CRCP FORENSIC INVESTIGATIONS AND REMEDIAL ACTIONS IN VIRGINIA

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And
Concrete Pavement Technology Program (CPTP)
Introduction
VDOT Objective
Background (Materials, Design, Construction)
Distress Identification/Forensic Investigations
Failure mechanism
Remedial Actions
Conclusions
Place High-Performance Concrete (HPC) Pavements that are:
Durable
Safe
Economical
Pavement performance is dependent on:

1. Materials Characteristics
2. Pavement Design
3. Construction Practice
• VDOT specifications require non-polishing aggregates at the surface

• Nominal Maximum Size Aggregate (NMSA) in early years were 50-mm (2-in) AASHTO # 357

• Introduction of the slipform paver in the 1960s, a 25 mm (1 in) NMSA AASHTO # 57 was used.

• The smaller size minimized segregation in aggregate stockpiles. Also less number of stockpiles.
Rich mixes for high early strength.

Rich mixes contribute to high shrinkage.

High Shrinkage leads to more cracks
• Using PCA Design Method resulted in thinner slab.
• CRCP typical thickness of 200 mm (8 in).
• Jointed plain slab typical thickness of 225 mm (9 in).
• Using 1986/93 AASHTO Design provided thicker pavements (now up to 325 mm, 13 inches).
CRCP Built Using Feed-Tube System in the early 1970’s
Pride in Capturing CRCP
Construction Operation

Date Oct. 28, 1971  File No. 71-1550
Location Between Rts. 33 & 665 on I-64
County New Kent  Route I-64
Description Laying of Concrete
Photographer Bill Jones

Please Credit
Virginia Dept. of Highways
CRCP Placement in Madison Heights 2005 (12 inch slab)
Side Delivery of Concrete
Potential cold joint due to uneven Concrete spreading
Distress types were identified

Failure mechanisms were established
Edge Punch-outs
Localized Areas of Broken Concrete
High Steel
Horizontal Delamination
Broken concrete at the header
Map Cracking/ASR
Longitudinal Cracking
Sags/approach slabs at the bridge
Cluster of Closely Spaced Transverse Cracks
Punch-out in the Presence of Closely Spaced Cracks
Y Shape Crack
Y Shape Crack Due to Lack of Consolidation
Evidence of Entrapped Air at Y Crack
Localized Broken CRCP
Localized Areas of Broken Concrete
Pothole as a Result of High Steel
High Steel caused by Feed Tube Installation
Separation Due to Delamination
Slab Acts as Two Thinner Slabs
Broken Concrete Attributable to Delamination and Loading
Header Construction, Use of 50% More Steel
Header failure
Close of Header failure
Evidence of Lack of Consolidation at the Header

1-64 EAST
SOV3 STA 119+60'
PAVEMENT FAILURE
01/14/08
Longitudinal Cracking
Sags or Depressions
Transverse Cracks in Approach Slabs
Faulting at the Bridge Approach
Bias Vs. Radial tires

- Truck tire pressure (70 Vs 120 psi)

Increased axle loads

- Legal single axle load (18,000 Vs 20,000)

Thinner pavement

- Due to lower predicted traffic
- Consolidation
- Thickness Control
- Curing
- Curling
- Location of Steel
- Chemical Distress (ASR)
- Construction methodology
Materials Selection and Testing
Pavement Design
Construction Practices
Industry
Applied Research
Aggregate Maximum Size and Grading
Use of 50 mm NMSA
Pack as much aggregate as possible
Minimizing paste content
Reducing the shrinkage potential
Pozzolans/Mineral Admixtures
Since early 1990s, VDOT has been requiring pozzolans (Class F fly ash) and slag to inhibit ASR if the alkali content of cement is high (currently 0.45% is the limit).
Pozzolans also reduce the permeability of concrete.
Strength Tests (correlation between flexural strength and compressive strength)
During Production accept concrete based on compressive strength.
Shrinkage tests.
Maturity Meter
Smart Rd (NMS 1”)
Newport News (NMS Slag 2”, Fly ash 1”)
Rte. 288 (NMS 2”)
Madison Heights (NMS 1”)
<table>
<thead>
<tr>
<th>Material</th>
<th>Smart Rd</th>
<th>Rte 288</th>
<th>Madison Heights</th>
<th>Newport News</th>
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<tr>
<td>Cement</td>
<td>384</td>
<td>472</td>
<td>423</td>
<td>375</td>
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<tr>
<td>Slag</td>
<td>206</td>
<td>-</td>
<td>-</td>
<td>160</td>
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<tr>
<td>Fly Ash</td>
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<td>-</td>
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<tr>
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<td>236</td>
<td>290</td>
<td>275</td>
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<tr>
<td>Max w/c</td>
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<td>0.49</td>
<td>0.49</td>
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</table>
Strength (AASHTO T22, 28 d)

- Smart Road
- Rte 288
- Madison Heights
- Newport News (F)
- Newport News (S)

**Compressive Str.**

**Flexural Str.**
Shrinkage, Smart Road, 1 in Aggregate (3-inch square prism)
Shrinkage, Rte. 288, 2 in Aggregate (6-inch square prism)
Maturity – Rte 288

- Flexural Str. (psi) vs. Temp-Time Factor (Fxhr)

- Flexural Str. (psi) ranges from 0 to 1500 psi.
- Temp-Time Factor (Fxhr) ranges from 1000 to 1,000,000.

The graph shows a trend indicating an increase in flexural strength with an increase in the temp-time factor.
Use of a wider travel lane of 4.3 m (14 ft) while keeping the delineating white line at 3.6 m (12 ft).

Recently 4.0 m (13 ft) wide travel lane is suggested.
Use of thicker slab to reduce the high shear stress at the level of steel.

In estimating the axle loading, each axle was assumed to be fully loaded, resulting in higher equivalent single axle loading (ESAL).
Increasing the amount of reinforcing steel from 0.65% to 0.70% to improve the crack spacing
Using transverse steel spaced at 1.2 m (4 ft) to support the longitudinal steel and to keep the longitudinal cracks tight in the event of their occurrence.
Change to Single Reinforced Approach Slabs

SECTION F-F
ANCHOR SLAB TYPE II

REINFORCED CONCRETE PAVEMENT (SEE NOTE 9)

1/4" GROOVE, HOT Poured SEAL

1" GROOVE, HOT Poured SEAL

HEAVILY GREASED SURFACE

1/2" DIA. X 8" STUDS AT 18" O.C. (SEE NOTE 12)

BRIDGE APPROACH SLAB OR ABUTMENT

LOAD TRANSFER DOWELS
EXPANSION JOINTS

TROWEL FINISH AND BOND BREAKER
1" EXPANSION JOINT MATERIAL

PAY LINES ANCHOR SLAB (INCLUDES SUB SLAB AND PAVEMENT SLAB)

*4 BARS AT 12" O.C.

W16X57

*5 BARS AT 8" O.C.

*5 BARS AT 6" O.C. - 3'-9" TOTAL LENGTH
Modified the requirements for constructing the backfill behind the backwall of bridges.

- Depth of select material, behind back wall, top 6 ft
- Type I Select Material CBR 30
- Minimum compacted dry density
  - 100% top 3’
  - 98% 3’-6’
  - 95% below 6’
Use of an asphalt layer 75 mm (3 in) thick that provides stability and drainability under the slab.

Drainable bases may reduce the amount of available moisture from the bottom, leading to less favorable condition for ASR formation.
### Sieve Analysis for Asphalt OGDL

<table>
<thead>
<tr>
<th>Sieve Size, mm</th>
<th>Percent Passing</th>
<th></th>
<th></th>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>Average</td>
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<tr>
<td>25.4</td>
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<td>1.75</td>
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</table>

A.C. Content: 4.3 ± 0.3%
Asphalt Treated OGDL Gradation

- Percent Passing
- Particle Diameter (mm)

Legend:
- Min
- Max
- Average
Asphalt Treated OGDL
<table>
<thead>
<tr>
<th>Sieve, mm</th>
<th>Percent Passing</th>
<th></th>
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<td>max</td>
<td>Average</td>
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<td></td>
</tr>
<tr>
<td>12.7</td>
<td>90</td>
<td>100</td>
<td>95</td>
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<tr>
<td>9.5</td>
<td>40</td>
<td>75</td>
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<tr>
<td>4.76</td>
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<td>25</td>
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<tr>
<td>1.18</td>
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<td>5</td>
<td>2.5</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
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<tr>
<td>D60</td>
<td>10.05</td>
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<tr>
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<tr>
<td>Cc</td>
<td>1.22</td>
<td>0.79</td>
<td>1.94</td>
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</table>

Cement Content: 225 lbs/yd^3
Cement Treated OGDL Gradation (AASHTO # 78)

- Percent Passing
- Particle Diameter (mm)

Graph shows the gradation analysis of Cement Treated OGDL with lines indicating Min, Max, and Average values.
Water Hose Permeability Test
Modifying Edgedrain standards & performing video inspection to ensure effective drainage during pavement service life.
Edgedrain Inspection Using Push Camera
Working Outlet
Large aggregate:
VDOT present projects have shown that slipform pavers can satisfactorily place concrete with large aggregate (50 mm) 2 inches top size.
Concrete Consolidation:
In VDOT present projects, the frequency of the vibrators will be continuously monitored. Cores taken from the pavement will be tested for air void system to determine the adequacy of consolidation.
Curing:
Timing is very important for curing compound

Proper curing ensures that the desired properties are achieved and that the volumetric changes that result in cracking are minimized.
Placement of steel:
Place longitudinal reinforcing steel on chairs rather than using the feed-tube system.
Chairs allow for the slab to be poured monolithically, which reduces the probability for cold joint at the reinforcing steel.
Concrete Delivery:
Concrete delivered must be workable with an adequate time of setting. Early stiffening of the concrete can lead to difficulties in placement and finishing (Gress, 1997)
The paving process must provide uniform quality of concrete, delivery and placement, and head of material in the paver to ensure uniform forces in front of and under the paver.
Testing Steel Mat Rigidity
Jointing and Finishing:
Initial saw cutting of the longitudinal joints needs to be done as soon as possible.
Tape (Ribbon) in the longitudinal joint is still allowed, but not for slabs greater than 225 mm (9 in).
Smoothness:
Requiring a smoother ride, with incentive and disincentive as part of the contract. VDOT uses a laser profiler.
1. Learn from past performances.
2. Forensic investigations are the best tools to establish pavement failure mechanism.
3. Remedial action/s need to address the components of the failure mechanism.
4. Preconstruction Conferences are important where the designer’s vision meets constructability.
Conclusions

5. Testing strip is well worth it.
6. Adopt and implement changes.
7. Monitor and provide feedback.
8. Establish Cooperation and Move forward.
THANK YOU
Questions?