CRCP FORENSIC INVESTIGATIONS AND REMEDIAL ACTIONS IN VIRGINIA

Mohamed Elfino, Ph D, PE
Celik Ozyildirim, Ph D, PE

2008 SE States Pavement Management and Design Conference
Little Rock, Arkansas
June 3, 2008

Presentation Sponsored

By

Virginia Department of Transportation

And

Concrete Pavement Technology Program (CPTP)

Outline

Introduction

VDOT Objective

Background (Materials, Design, Construction)

Distress Identification/Forensic Investigations

Failure mechanism

Remedial Actions

Conclusions

Concrete Pavement in Virginia Since 1913

VDOT Objective

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 stock piles.

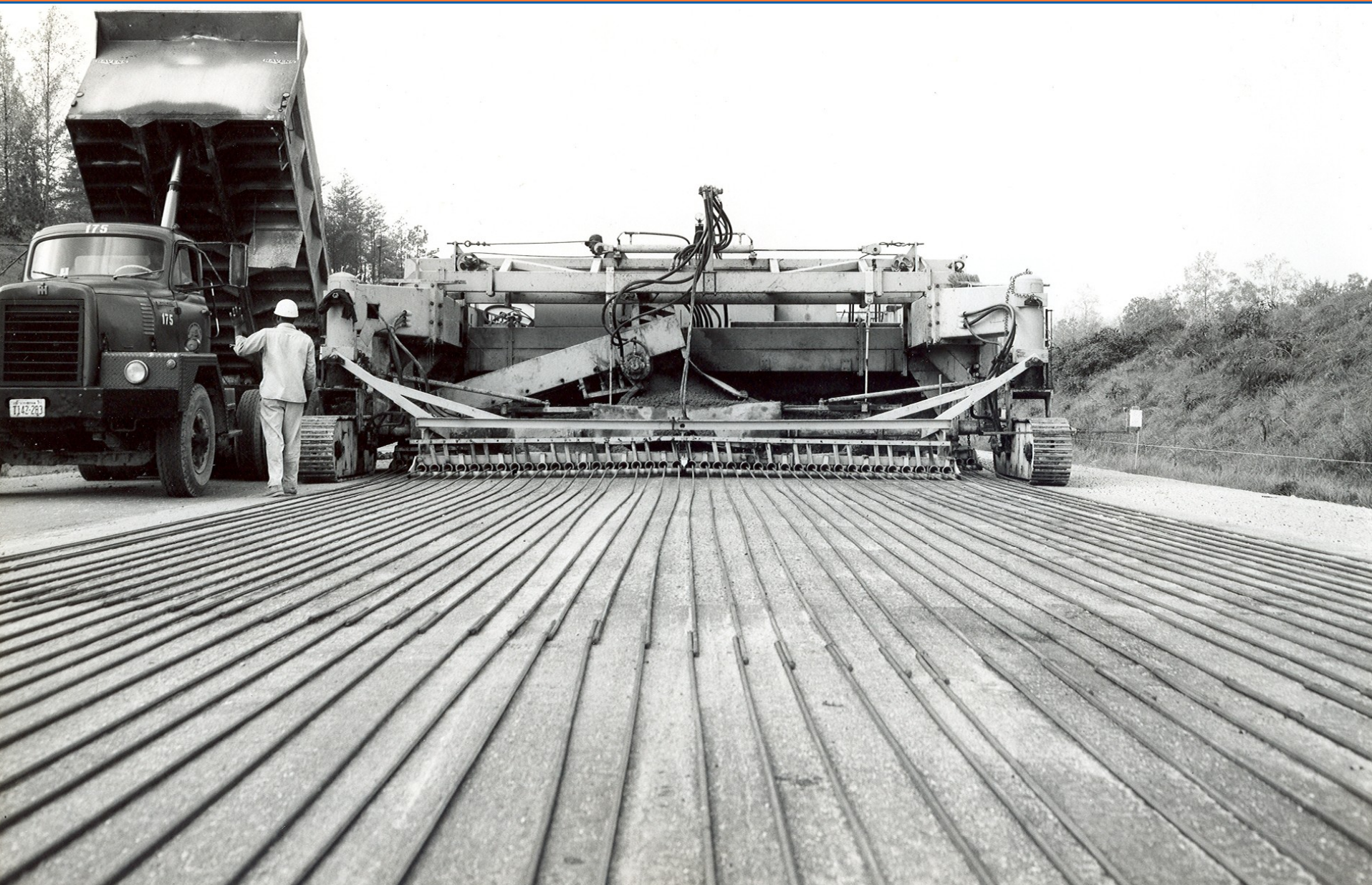
Rich mixes for high early strength.

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



Construction Practices on I-64

Construction Practices

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

DISTRESS IDENTIFICATION

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

Edge Punch-out

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

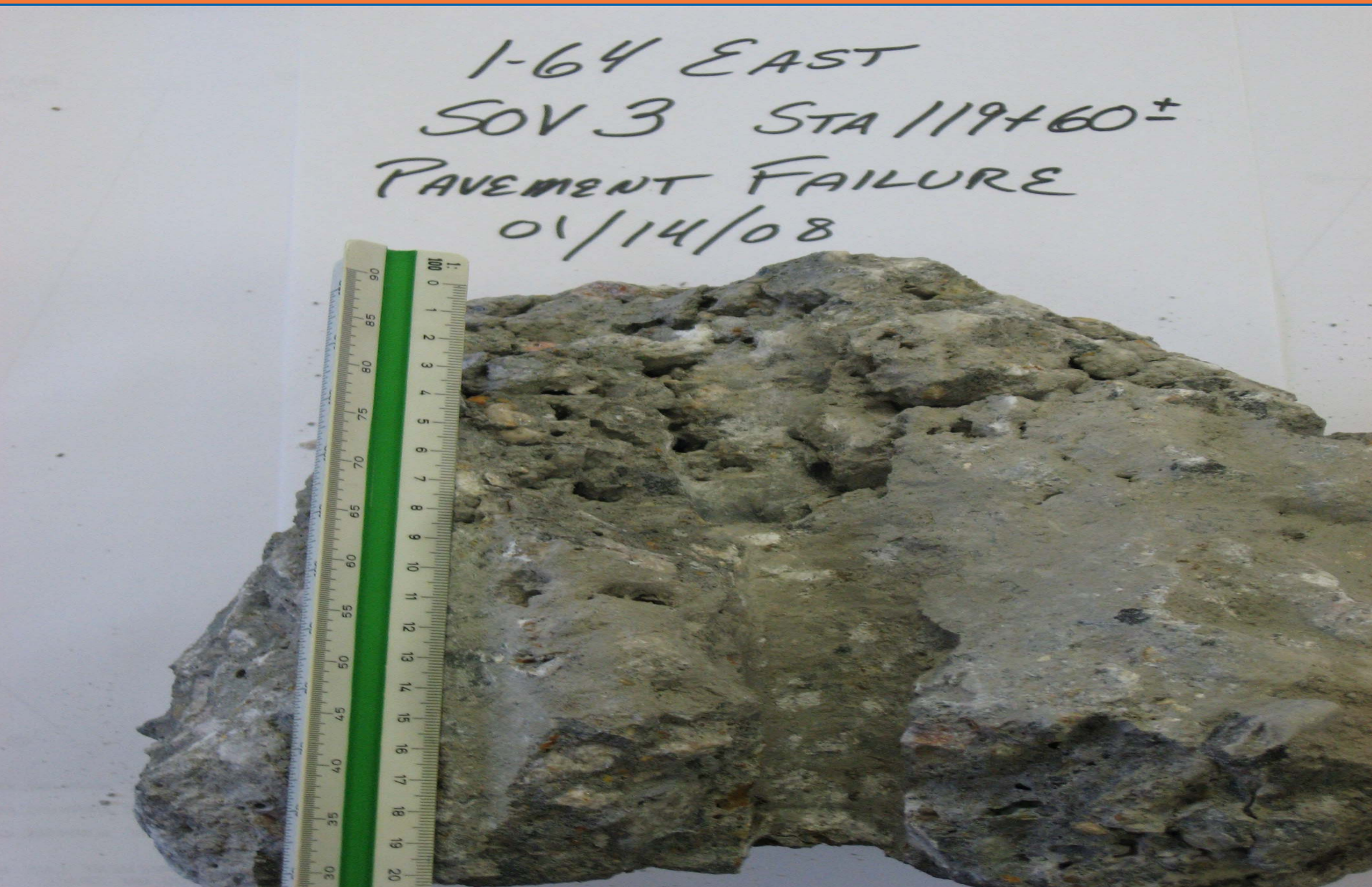
Header failure

Header failure Close up

Close of Header failure

Header Failure with Abrupt width Reduction

Evidence of Lack of Consolidation at the Header



I-64 East Bound CHARLOTTESVILLE METABASALT COARSE AGGREGATE

I-295 METARHYOLITE

ASR Formation in Concrete Pavement

Longitudinal Cracking

Sags or Depressions

Transverse Cracks in Approach Slabs

Close up of Crack at Approach Slab

Faulting at the Bridge Approach


'00 9 25


'00 10 13

Factors Affecting Pavement Distress

- 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

Factors Affecting Pavement Distress

- Consolidation
- Thickness Control
- Curing
- Curling
- Location of Steel
- Chemical Distress (ASR)
- Construction methodology

VIRGINIA'S PLAN OF ACTION

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”)

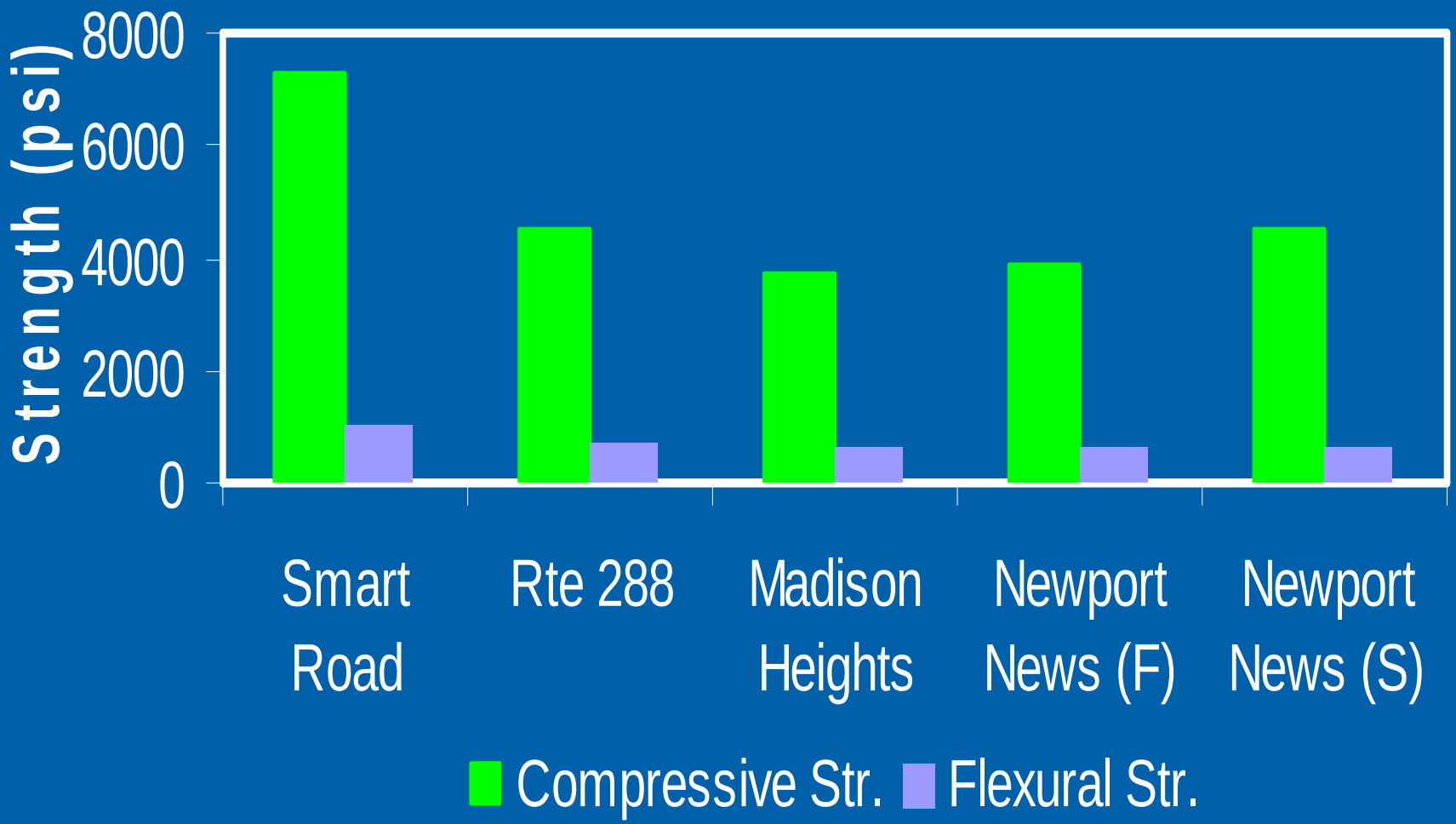
Rte. 288 (NMS 2”)

Madison Heights (NMS 1”)

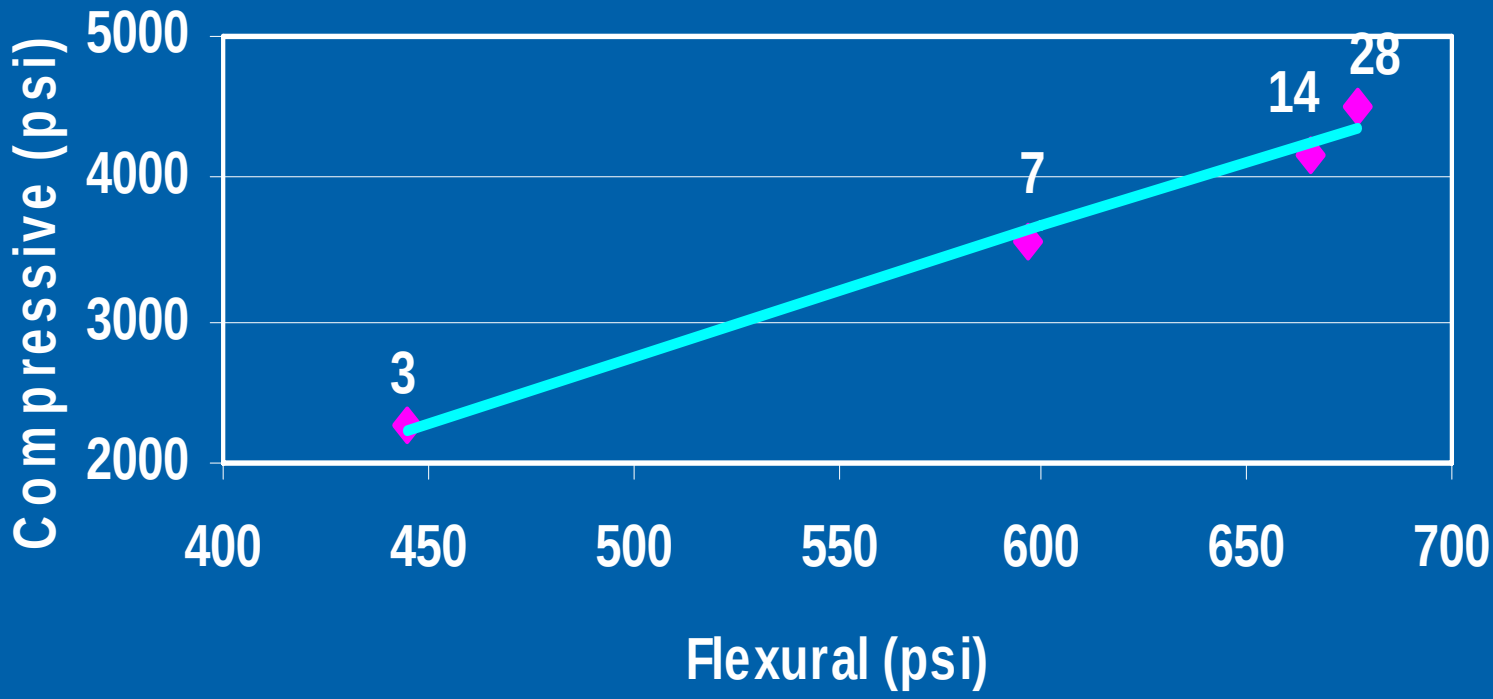
Pavement Mixture Proportions, lb/ft³

Material	Smart Rd	Rte 288	Madison Heights	Newport News	
Cement	384	472	423	375	423
Slag	206	-	-	160	-
Fly Ash	-	118	141	-	141
Water	236	290	275	242	250
Max w/c	0.40	0.49	0.49	0.45	0.44

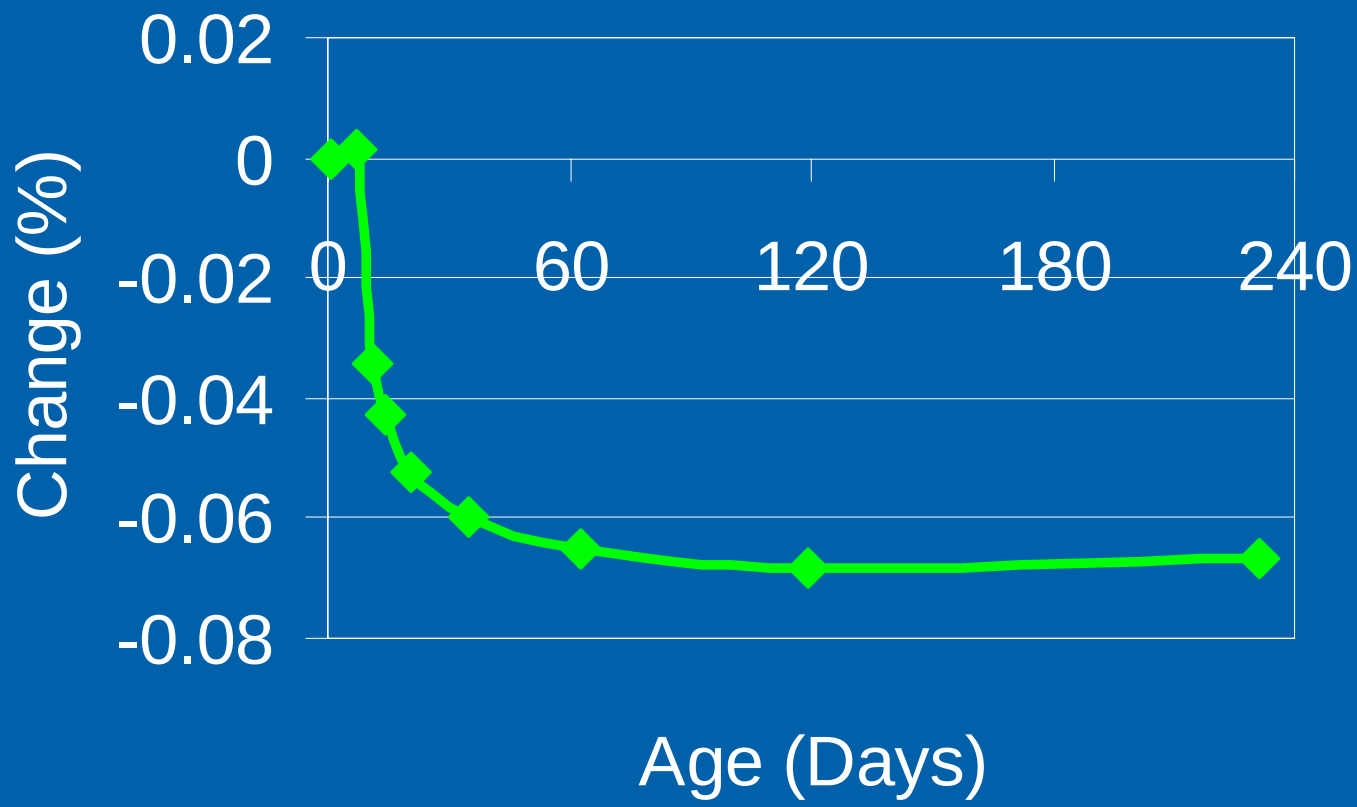
Strength (AASHTO T22, 28 d)



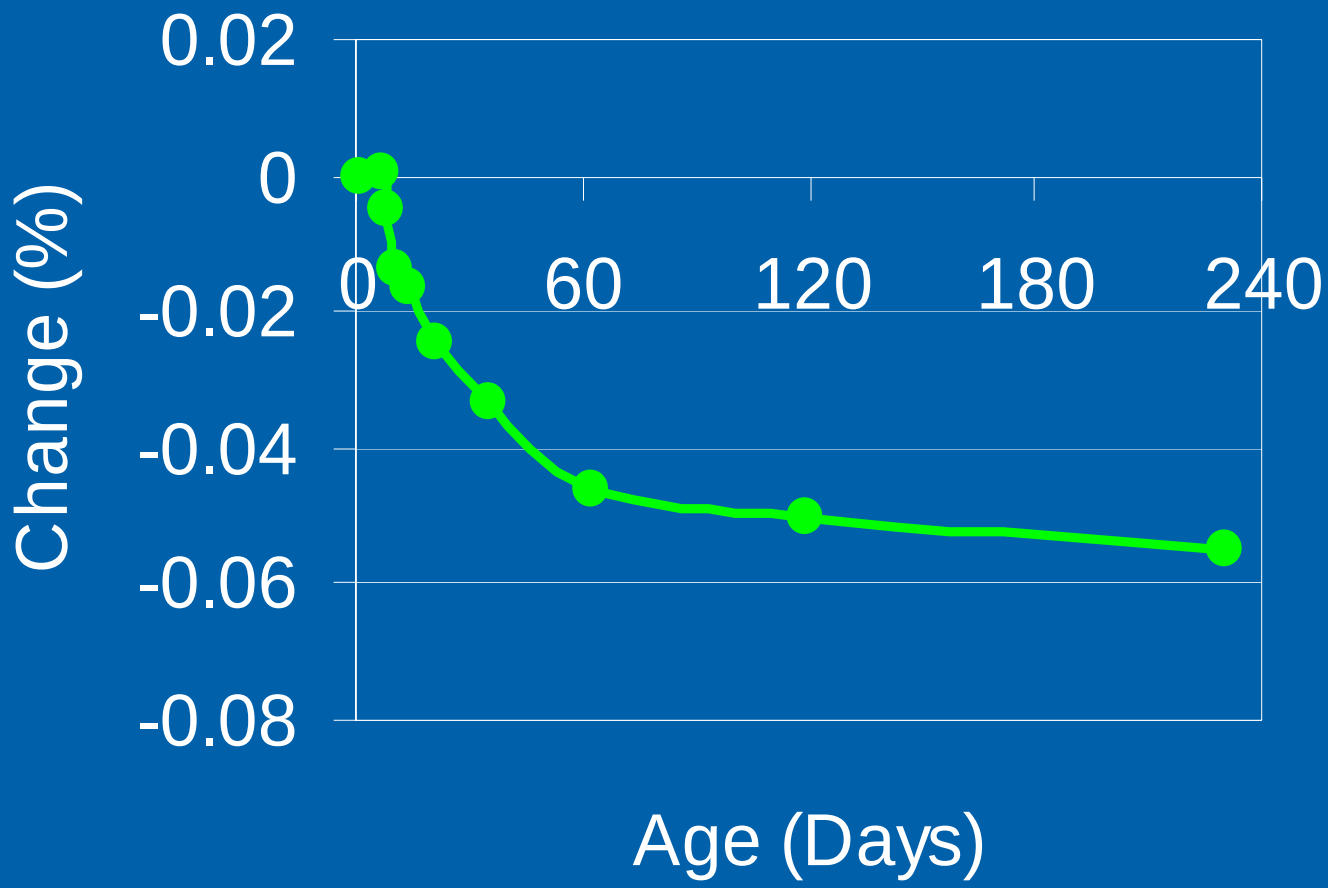
Compressive vs. Flexural Strength Rte 288



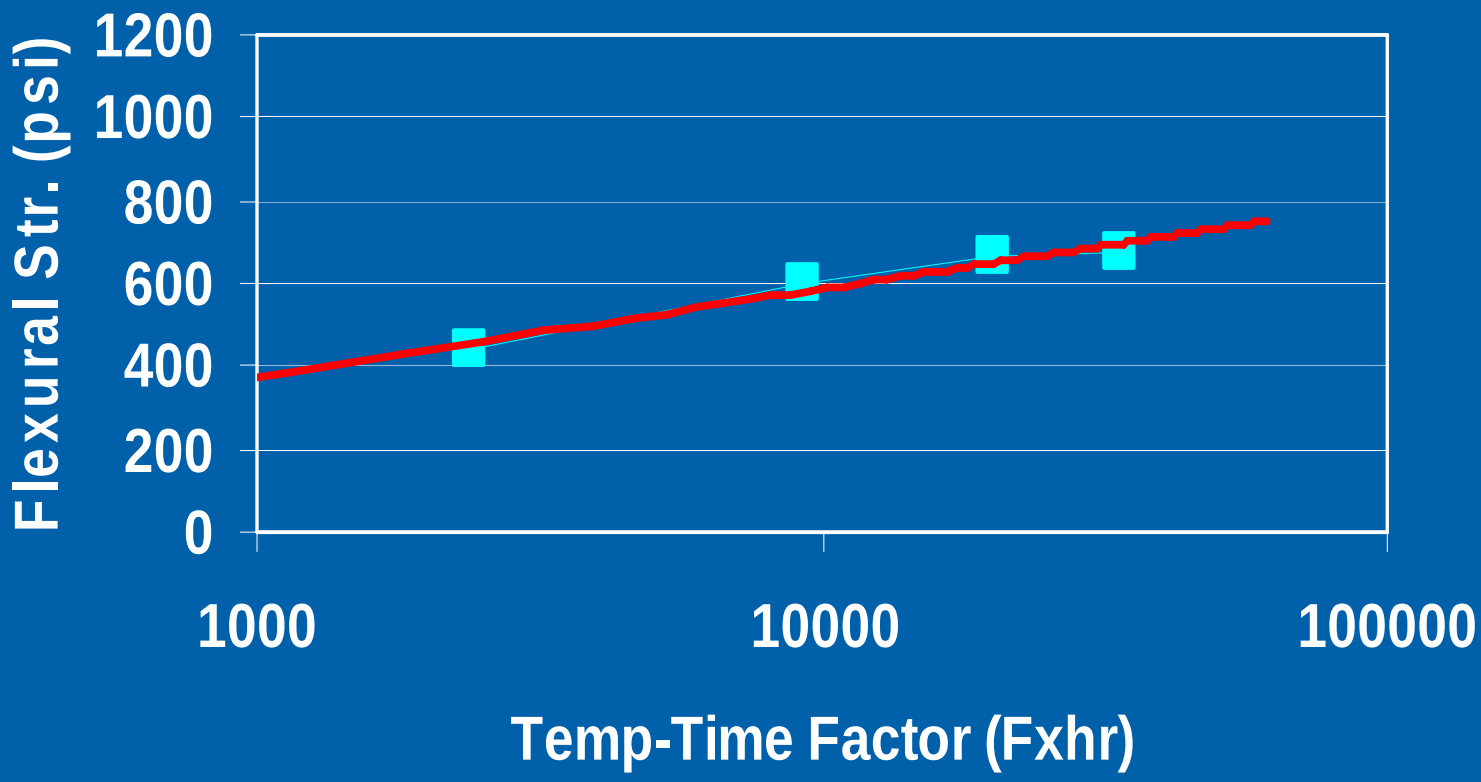
Shrinkage, Smart Road, 1 in Aggregate (3-inch square prism)



Shrinkage, Rte. 288, 2 in Aggregate (6-inch square prism)



Maturity – Rte 288



Pavement Design Changes

- 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

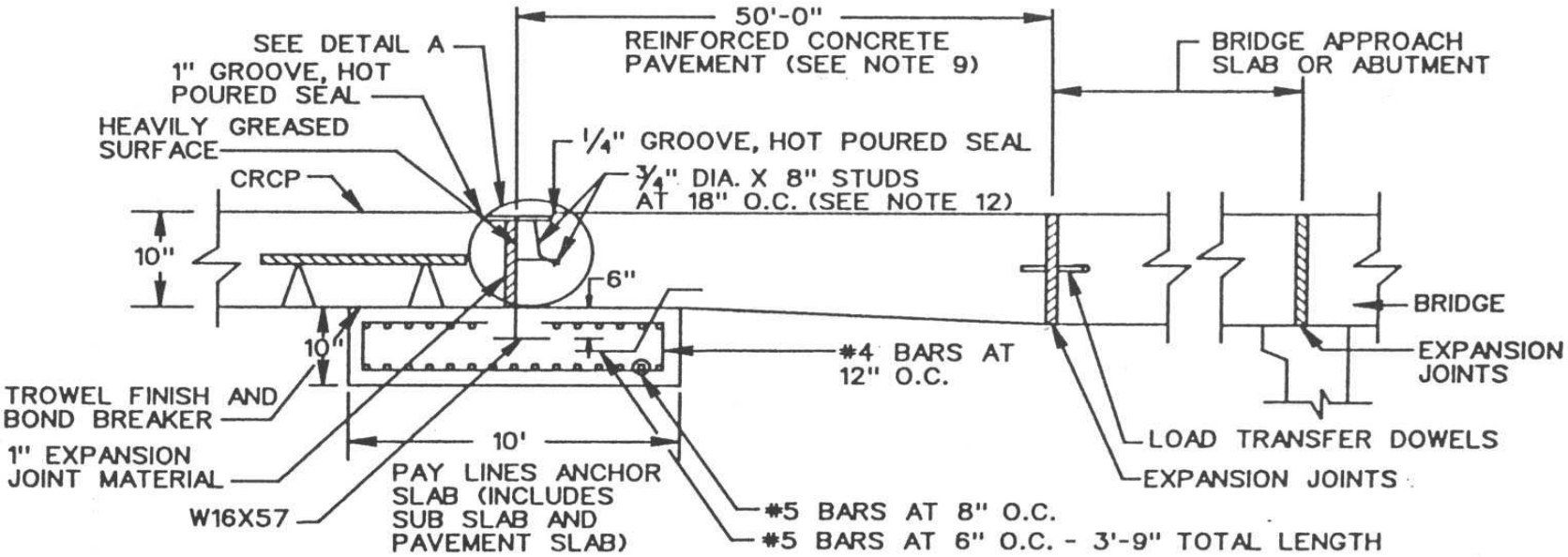
- Use of thicker slab to reduce the high shear stress at the level of steel
- In estimating the axle loading, each axle was assumed to be fully loaded, resulting in higher equivalent single axle loading (ESAL).

Pavement Design Changes
Percent of reinforcing steel

- 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

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.

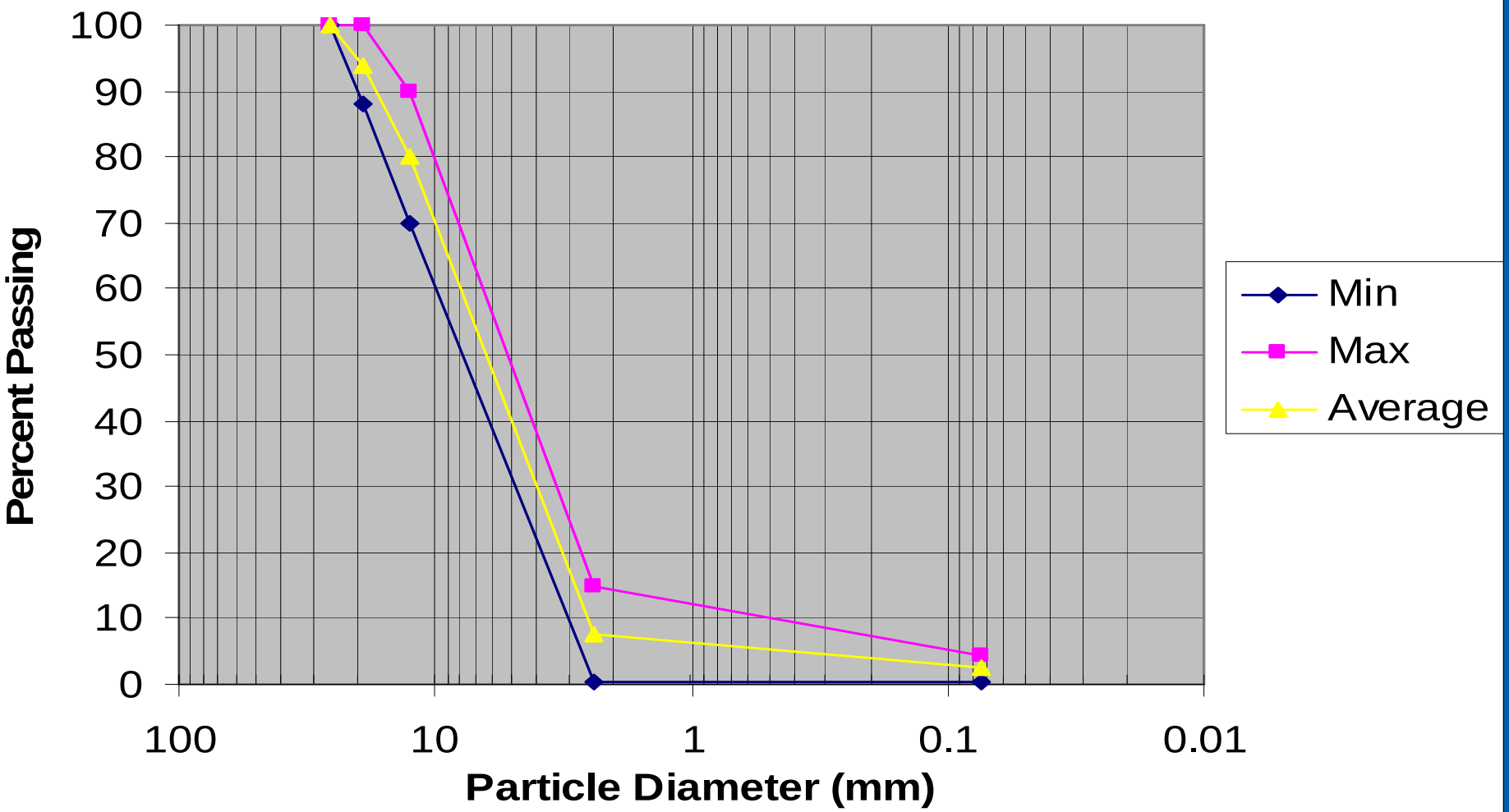
Drainable bases may reduce the amount of available moisture from the bottom, leading to less favorable condition for ASR formation.

Sieve Analysis for Asphalt OGDL

Sieve Size, mm	Percent Passing		
	min	max	Average
25.4	100	100	100
19	88	100	94
12.5	70	90	80
2.36	0.5	15	7.75
0.074	0.5	4.5	2.5
A.C. Content: 4.3 ± 0.3%			

	Min	Max	Average
D60	10	6.3	8
D10	3	0.4	2.4
D30	4	2.1	3
Cu	3.33	15.75	3.33
Cc	0.53	1.75	0.47

Asphalt Treated OGDL Gradation

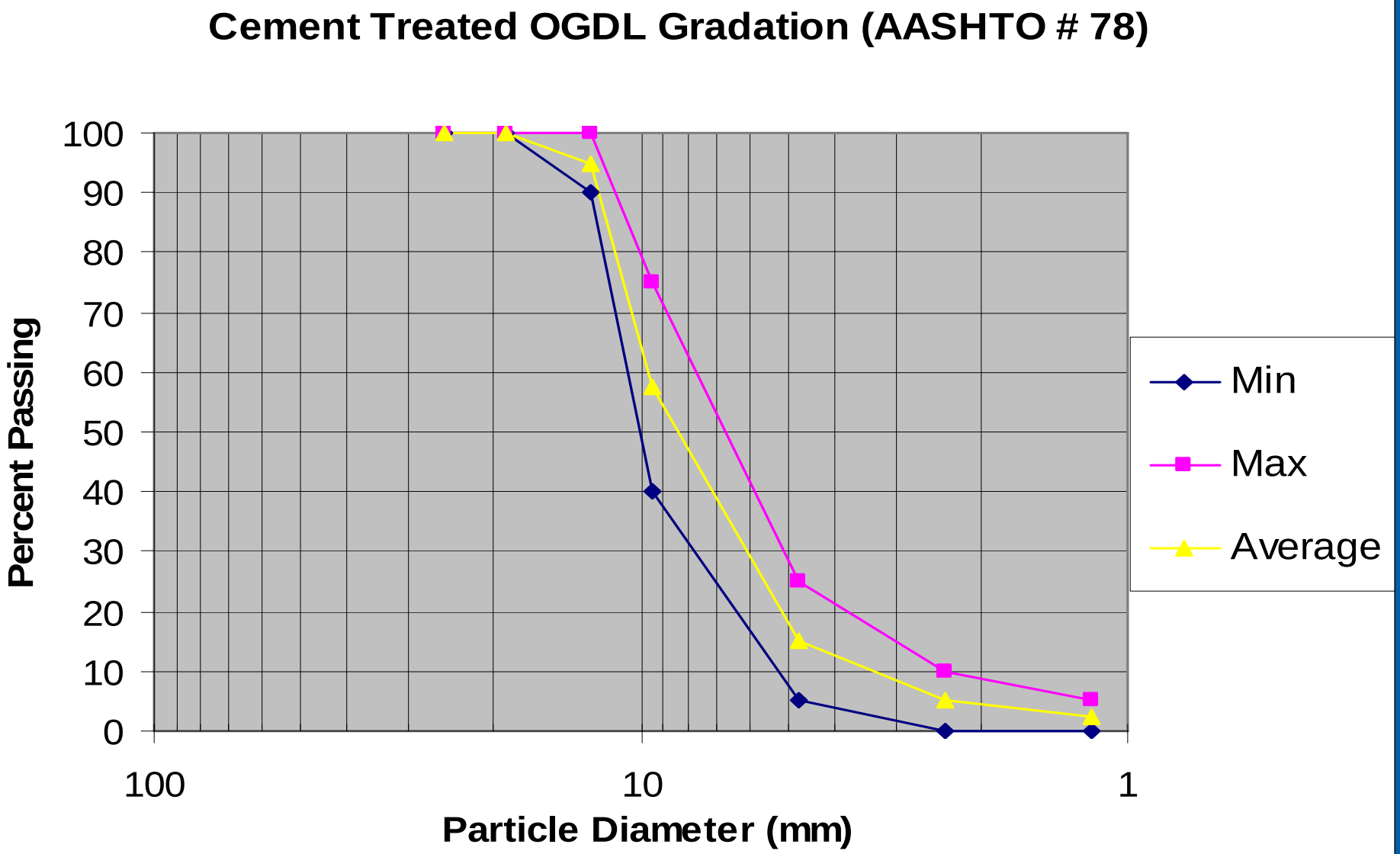


Asphalt Treated OGDL

Sieve, mm	Percent Passing		
	min	max	Average
19	100	100	100
12.7	90	100	95
9.5	40	75	57.5
4.76	5	25	15
2.36	0	10	5
1.18	0	5	2.5
Cement Content: 225 lbs/yd^3			

	Min	Max	Average
D60	10.05	9.9	7.8
D30	7.9	5	6
Cu	1.97	3.09	3.28
Cc	1.22	0.79	1.94

Cement Treated OGDL



Cement stabilized OGDL

Bottom of Cement Treated OGDL

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

CRCP 300 ft Testing Strip

CRCP 300 ft Testing Strip

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.

Conclusions

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.

VDOT

102 Years of Excellence 1906-2008

VTRC
Virginia Transportation Research Council

THANK YOU

Questions?