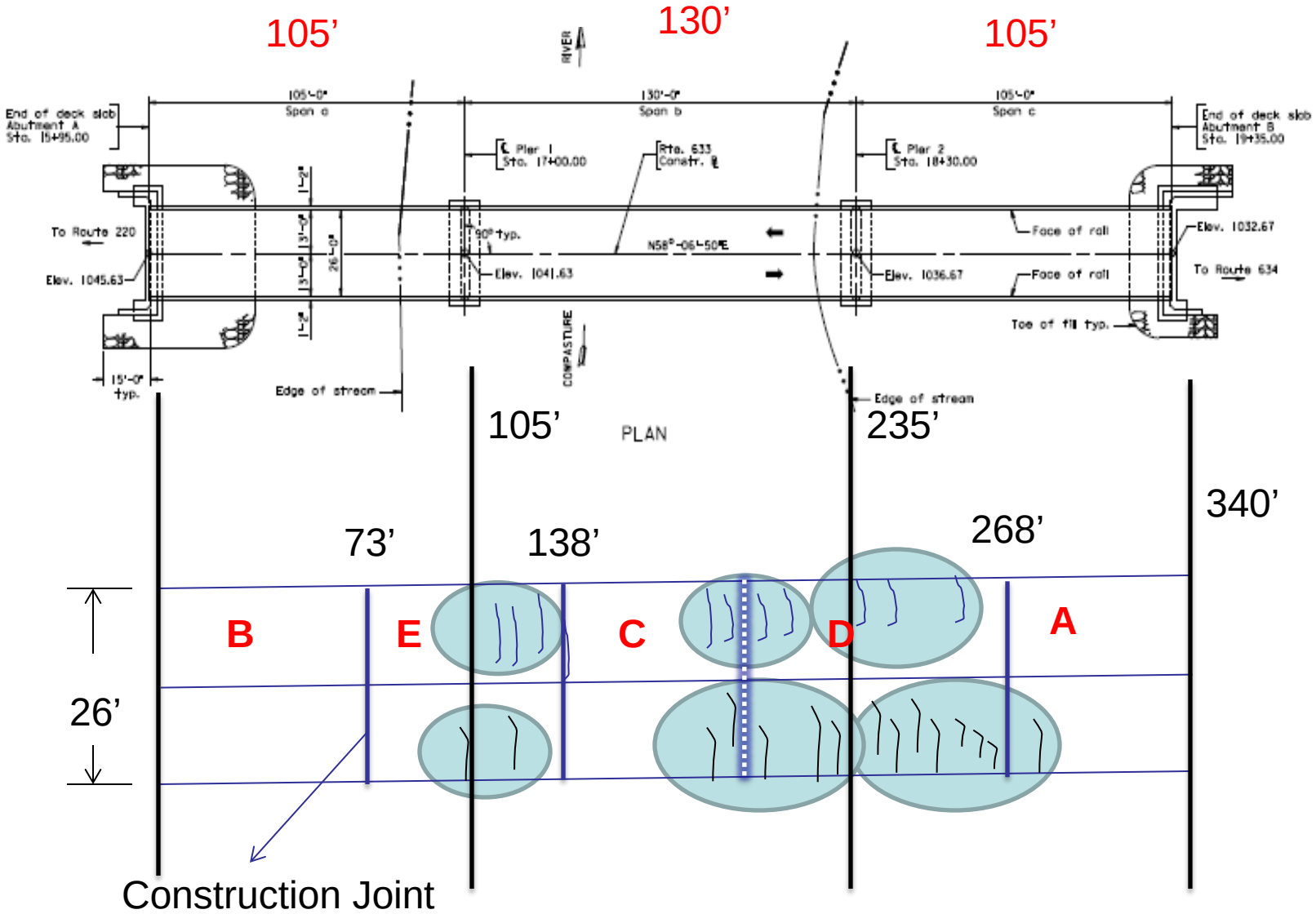
Rte. 633 Covington, Staunton District

Shrinkage Results



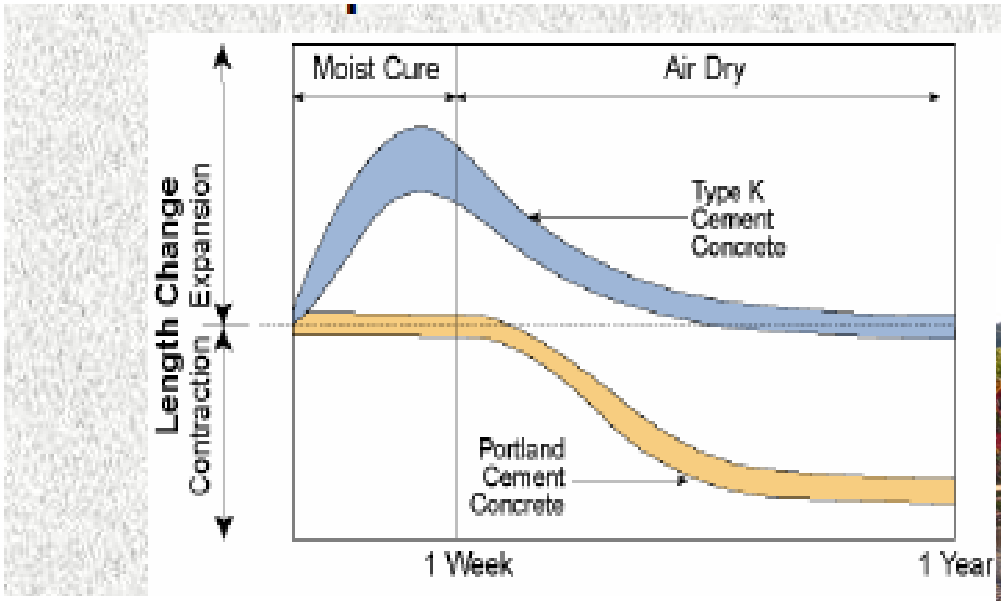
Normal weight concrete with SRA

Crack Survey (18 months), Rte 633 Staunton District



Did not follow placement sequence

Shrinkage compensating concrete (Type K cement)



Route 613 Bentonville – Staunton District

Slump loss under hot weather is more serious than normal concrete.

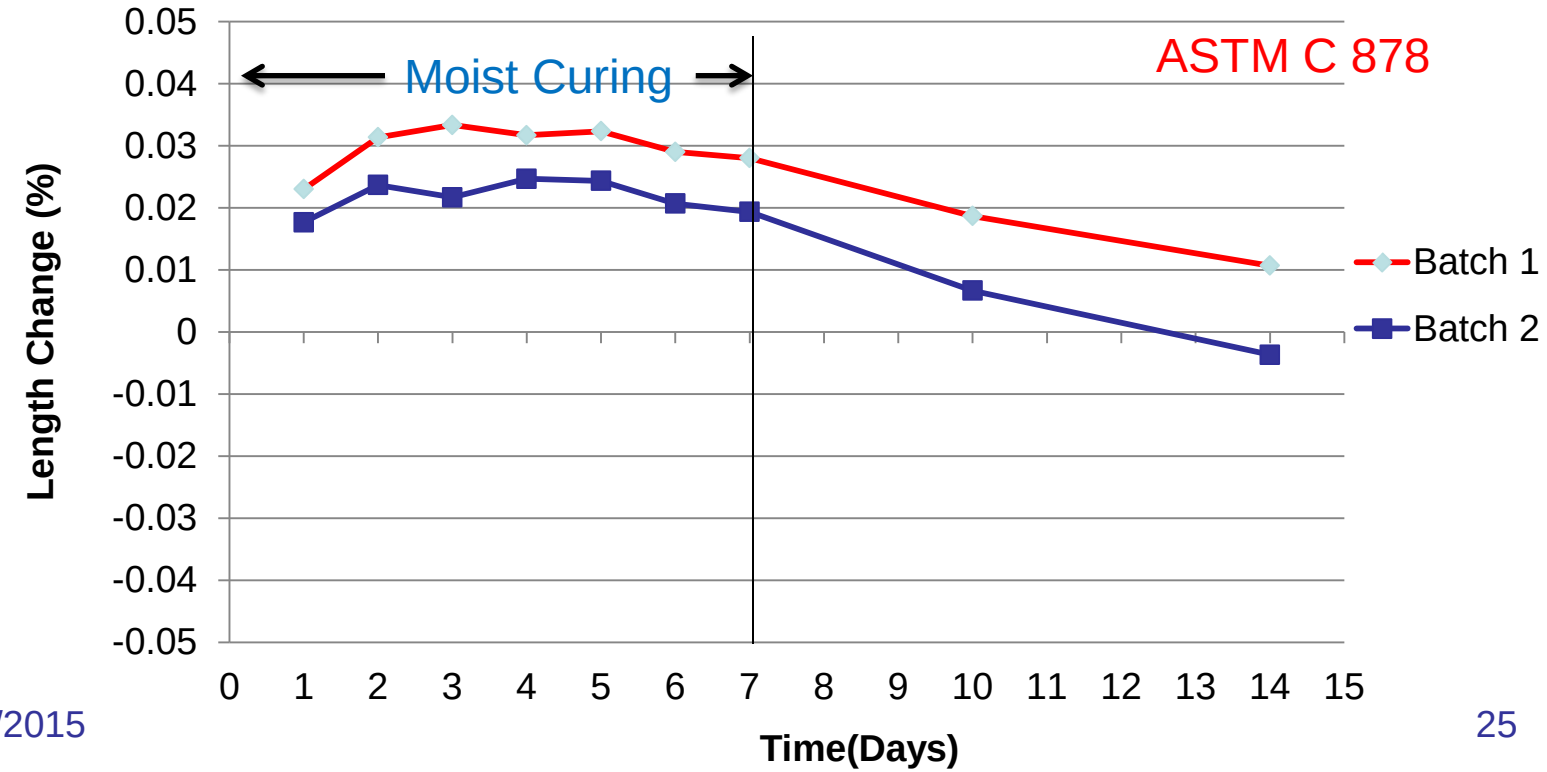
Recommend use of hydration stabilizer.

Mix Design

Type K cement: 572, Fly Ash: 143 lb, w/c =0.48

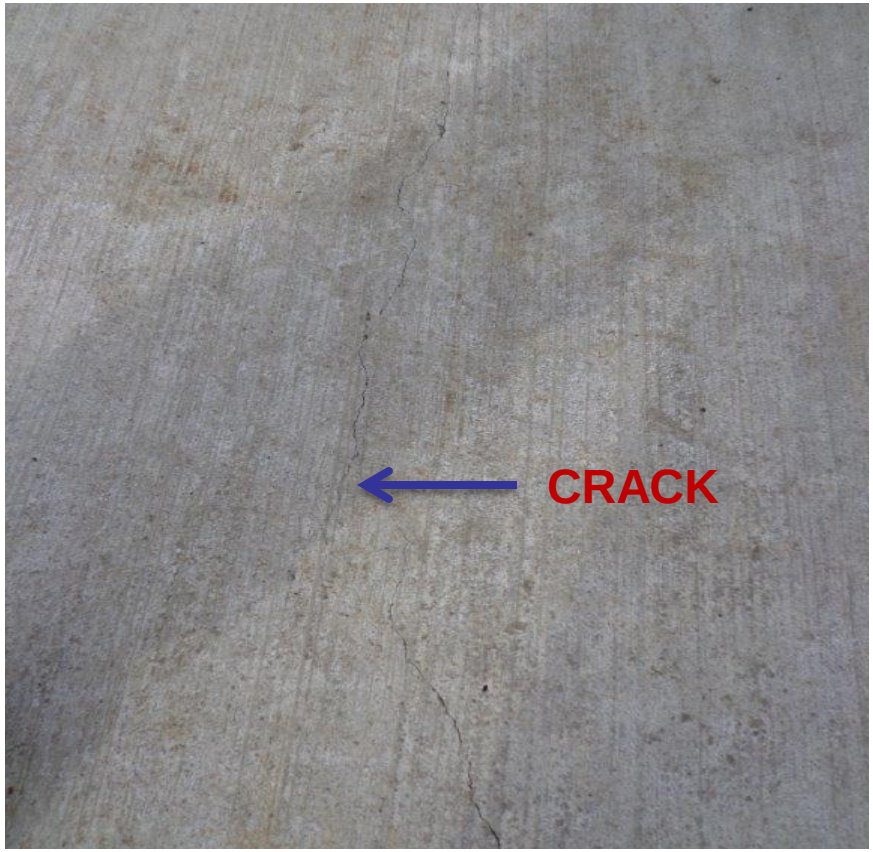
Route 613 Bentonville – Staunton District

Properties	Batch 1	Batch 2
compressive Strength		
28 Days (psi)	**4170**	**4720**
Elastic Modulus		
28 Days (10^6 psi)	**3.32**	**3.74**
Permeability (coulomb)	**1031**	**691**

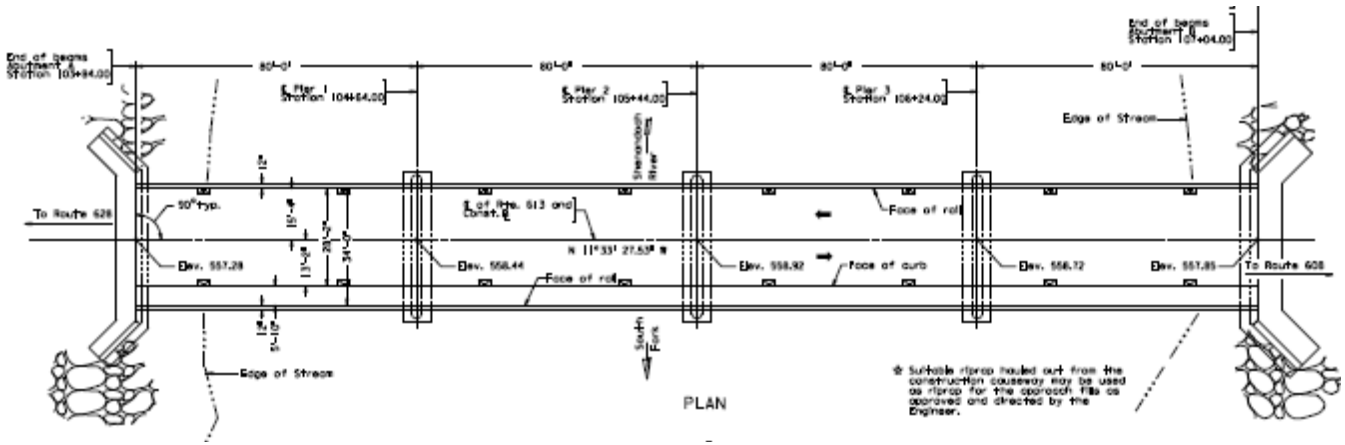


Route 613 Bentonville – Staunton District

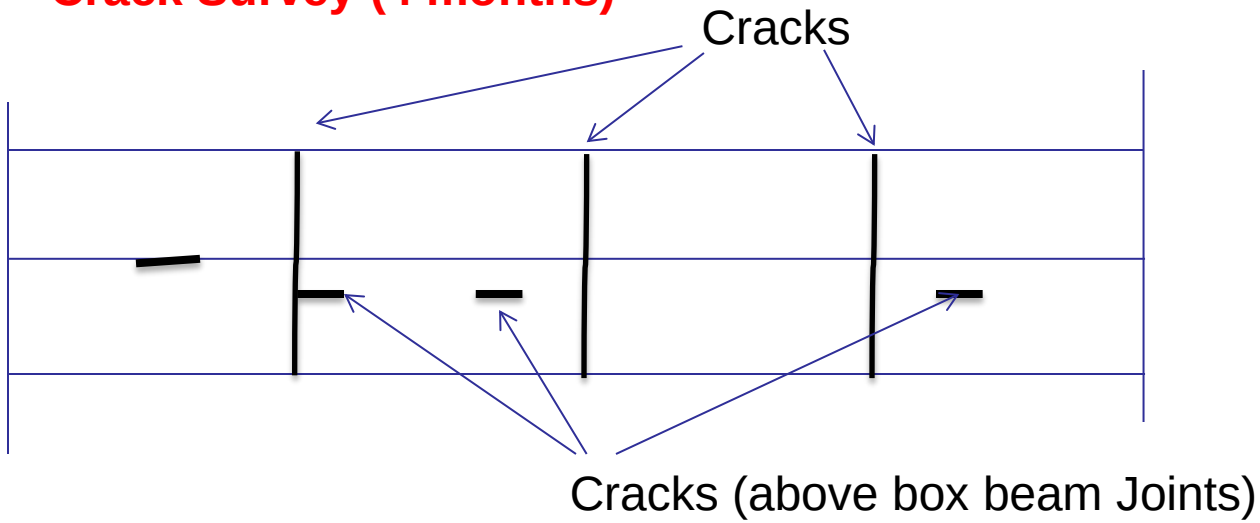
Crack Survey (1 month)



Route 613 Bentonville: Shrinkage compensating concrete

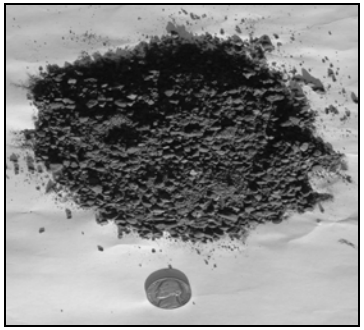


Crack Survey (4 months)



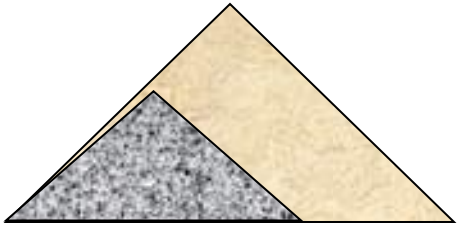
Future Projects

1. All Lightweight Concrete – Fredericksburg District



2. Concrete with Low Paste Content – Lynchburg District

3. Normal weight concrete with Lightweight Fine aggregate



10-25% LWAS **Natural Sand**

Expected Cost Increase

Lightweight Coarse aggregates adds $50 per yd^3

Shrinkage Reducing Admixture adds $50 per yd^3

Type K cement adds $50 per yd^3

Less Cement material: 600 lb/yd^3 adds no cost

$50 per yd^3 adds about $15 per yd^2 to deck concrete that costs about $175 per yd^2 placed.

CONCLUSIONS

Shrinkage cracking can be minimized with the use of one or more of the following options:

-Lightweight (LW) Concrete with LW coarse aggregate
-Normal weight Concrete with Shrinkage Reducing Admixture (SRA)
-Shrinkage Compensating Concrete (Type K)

-Concrete with Low Paste Content
-Normal Weight Concrete (NWC) with LW fine aggregate

However, proper concrete placement, consolidation and curing are important factors in achieving crack free structures.

ACKNOWLEDGEMENT

VCTIR
VDOT Central Office and Districts
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