High Friction Surface Treatments at High-Crash Horizontal Curves

Arizona Pavements/Materials Conference

Phoenix, AZ

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Office of Infrastructure

U.S. Department of Transportation

Federal Highway Administration

About Every Day Counts

- Launched in 2010
- Encourages the rapid deployment of existing, proven technologies to:
  - Shorten project delivery
  - Enhance highway safety
  - Protect the environment
- Initiatives range from modern project delivery techniques such as cloud-based data sharing to GPS guided paving machinery

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A Continuous Cycle of Innovation

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Completed Summit Schedule

Fall 2012 Summits

Accelerating Project Delivery

- Programmatic Agreements
- Locally Administered Projects

Reducing Construction Time

- 3D Engineered Models for Construction
- Accelerated Bridge Construction
- Intelligent Compaction

Innovative Contracting

- Design Build
- CMGC
- Alternative Technical Concepts

Spring 2013 Virtual Summits

Accelerating Project Delivery

- Geospatial Data Collaboration

Improving Performance

- **High Friction Surface Treatments**
- Intersection and Interchange Geometrics
- Implementing Quality Environmental Documentation
- National Traffic Incident Management Responder Training (SHRP 2)

High Friction Surface Treatments (HFST)

- **Key message:** ***HFST reduce crashes, injuries, and fatalities.***
- Benefits include:
  - customizable to specific state and local safety needs
  - high return on investment
  - minimal impact to traffic during construction
  - negligible environmental impact

Overview

- What are High Friction Surface Treatments?
- Why HFST for Horizontal Curves?
- SEAHC Demonstration Projects.

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What is a High Friction Surface Treatment?

- High Friction Surface Treatments (HFST) are pavement surfacing systems with exceptional skid-resistant properties that are not typically acquired by conventional materials
- Generally proprietary resin-based products and processes
- Guidelines from the British Board of Agrément (BBA)*"…defined as having a minimum skid resistance value (SRV) of 65 measured using the portable Skid-Resistance Tester as defined in TRL Report 176: Appendix E."*

HFST Materials

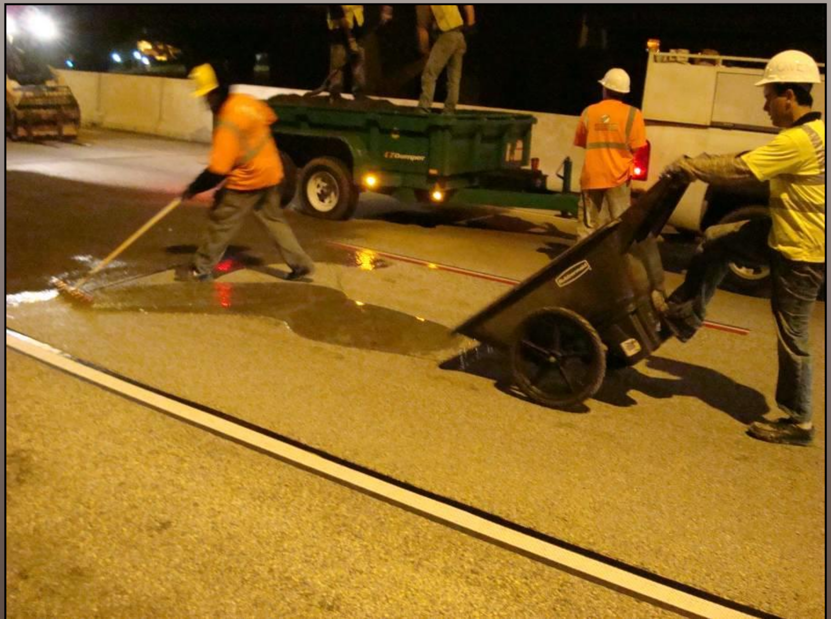
- Aggregates
  - Generally calcined bauxite or flint, but slags, granite, and other materials with high PSV have also been used
  - Generally 3-4 mm maximum size

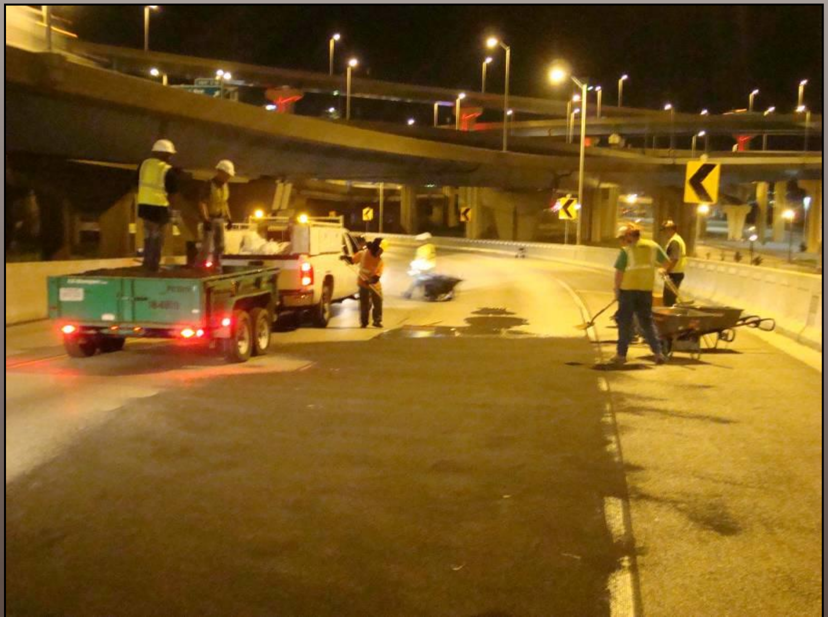
HFST Materials

- Binder system (proprietary blends)
  - Bitumen-extended epoxy resins
  - Epoxy-resin
  - Polyester-resin
  - Polyurethane-resin
  - Acrylic-resin

HFST Installation

- Manually
  - Manual mixing of epoxy material
  - Manual application of epoxy with squeegee
  - Hand broadcast and distribution of aggregate
  - Production rates: 165-420+ m^2/hr (200-500+ SY/hr.)

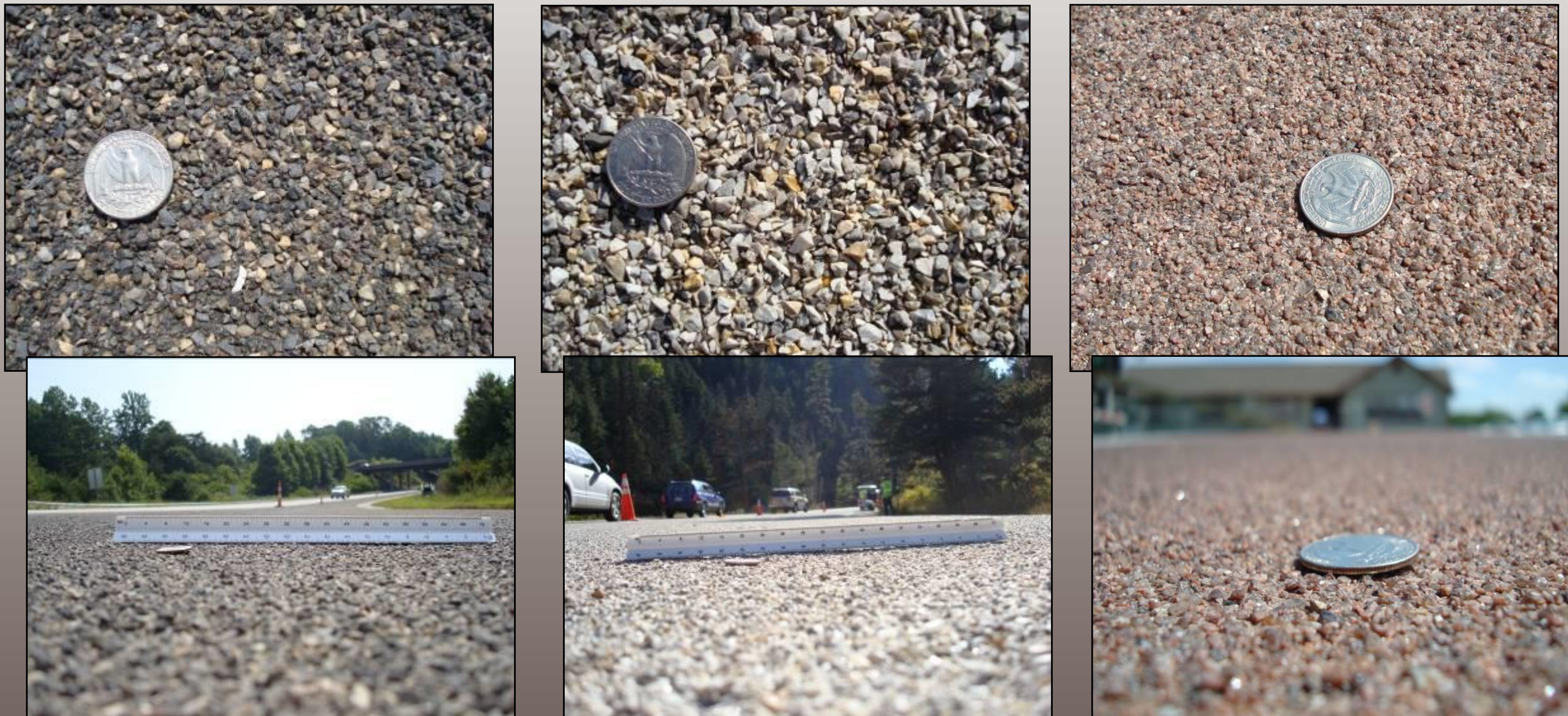




HFST Installation

- Automated (machine-aided)
  - Machine mixing and application of epoxy (limited hand/squeegee work)
  - Machine broadcast/application of aggregate
  - Production rates up to 1920 m^2/hr (2,300 SY/hr.)

HFST Finished Product



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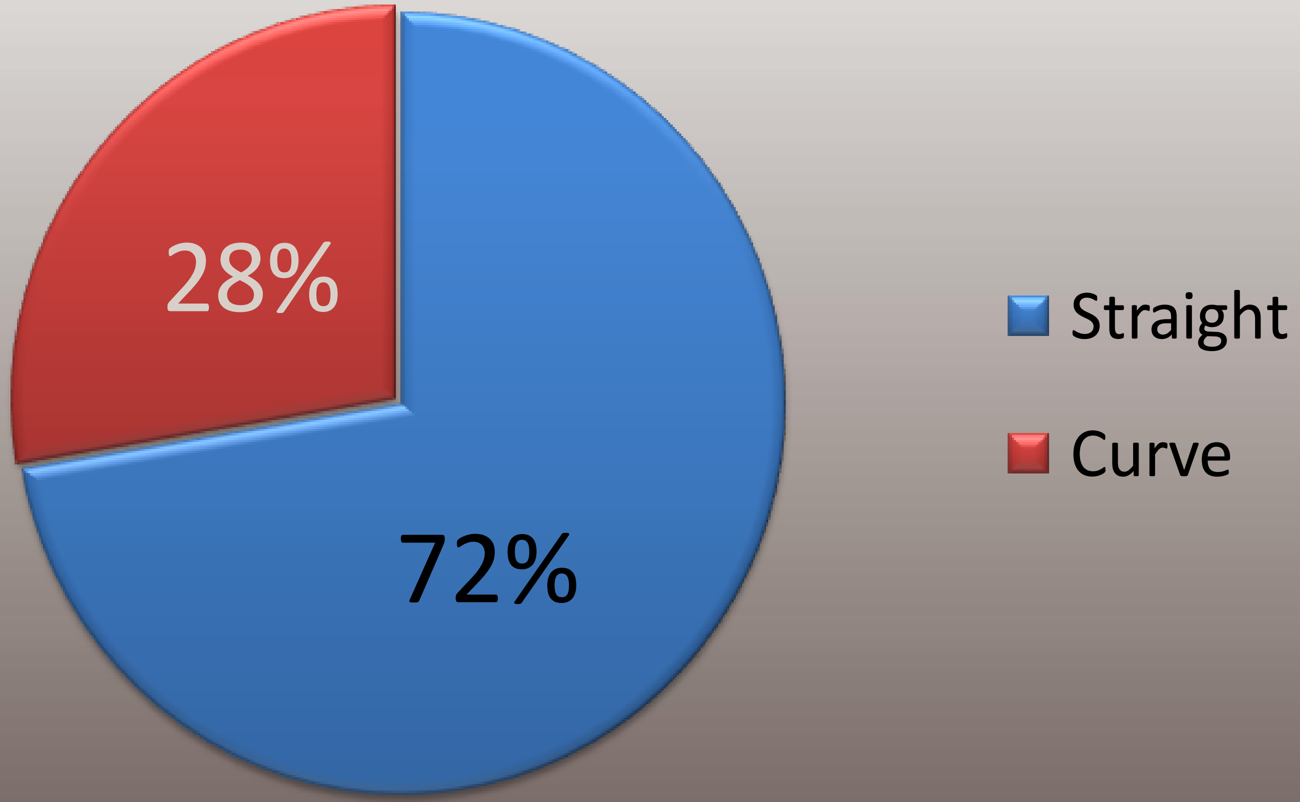
- Why HFST for Horizontal Curves?
- SEAHC Demonstration Projects.

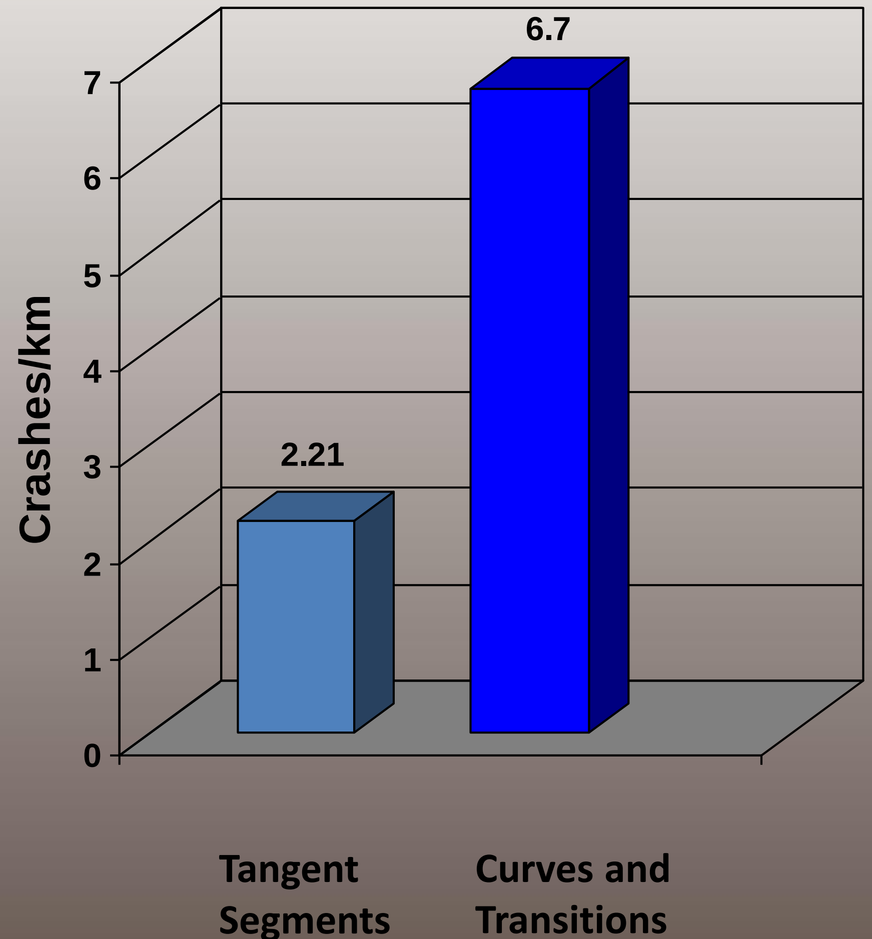
Why HFST for Horizontal Curves

- Horizontal Curve Crash Picture
- Strategies for reducing crashes
- Pavement Friction Demand and location selections for HFST

Fatal Horizontal Curve Crashes



Horizontal Curves and Safety



Average crash rates for horizontal curves is about 3 times that of tangent segments

Source: Glennon, et al, 1985 study for FHWA

Roadway Departure Risk Strategy

- *Keep Vehicles on Roadway*
- *Reduce Likelihood of Crashes*
- *Minimize Severity*

Where Can HFST Benefit Safety?

1. Horizontal curves
2. Approach to intersections

When the pavement has:

- Low friction
- Marginal friction effected by weather
- Friction values not compatible with approach speeds and geometrics (friction demand)

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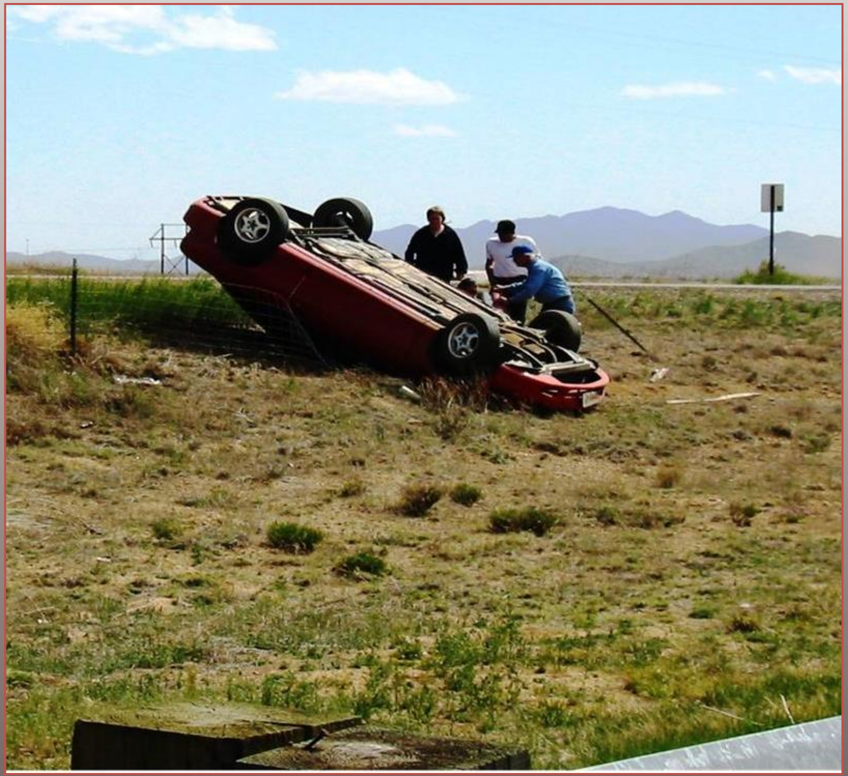
Skid related crashes are determined by many factors:

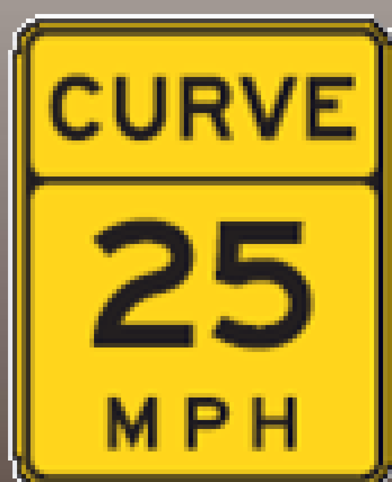
- Friction Demand
  - Road Geometry
  - Vehicle Speeds
- Weather Conditions
- Traffic Characteristics
- Driver Actions



Source NCHRP 108

Basis for AASHTO Curve Design Model Is Driver Comfort

Although the curve design policy stems from the laws of mechanics, the values used in design depend on practical limits and factors determined empirically over the range of variables involved.



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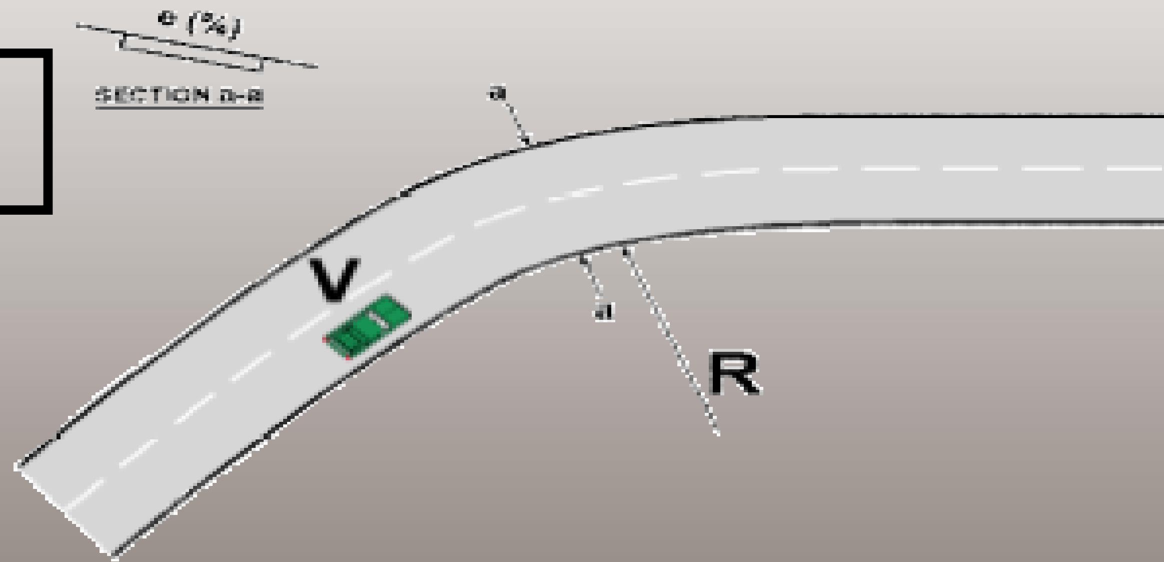
AASHTO Horizontal Curve Design Model

$$\boxed{e+f = V^2/15\,R}$$



e = superelevation

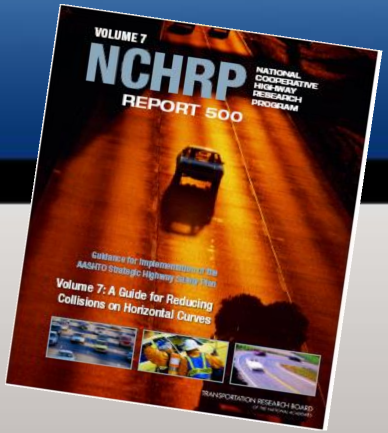
f = side friction factor

V = design speed (mph)

R = radius of curve (ft)

US Customary	Metric
$R = \frac{V^2}{15\,(e+f)}$	$R = \frac{V^2}{127\,(e+f)}$
where R = Radius of circular curve (ft) V = Design speed (mph) e = Superelevation f = Side "friction" or comfort	where R = Radius of circular curve (m) V = Design speed (km/h) e = Superelevation f = Side "friction" or comfort

Improving Friction to Keep Vehicles on the Roadway



AASHTO Design assumes vehicles:

- Do not exceed the design speed
- Traverse the curve following a constant radius.

Likelihood of skidding increases when these assumptions are violated.

Several studies have shown that under real world conditions both of these assumption are violated.

NCHRP 500 Volume 7

What about Friction Demand?

When the:

- superelevation,
- radius
- approach speed is known

Solve for friction demand:

$$F_s = \frac{V^2}{15R} - e$$

Truck Operations on Curves

- Skidding trucks may lead to overturn
- Friction demand varies per tire
- Trucks on downgrade curves generate greater lateral friction demand
- Margin of safety for ‘f’ is lower for trucks
- Trucks with high centers of gravity may overturn before losing control due to skidding

Source NCHRP 505

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- SEAHC Demonstration Projects.

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- Overview of SEAHC Program
- Results from SEAHC Study
- NCAT Aggregate Durability Study
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FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program

- Goals of SEAHC:
  - Demonstrate the effectiveness of High Friction Surface Treatments (HFST) in enhancing/restoring friction to reduce lane departure crashes at horizontal curves (and ramps).
  - Measure the properties of HFST and monitor changes and performance over first year
  - Monitor crashes before and after HFST application
- Utilize currently available HFST products
- 3+ year study for each site
- Generally 1-5 sites per State

FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program

- 24 Installations in 10 States
  - Installation, Testing, Monitoring: 19
  - Testing Only: 5
- 5 Different HFST vendors
- 5 Pavement types
  - PCCP
  - Conventional dense-graded HMA / SMA
  - Chip Seal
  - Open Grade Friction Course

FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program

FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program

- Data Collection
  - Crash Data:
    - Historical: min. 3 years prior to installation
    - Post-Installation: 3 years following installation
  - Friction
  - Texture
  - Tire-Pavement Noise (*OBSI, select sites only*)

Friction

Dynamic Friction Tester (DFT)

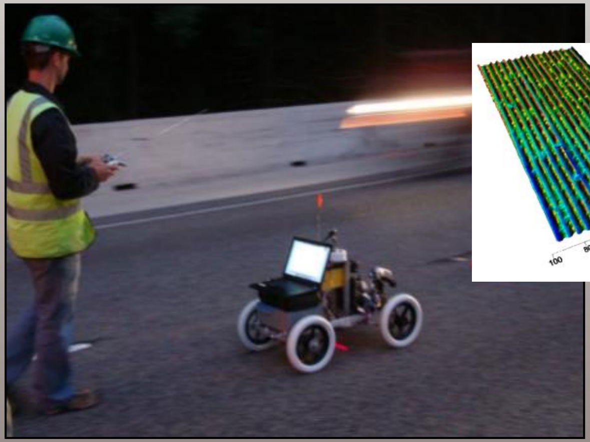
GripTester

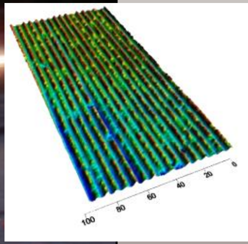
Highway Friction Tester

DOT-provided Locked Wheel Skid Trailer (ribbed and/or smooth tire)

Texture

Circular Track Meter (CTM) – MPD





RoboTex – MPD

ASTM E965 (“Sand Patch”) – MTD

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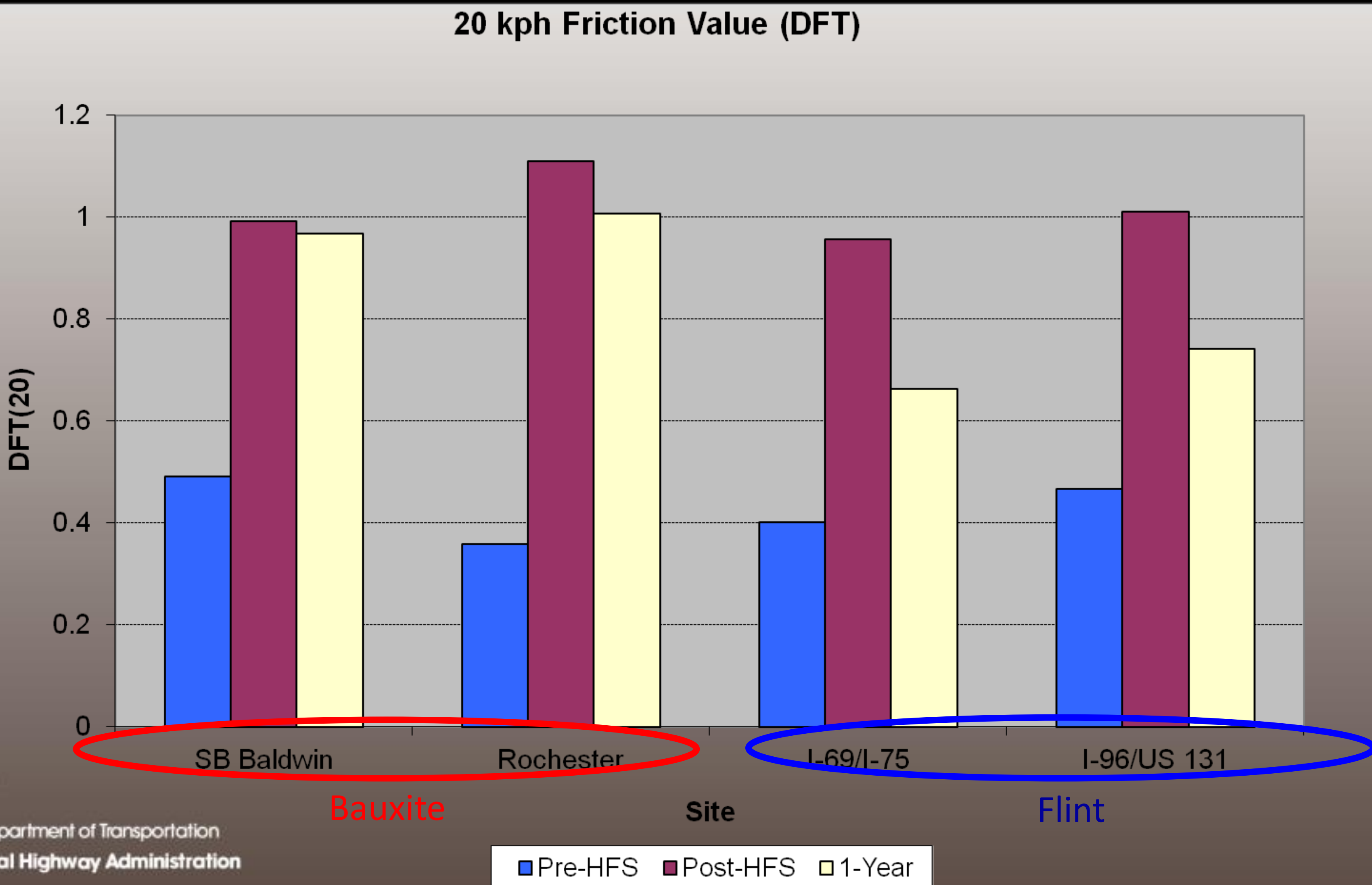
MICHIGAN

- Aggregate: Calcined Bauxite and Crushed Flint
- Projects:
  - NB I-75 to NB Baldwin Rd. ramp, Auburn Hills (PCC)
  - NB I-75 to Rochester Rd. ramp, Auburn Hills (HMA)
  - WB I-69 to SB I-75 ramp, Flint (PCC)
  - WB I-96 to NB US 131 ramp, Grand Rapids (PCC)

Michigan – PRELIMINARY Results



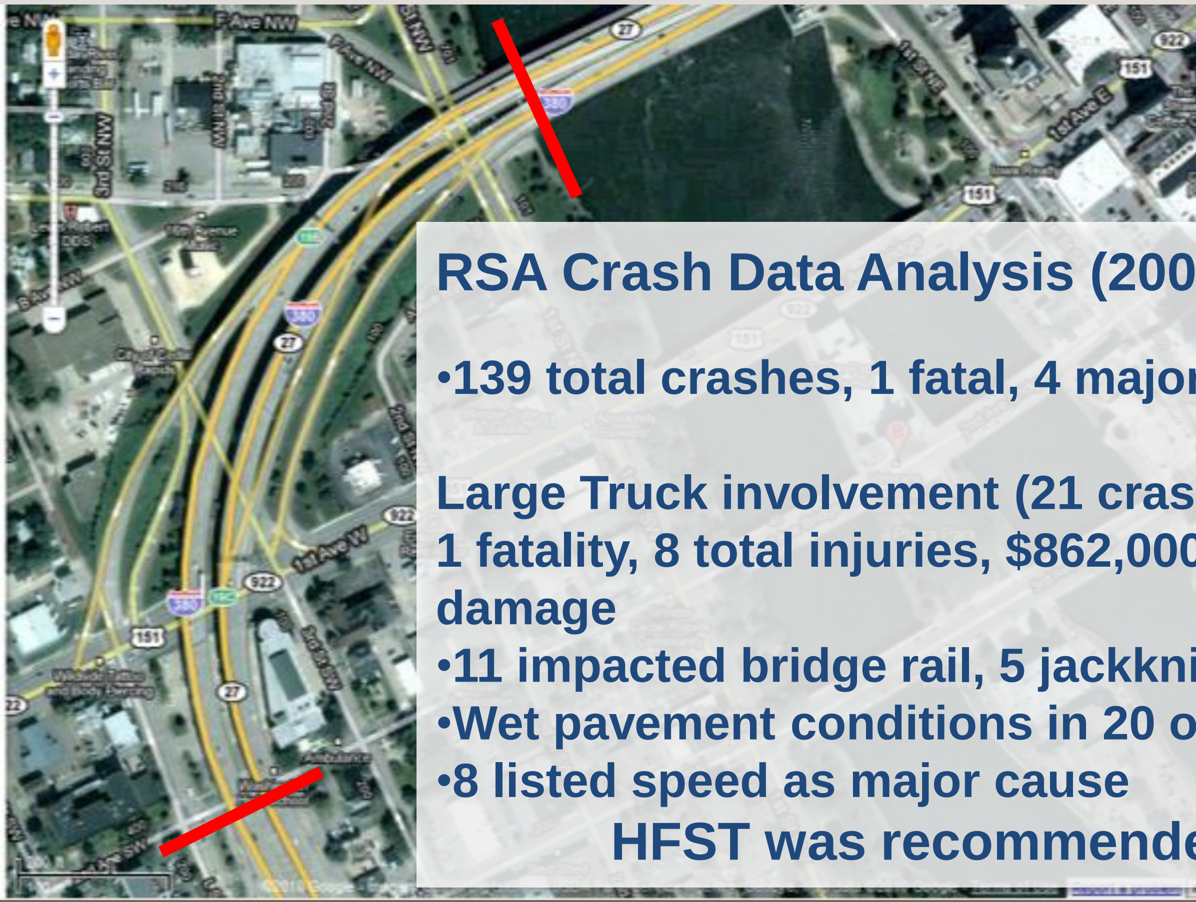
Michigan – 1-Year Performance

Preliminary Crash Reduction Results

- Michigan
  - Site 1
    - 3 yr before: 26 crashes (8 wet)
    - 1 yr after: 4 crashes (1 wet)
  - Site 2
    - 3 yr before : 55 crashes (15 wet)
    - 1 yr after: 16 crashes (2 wet, 3 snow/ice)
  - Site 3
    - 3 yr before : 22 crashes (7 wet)
    - 1 yr after: 2 crashes (1 icy)
  - Site 4
    - 3 yr before : 25 crashes (12 wet)
    - 1 yr after: 3 crashes (1 wet, 1 icy, 1 alcohol)

Overall, 60% crash reduction in first year!

I-380 Cedar Rapids, IOWA



RSA Crash Data Analysis (2001-2008):

•139 total crashes, 1 fatal, 4 major injury

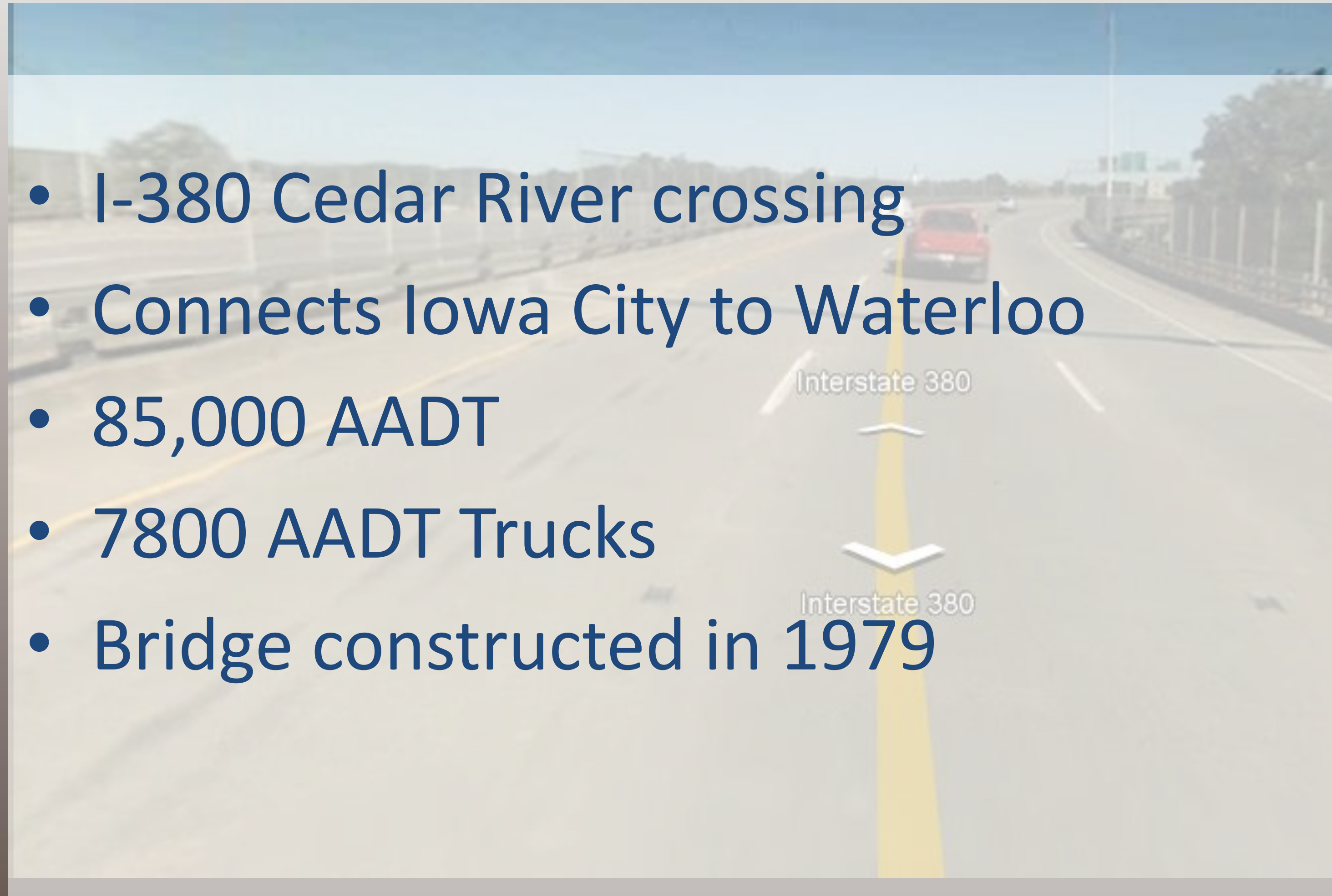
Large Truck involvement (21 crashes):
1 fatality, 8 total injuries, $862,000 property damage
•11 impacted bridge rail, 5 jackknife
•Wet pavement conditions in 20 of 21
•8 listed speed as major cause

HFST was recommended

Interstate 380 Cedar River Crossing

Cedar Rapids, IA

I-380 Cedar Rapids



- I-380 Cedar River crossing
- Connects Iowa City to Waterloo
- 85,000 AADT
- 7800 AADT Trucks
- Bridge constructed in 1979

Potential Solution

- FHWA Surface Enhancement at Horizontal Curves (SEAHC) Demo
  - Would provide additional funding
  - Monitor crashes before and after HFST application
  - Friction testing before and after HFST
  - Contribute to the national evaluation

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Construction Components

- **Night Work**
  - Deck Patching
  - Pavement marking removal
  - Joint covering
  - Shot-blasting
  - Mechanical Application

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Shot-Blasting

- 1 foot per pass

Binder Application

Mechanical Application

Sweeping

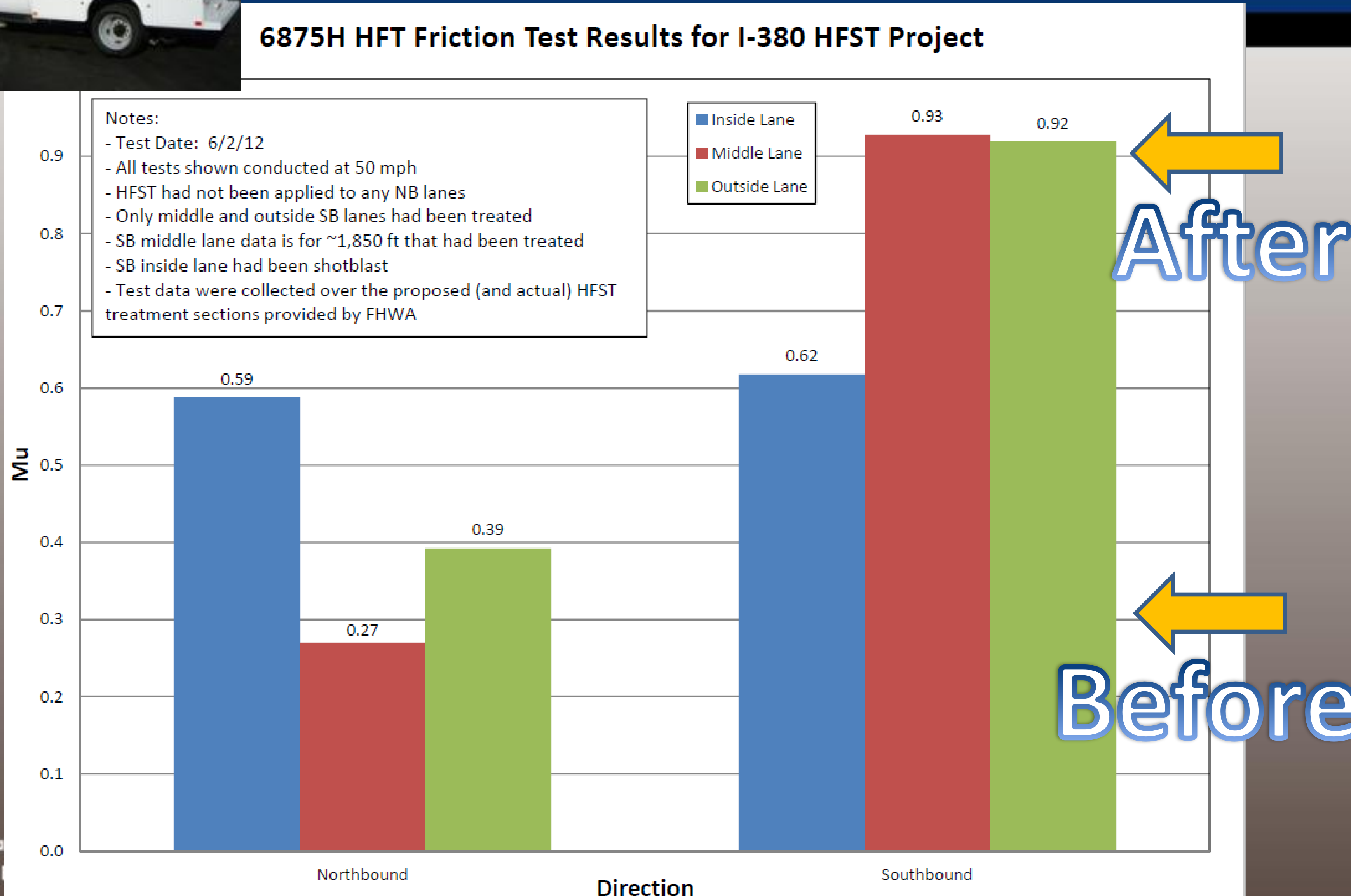
Testing

- DOT Friction Testing

SBL
Standard Tread
40 MPH

	Prior Section	HFST Section	Post Section
Lane 1(Outside Lane)	29.9	73.0 71.7	33.9
Lane 2 (Middle Lane)	26.3	70.9 70.9	30.5
Lane 3(Inside Lane)	38.6	79.8 79.1	39.0

Highway Friction Tester



Cost

- Total Cost: $493,725.60
- Friction Treatment: $22.00 per yd^2

Crash Reduction

I-380 Cedar River Crossing, Cedar Rapids, IA			
	Before HFST		After HFST	
	May 1, 2008 - April 30, 2012		June 13, 2012 - June 12 2013*	
	5-yr Total	Annual Avg (5 yrs)	Annual (1 yr)	
Crashes:	54	10.8	4	
Injuries	28	5.6	1	
Tractor/Semi-trailer	8	1.6	0	
Property Damage	$981,616	$196,323	$9,500	
Lost Control/Speed Too Fast/Evasive	29	5.8	0	
Road Surface Contributing	9	1.8	0	
Wet Roadway	17	3.4	2	(1 asleep)
Snow/Ice/Slush	17	3.4	0	

* 2013 data is preliminary

Benefits

- Fewer Crashes
- Fewer Traffic Impacts
- Much Quieter Ride

What's Next for Iowa?

- EDC2 Implementation Plan
  - Data Analysis (Fall/Winter 2013)
    - Curve Identification
    - Crash, Friction, and Pavement Assessment
  - Identify Candidate Locations (Spring 2014)
  - Develop Projects (Summer/Fall 2014)
  - HFST Installation (by Fall 2015)

Marquette Interchange

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Wisconsin – Marquette Interchange

Construction Completed: November 2008

Application Type: Rehabilitation

Treatment Date: October 2011

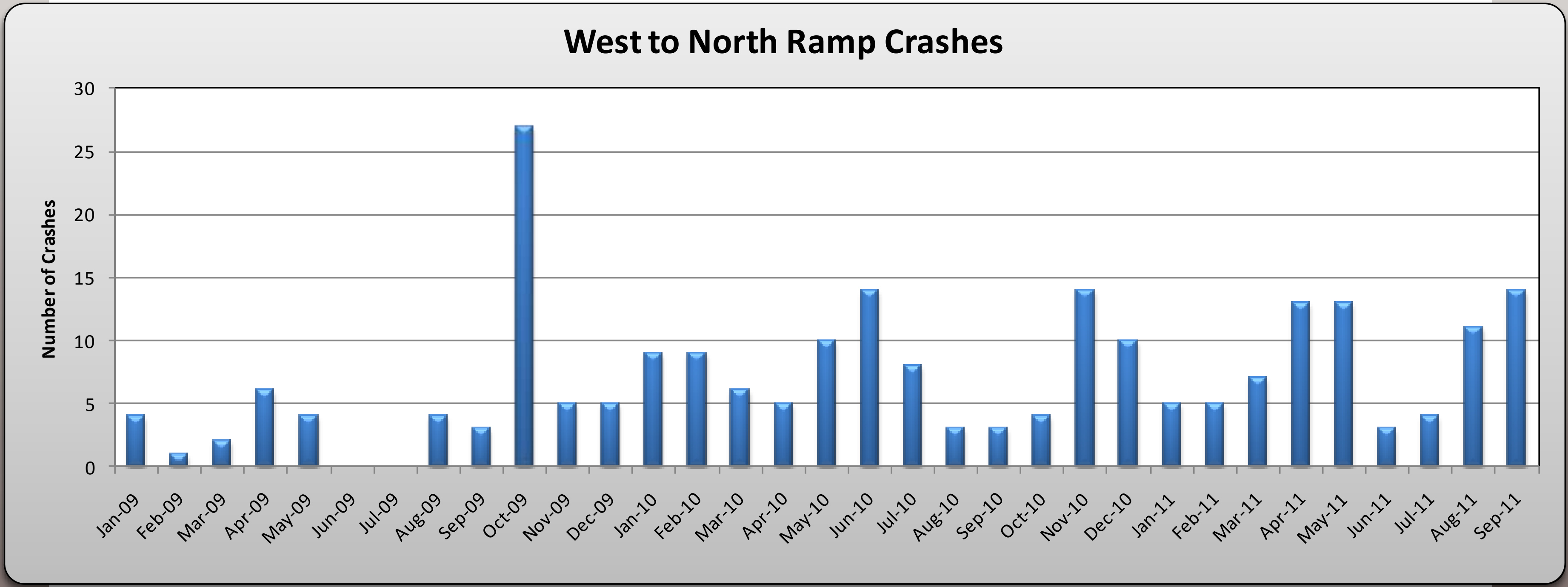
Purpose: High Incident Rate

- ***2009: 61 crashes***
- ***2010: 95 crashes***
- ***2011: 76 crashes***

Case Study #1 - The Issue

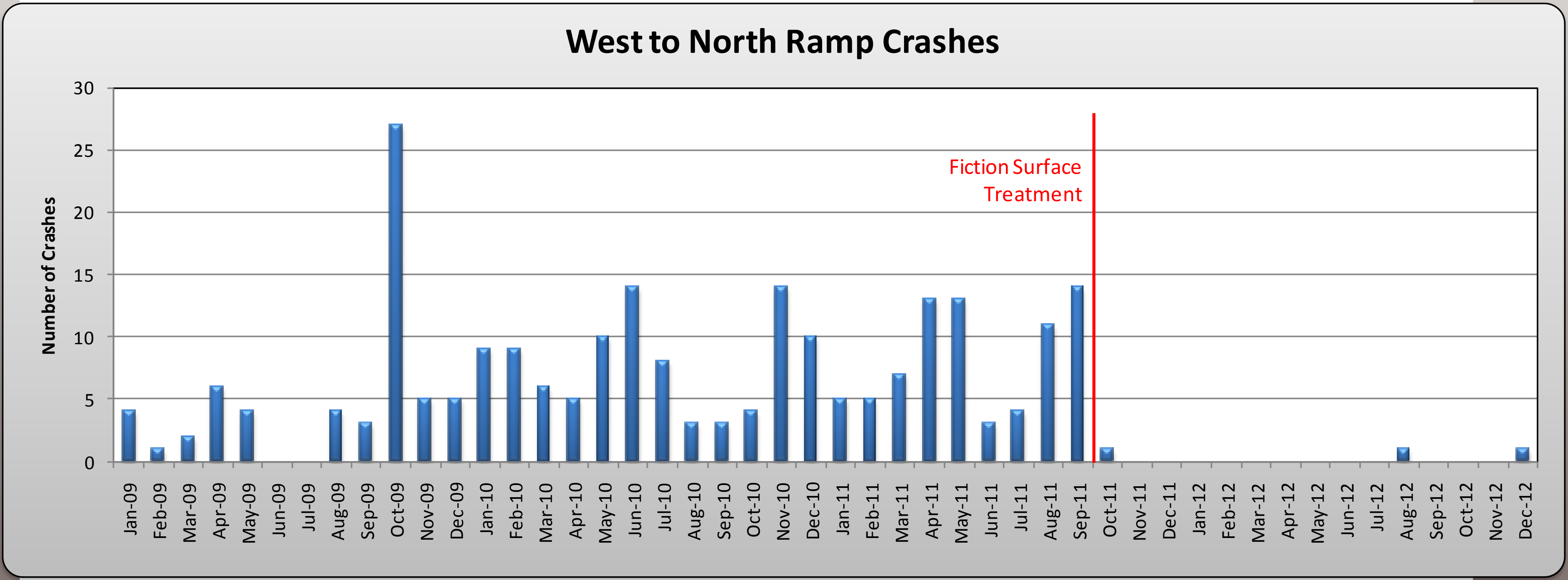
Case Study #1 – Marquette Interchange

Pre-Application Incident Statistics



Marquette Interchange

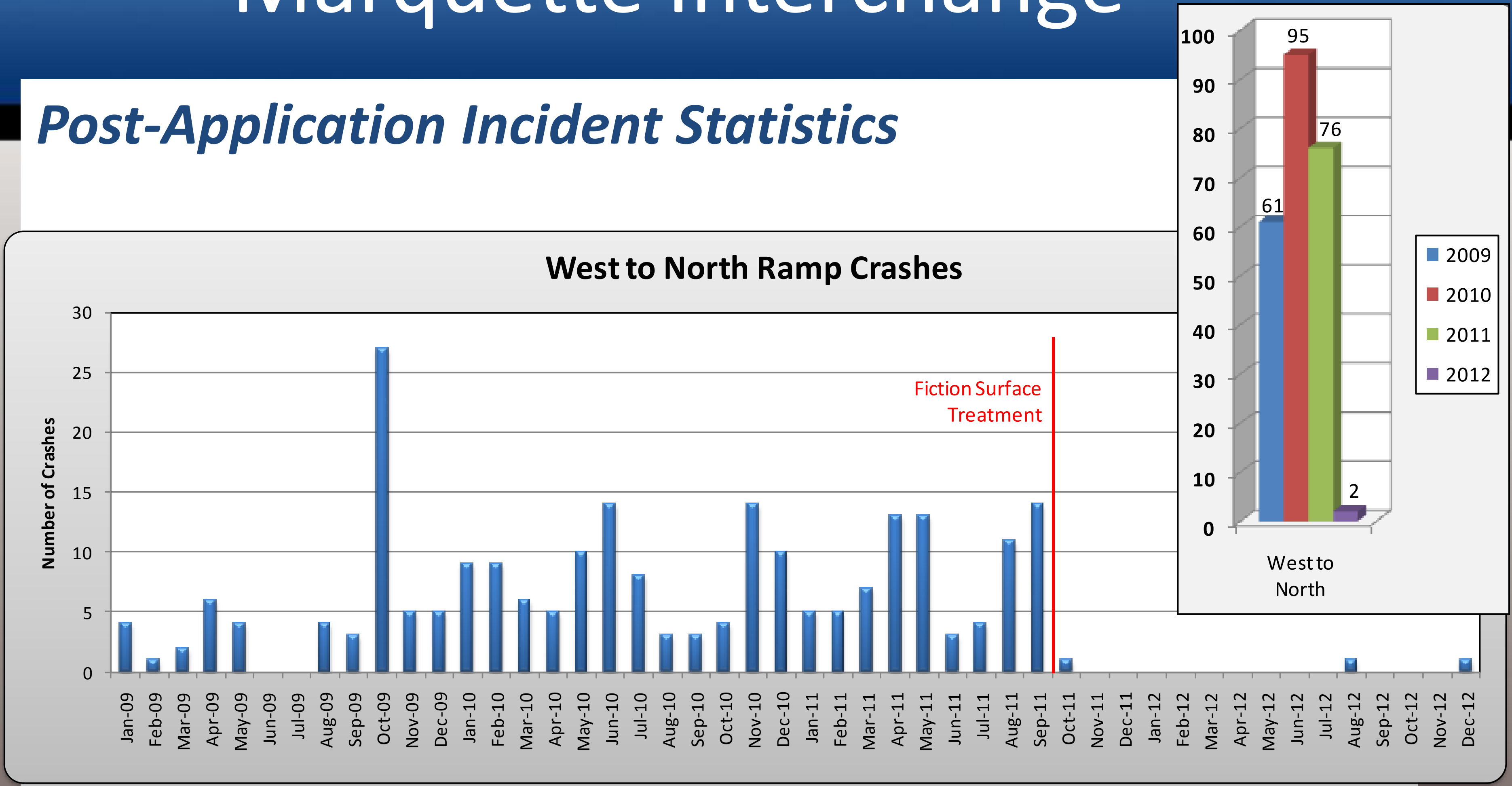
Post-Application Incident Statistics



97% REDUCTION

Marquette Interchange

Post-Application Incident Statistics



97% REDUCTION

I-43 at North Avenue

Construction Completed: September 2008

Application Type: Resurface

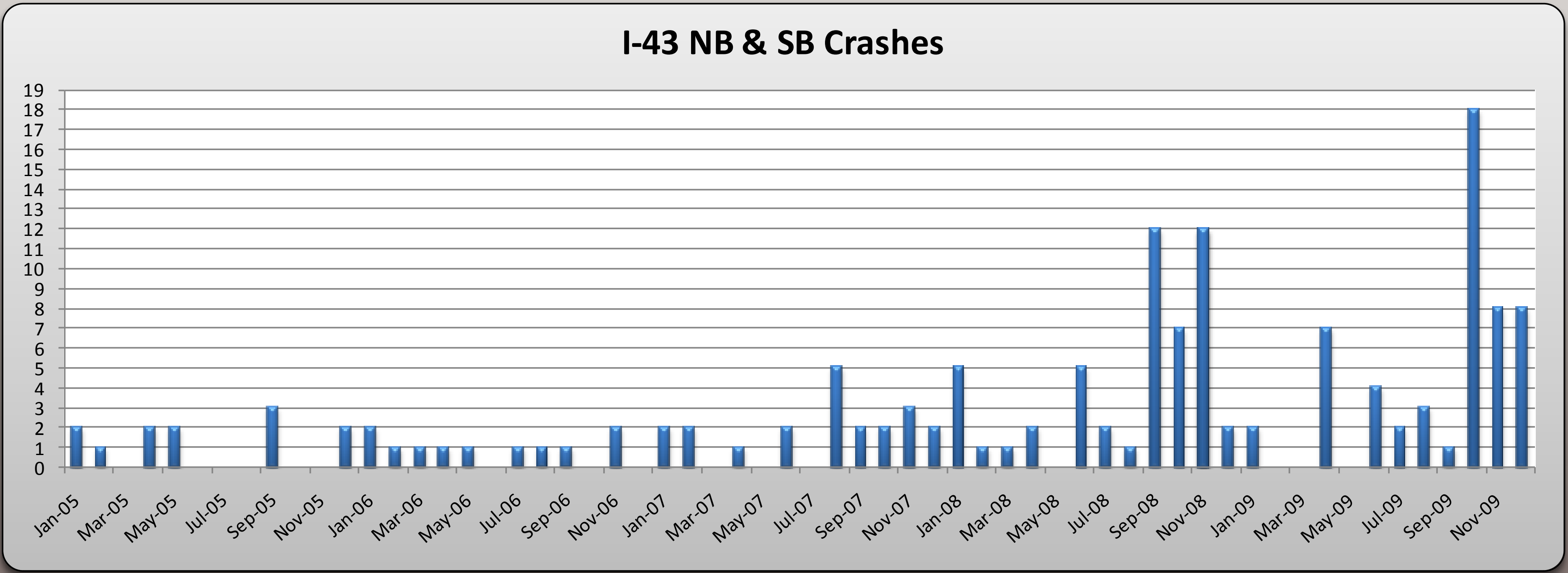
Treatment Date: November 2012

Purpose: High-Density Incident Rate (0.5 mile)

- ***2005: 12 crashes***
- ***2006: 11 crashes***
- ***2007: 21 crashes***
- ***2008: 50 crashes***
- ***2009: 53 crashes***

I-43 at North Avenue

I-43 at North Avenue



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Mitchell Interchange

Construction Completed: October 2012

Application Type: Resurface

Treatment Date: November 2012

Purpose:

Incident Prevention

- friction scans indicated low coefficient

Incident Study:

Ongoing

Additional Projects: I-94E at STH 67

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Additional Projects: I-94W at CTH F

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- Results from SEAHC Study
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NCAT Aggregate Durability Study

- Purpose: Test the durability of various aggregate types under the same conditions
  - Installed on similar sections NCAT Test Track <u>on a curve</u>
  - Installed by same HFST supplier using the same resin, crew, and equipment
  - Exposed to the same traffic and climatic conditions

NCAT Aggregate Durability Study

- Purpose: Test the durability of various aggregate types under the same conditions
  - Installed on similar sections NCAT Test Track on a curve
  - Installed by same HFS supplier using the same resin, crew, and equipment
  - Exposed to the same traffic and climatic conditions
- 5+ Million ESAL applications (April 2011 - July 2013)

NCAT Aggregate Durability Study

- Laboratory Testing of smaller samples of each
- Aggregates Tested:
  - Granite, Bauxite, Flint (100’ each)
  - Basalt, Silica, Steel Slag, Emery, Taconite (15’ each)
- Phase II (ongoing)
  - Bauxite, Steel Slag, OK Chat, Taconite

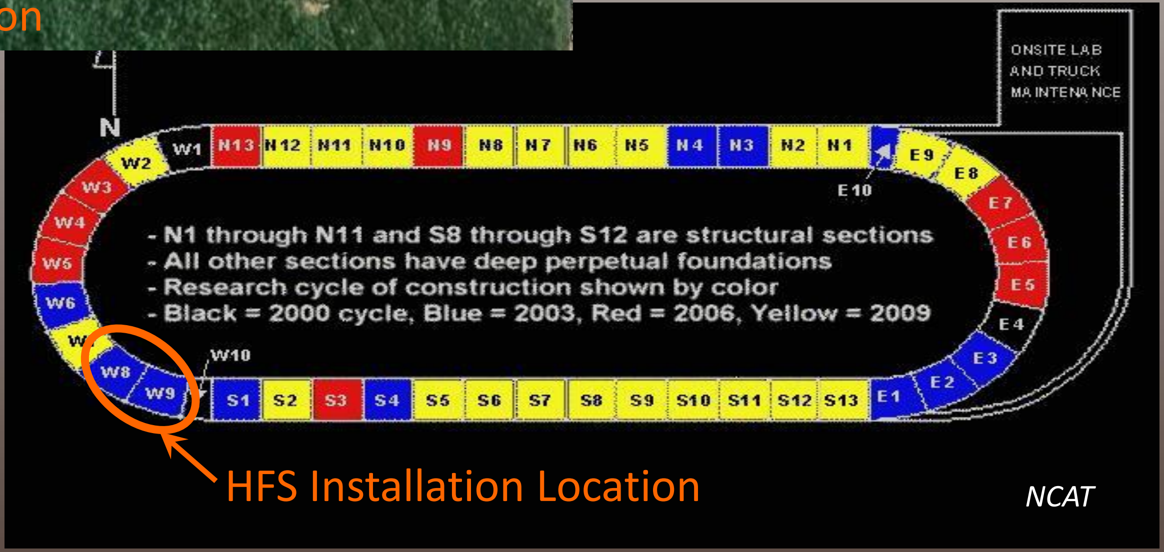
NCAT Aggregate Durability Study

NCAT

NCAT

NCAT

NCAT Aggregate Durability Study



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NCAT Aggregate Durability Study

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NCAT Aggregate Durability Study

100’

Flint

Bauxite

Granite

NCAT Aggregate Durability Study

15’
Taconite
Emery
Steel Slag
Silica
Basalt

100’
Flint
Bauxite
Granite

Night View

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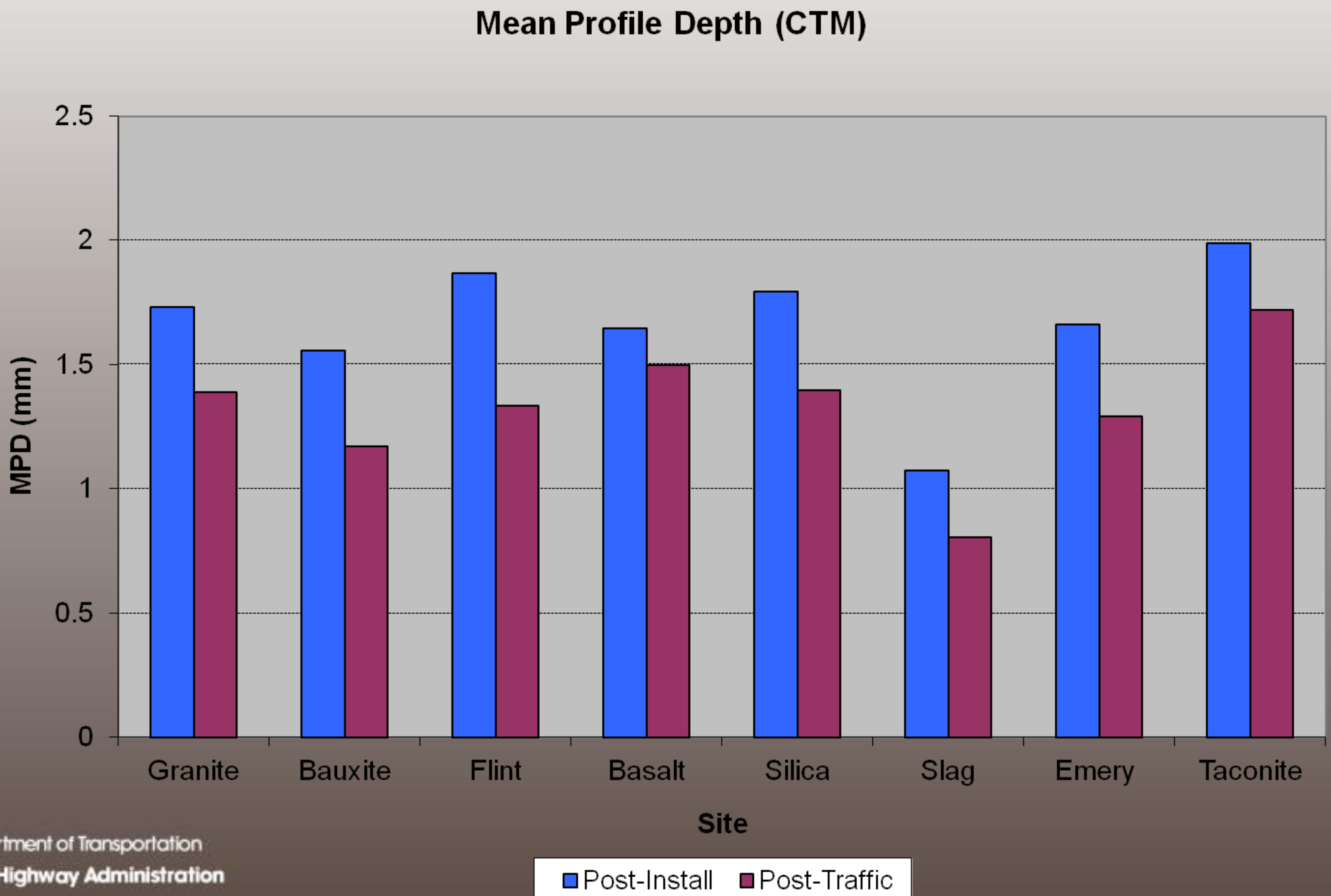
NCAT Aggregate Durability Study

- Laboratory Testing
- Three Wheel Polishing Device
  - Friction and Texture tested at 70k and 140k cycles
  - 2 replicates for each aggregate type

NCAT – PRELIMINARY Test Track Results



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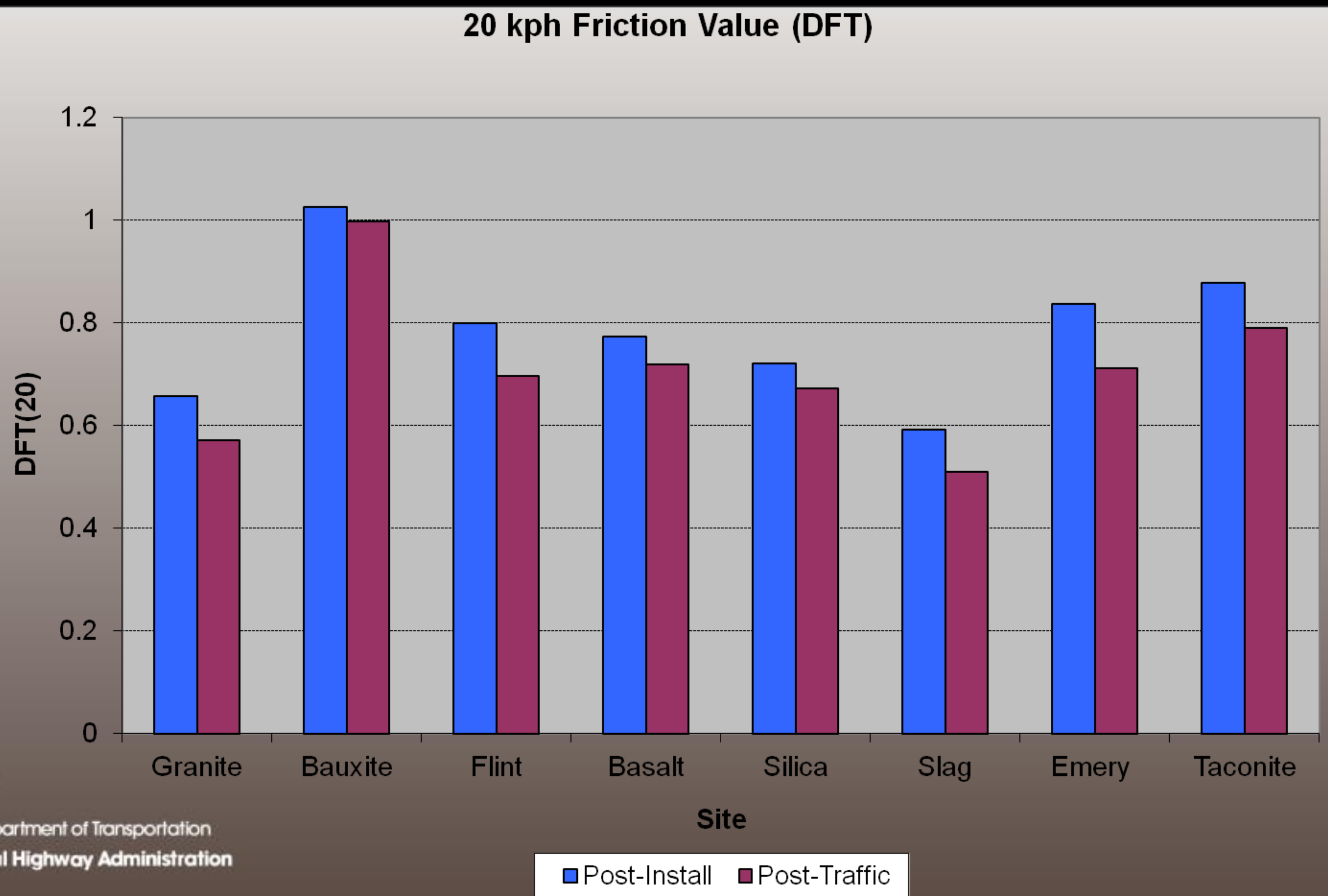

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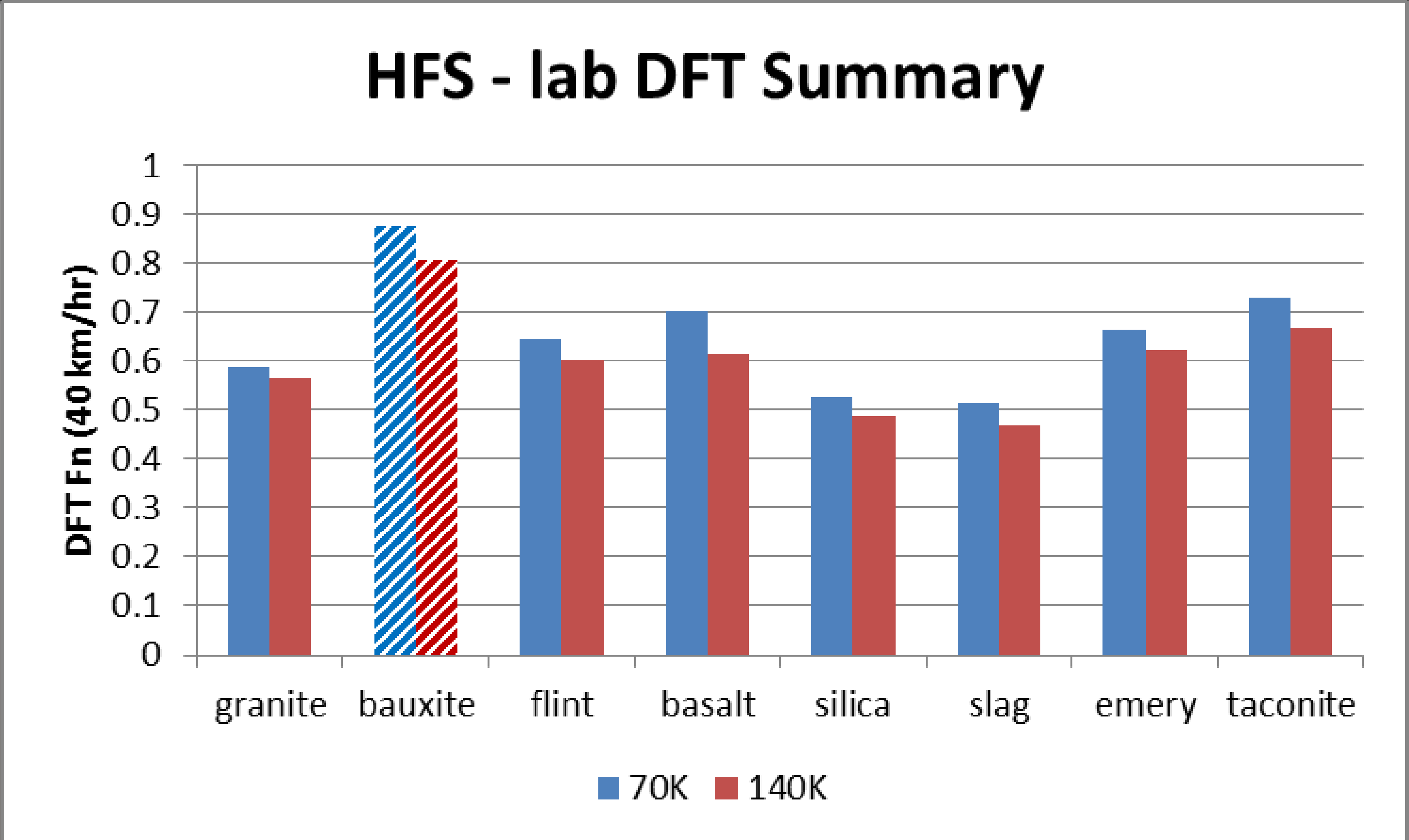

SEAHC - General Observations

- Wind is another potential weather delay
- Ensure adequate lighting for night work
- Need bigger shot blasters (width)
- Strong vacuums are needed to collect extra aggregate from lane and shoulder debris
- Review the weight of the machine and loaded materials
- HFST is working well by both crash and friction performance metrics

SEAHC - General Observations

- Underlying pavement must be in good condition – no alligator/block/map cracking
  - Cracks will reflect through regardless of the pavement type
  - HFS still adheres well in the presence of cracking

SEAHC - General Observations

- HFST products used to date have adhered well to all pavement types – HMA, Chip Seal, SMA, and PCC
- Surface preparation is very important
  - Shotblasting is generally required for concrete pavement
  - Removal of latent oils/grease and debris for all pavement types

SEAHC - General Observations

- HFST naturally “sheds” aggregate for the first few weeks/months after installation
  - May result in “artificial” texture depth and friction readings immediately after installation
  - Shoulders must be monitored and cleared of loose aggregate

SEAHC - General Observations

- HFST appears to perform well under snowplow wear, but poorly under studded tires / chains
  - Double-layer HFS may be necessary for these locations

SEAHC - General Observations

- Calcined Bauxite is the “premium” aggregate for HFST, but other aggregates have also performed satisfactorily under non-aggressive conditions
  - NCAT Durability Study showed other potentially promising aggregates, but requires further testing and evaluation
  - Selection of aggregate type should be governed by traffic and environmental conditions

SEAHC - Summary

- HFST has been demonstrated to be an effective surface treatment material for reducing crashes at curves.
- HFST vendors are continually seeking to improve materials, application equipment, and installation practices
- HFST vendors have been extremely supportive and are the key element to the successful projects to date
- FHWA continues to support HFS as a solution for enhancing safety on pavement surfaces

SEAHC - Summary

- FHWA continues to support HFS as a solution for enhancing safety on pavement surfaces
- HFST has been selected by FHWA as an Every Day Counts 2 (EDC2) initiative and as a result will be highly promoted in the next two years.

Questions

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IRM
Interstate Road Management
High Friction
Surfacing Treatment Division
DOW
Formulated Systems
POLY-CARB
CRAFCO
AN ERGON COMPANY
Traffic Calming USA
Making Our Roads Safer!
ENNIS
UNITEX
KWIK BOND
POLYMERS