VTTI Research Spotlight

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Center for Sustainable & Resilient Infrastructure

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2. TSDD Implementation
3. Pavement Safety
4. High-RAP HMA using BMD - APT Experiment
5. Future Initiatives

1. Introduction

Center for Sustainable and Resilient Infrastructure

Partnership between the Virginia Tech Transportation Institute (VTTI) and the Via Department of Civil and Environmental Engineering (CEE) Transportation Infrastructure and Systems Engineering (TISE) Program

Re-inventing our infrastructure

→ **Save lives**

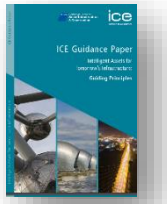
→ **Save money**

→ **Protect the environment**

Motivation

Disruptive Technological Trends

- ✓ **"Smart" Infrastructure**
  - **Sensors**
  - **Communication**
  - Multi-function
  - Self-Healing



- ✓ **"Smart" Cities**
- ✓ **"Smart" Vehicles**
  - **Connected and Automated**
  - Electric, Shared

- ✓ "Smart" Construction
  - BIM
  - Automated equipment
- ✓ Sustainable Energy
- ✓ **Multifunctionality**
- ✓ Advanced materials

Sustainable and Resilient Transportation infrastructure (Multi-functional, Automated, etc.)

WORLD ECONOMIC FORUM **Infrastructure 4.0**

Increasing Demands

- ✓ **Complexity**
  - Interconnected Networks
  - Systems of systems

- ✓ **Socioeconomic Trends**
  - Sustainability
  - Megacities
  - E-commerce
  - Human-Centered Communities
  - Quality of Life
  - Equity

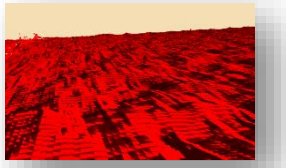
- ✓ **Climate Change**
  - Resilience
  - Flooding
  - Severe storms …

VIRGINIA TECH TRANSPORTATION INSTITUTE
Center for Sustainable & Resilient Infrastructure

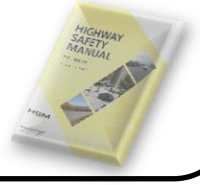
Scope - Support the Full Research “Arch”

Concept → **Research** → **Development** → **Implementation**

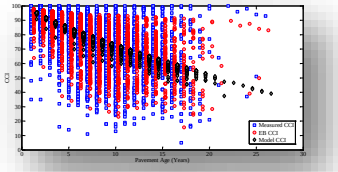
Basic Research



Literature Reviews

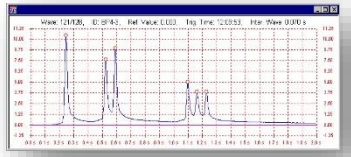


PMS Data Analysis



Laboratory Performance

Modeling & Simulation



APT

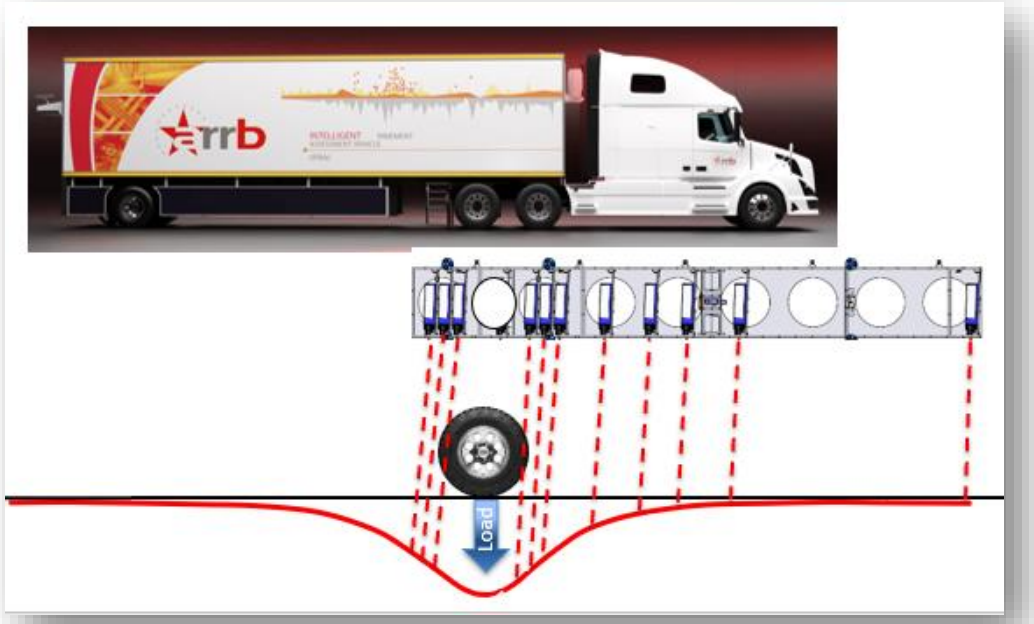
Full Scale
(Test Sections)

Deployment

Life-cycle Monitoring

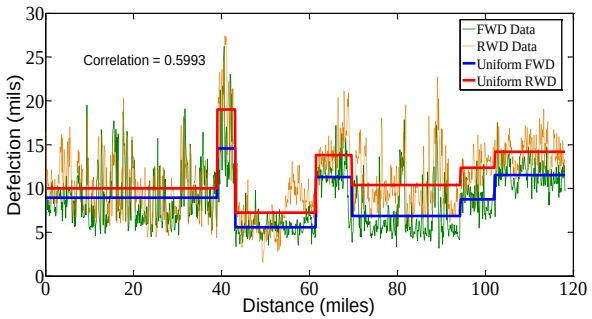
Training & Outreach

VIRGIN
TRANS

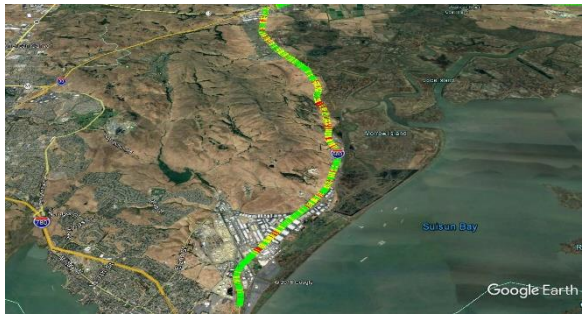


2. TSDD Implementation

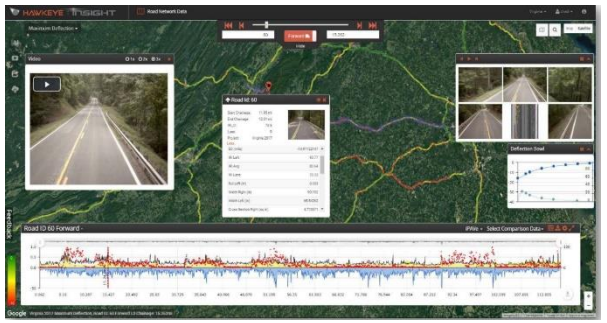
Structural Health Evaluation Sample Projects



Development of Continuous Deflection Device



Demonstration of Network Level Pavement Structural Evaluation with TSD



Pavement Structural Evaluation with TSDDs Pooled Fund Operation

Partners: AR, CA, CO, FHWA, GA, ID, IL, IN, KS, KY, LA, MI, MN, MO, MS, MT, NC, NM, NV, OK, PA, SC, TN, TX, VA, VT, WI

Supported by:

Network Level Pavement Structural Testing with the Traffic Speed Deflectometer

Implementation of TSD Data in the PMS and District Level Training

Center for Sustainable & Resilient Infrastructure

TPF-5(385) Main Products

- ✓ Review of available TSDDs and analysis methods
- ✓ Guide for data collection
  → **Sent to AASHTO**
- ✓ Guide for PMS implementation → Send to AASHTO?
- ✓ Webinars (9 in total)
  - Summary E-Circular for TRB
- ✓ Segmentation tool
- ✓ Idaho case study and report
- ✓ EFL case study and report
- ✓ Wisconsin data analysis support (results in TRR)
- ✓ Analysis of rigid pavement joints
- ✓ **Symposia/ User Group Meetings (2)**
  - Summary E-Circulars for TRB
- ✓ Project about metrics

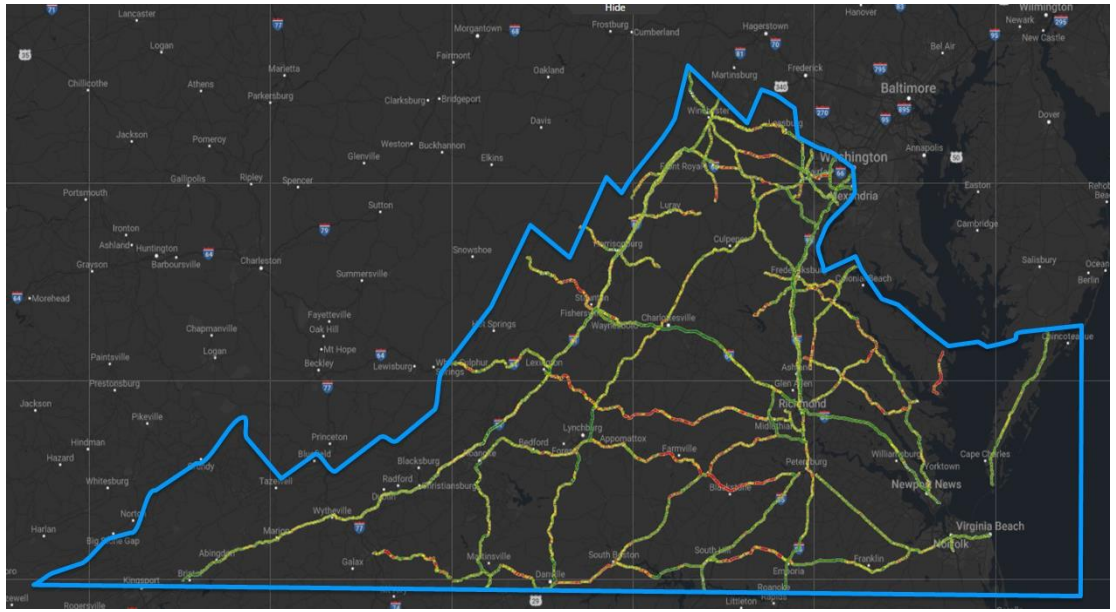
TPF-5(385) Preliminary Conclusions

- ✓ The technology is **mature for network-level pavement management**
  - Accuracy and precision is adequate
  - Useful information to make better (more cost-effective) decisions
- ✓ It looks **very promising for project/ corridor analysis**
  - May need better calibration/ verification/ QA
  - Device specific analysis methods may produce even better results
- ✓ We can make a strong business case for collecting structural condition at the network, corridor, and project level showing **very high returns on investment**

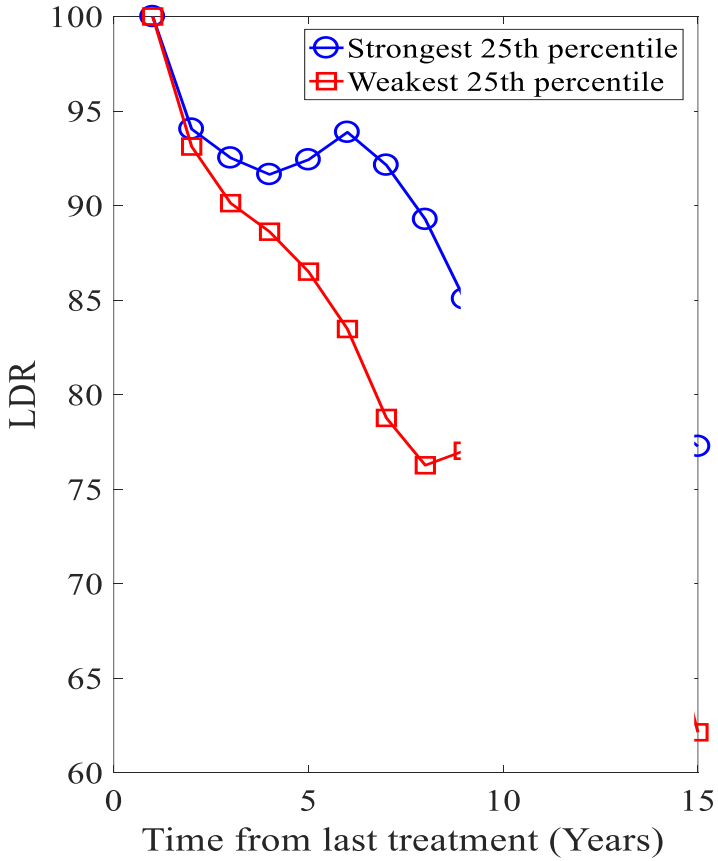
VDOT TSD Data Integration

Objectives

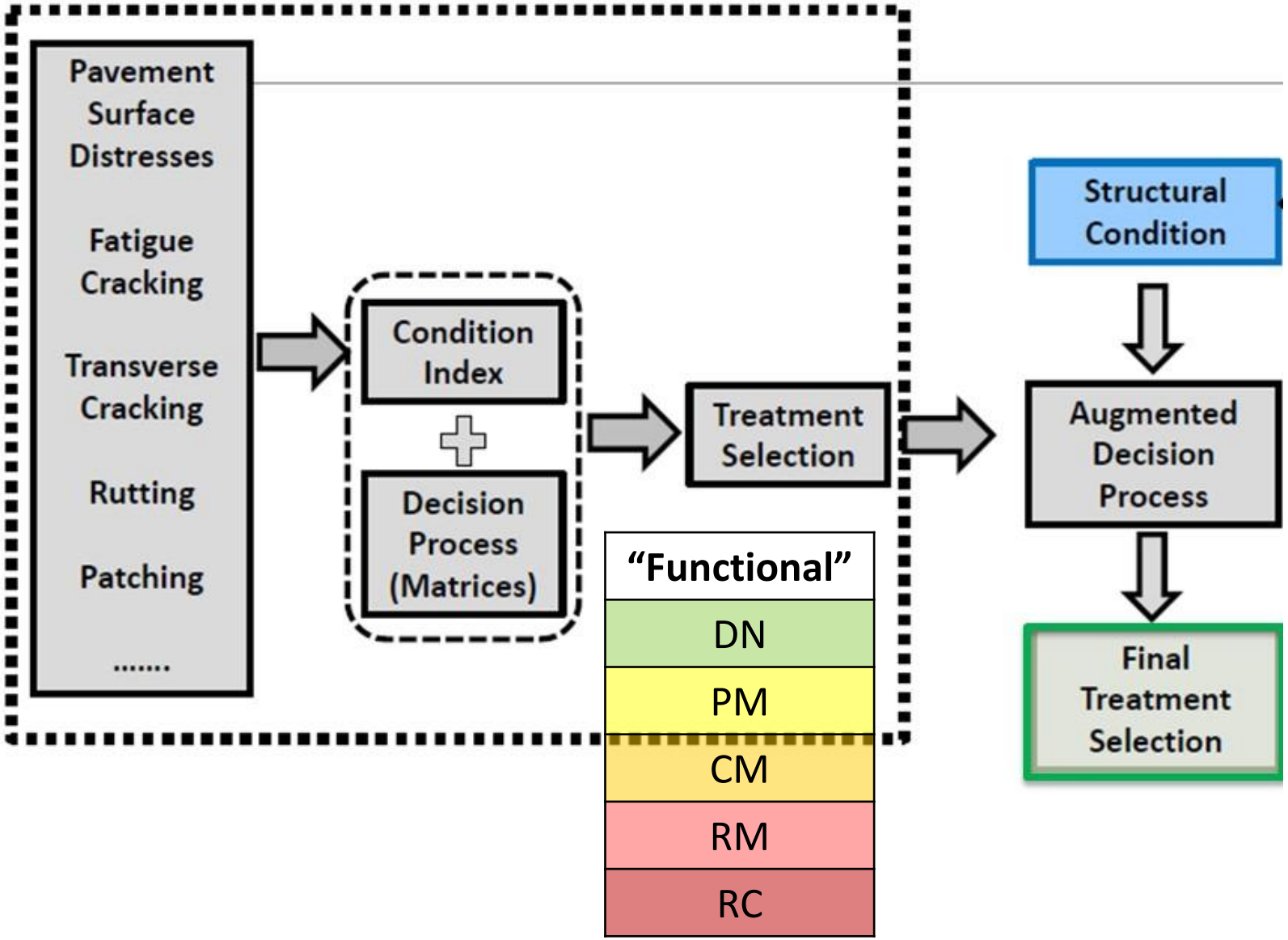
1. Integrate the data collected into the pavement management system
2. Develop training materials on how to effectively use the network level structural evaluation data
3. Deliver regional training



SCI_{300} and Deterioration



Structural Data Use



"Structural"	
Treatment	**RSL**
DN	>20
PM	20 – 12
CM	12 – 8
RM	8 – 3
RC	<3

$$SN_{eff} = 0.0045 H_p \sqrt[3]{E_p}$$

$$\text{ESALs} = \text{f}(SN_{eff})$$

$$\text{RSL} = \text{f}(\text{ESALs})$$

Preliminary Results for the Primary Network

	Treatments																									
Func.	DN					PM					CM					RM					RC					
Struct.	DN	PM	CM	RM	RC	DN	PM	CM	RM	RC	DN	PM	CM	RM	RC	DN	PM	CM	RM	RC	DN	PM	CM	RM	RC	
Final	DN	DN	DN	DN	DN	PM	PM	PMDN*	DN	DN	PM/CM	PM/CM	CM	RM	RC	CM	CM	CM	RM	RC	CM	CM	RM	RM/RC	RC	

- ✓ Cost of surface condition only: $175 mil.
- ✓ Enhanced (surf. condition + traffic and age): $194.4 mil.
- ✓ Surf. condition + structural condition: $130.9 mil. (potential 25% reduction)
  - Caveat: some treatments are deferred to the future

→ **LCCA**

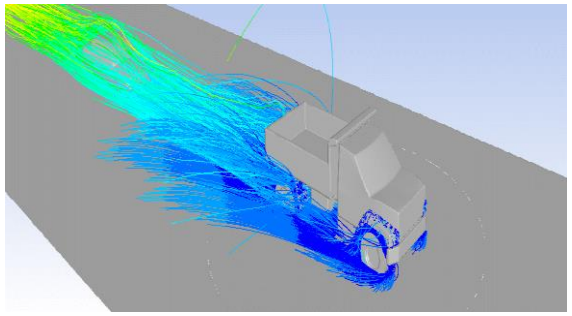
3. Pavement Safety

Vehicle–Pavement Interaction Sample Projects

Pavement Surface Properties Consortiums Phase I, II, III

PFMP in ND, KS & IL

Estimating Tire-Road Friction from Probe Vehicles & Smart Tires



Splash and Spray development program

Pavement Friction Management Program

CPFM and PFM for Safety

Relationship of asphalt mix gradation to macrotexture and safety

Guidance to Predict and Mitigate Dynamic Hydroplaning on Roadways

Protocols for Network-Level Macrotexture Measurement

Pavement Friction Management Program Pilot Démonstration

Virginia PFMP Phase 2 – COSS

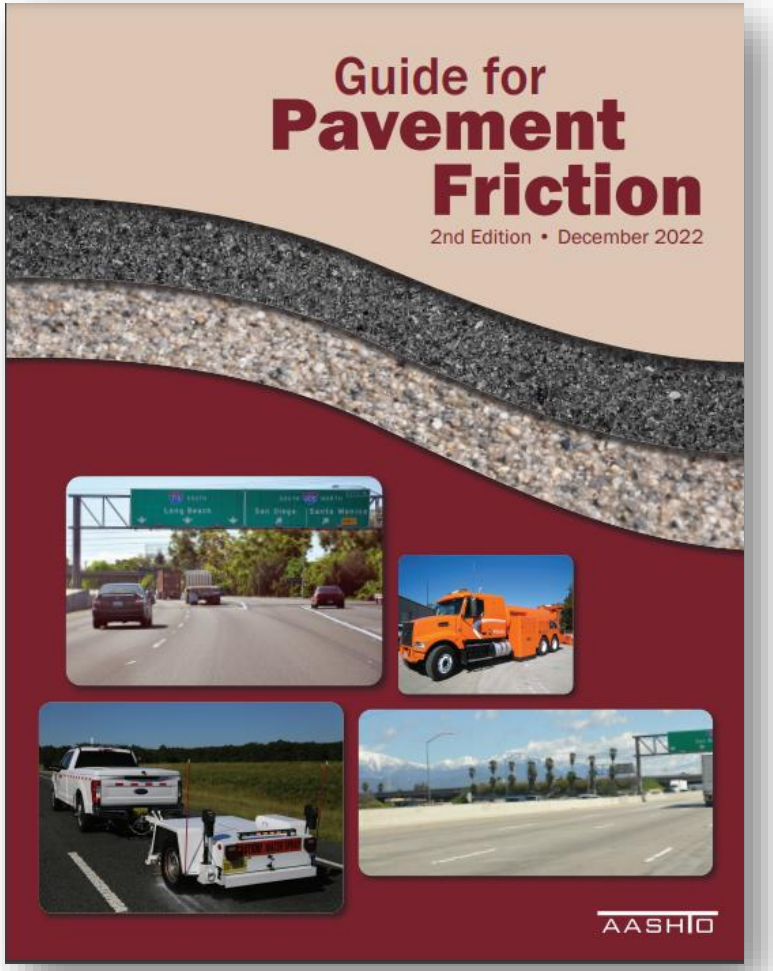
District-level PFMP Implementation for the VDOT (Phase 3)

Transitioned from TPF-5(345) to TPF-5(463)

TPF-5(463) Objective

- ✓ *To conduct applied research focused on enhancing the level of service provided by the roadway transportation system by optimizing pavement surface characteristics*
  - Support the implementation of asset management approaches and tools that help improve the safety of our road networks by reducing the number of crashes and related fatalities.
  - Bring pavement design and evaluation experts together with maintenance and safety professionals

The PFM methodology proposed by CSRI included in the 2022 AASHTO Guide for Pavement Friction



Based on recent FHWA-sponsored work

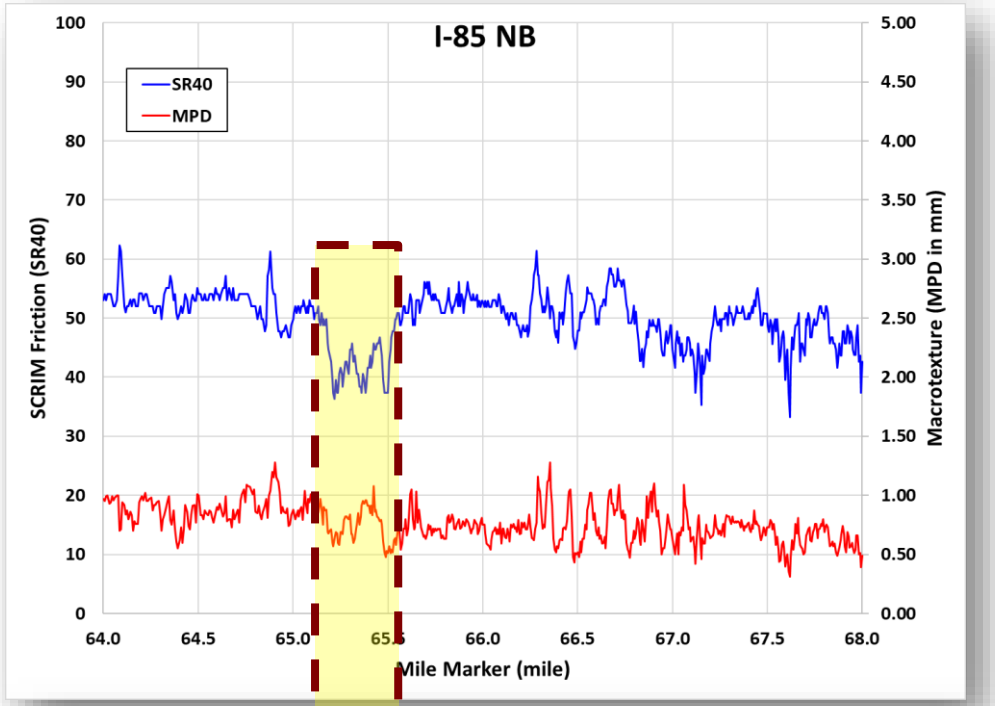
Key updates

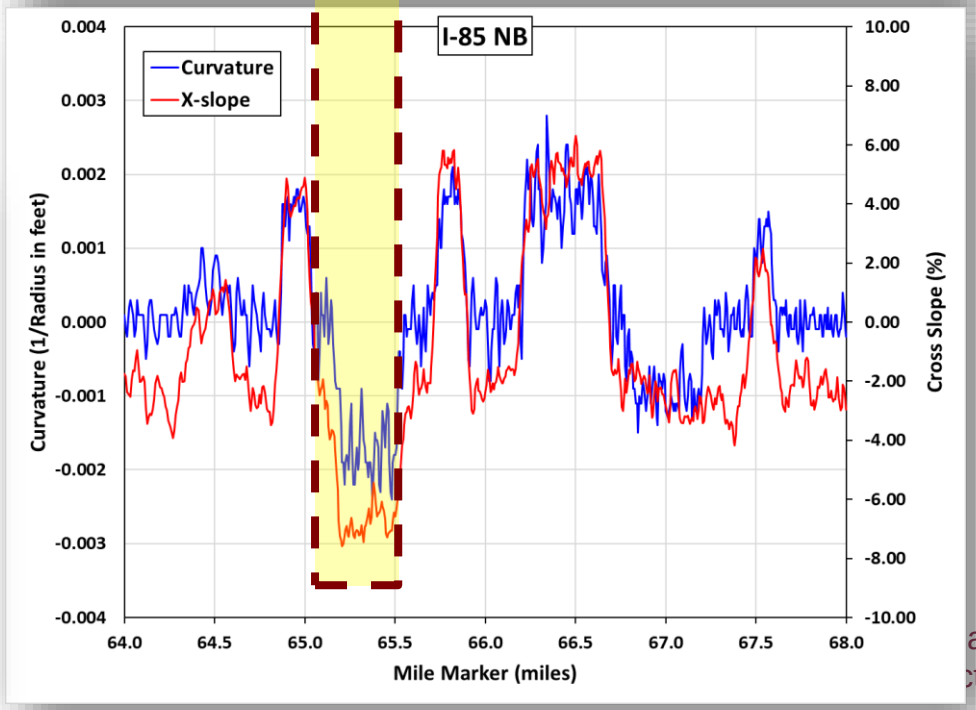
- ✓ Friction impact both dry and wet crashes.
- ✓ Importance of continuous friction and macrotexture measurement for improved safety performance
- ✓ Investigatory levels only
- ✓ Cost-benefit approach for prioritizing safety enhancement treatments

Implementation of pavement friction management in Virginia - Objective

- ✓ *To continue the development and implementation of a continuous data-based pavement friction management (PFM) program by exploring use of other important pavement surface characteristics*
  - Support Pavement Friction Management District Implementation
  - Line-laser Acquisition and Implementation for MPD Measurements
  - Deployment of Project-level Data Collection
  - Draft **Technical Memo** under internal review

Example: I-85 NB in Richmond





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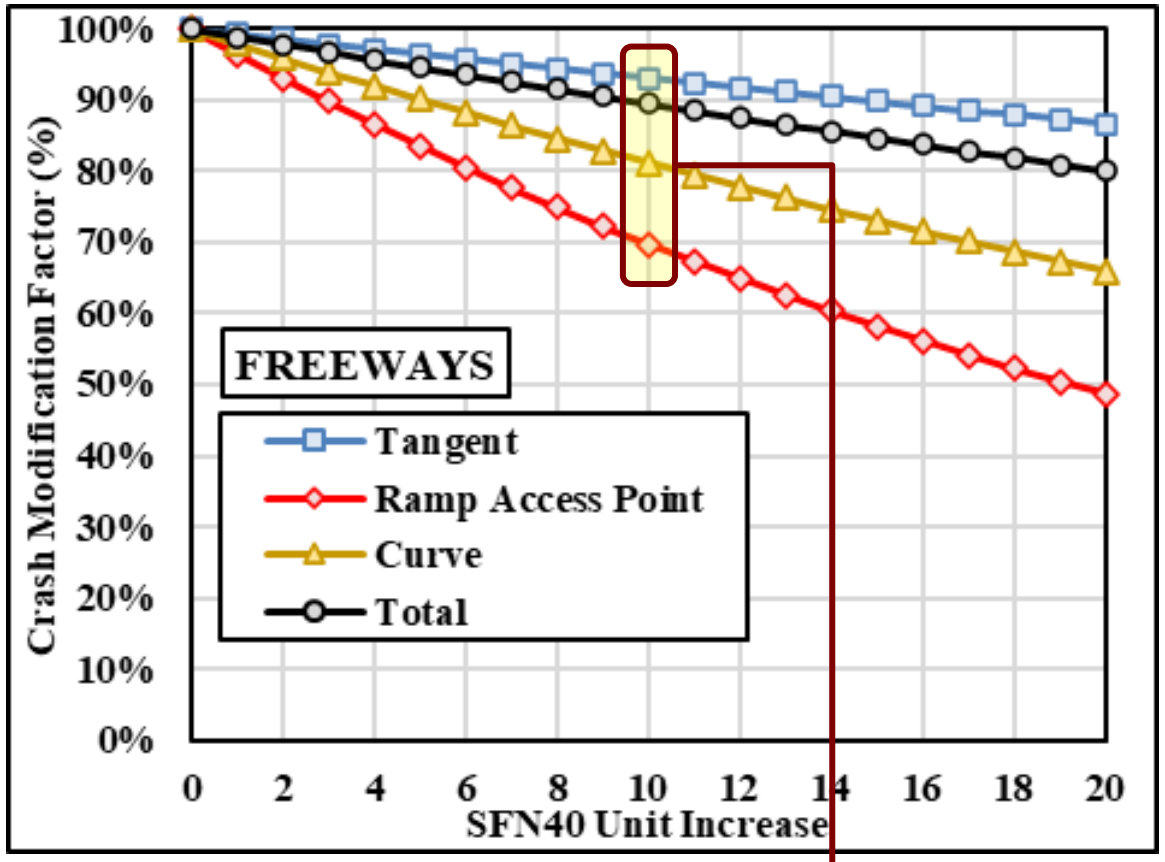
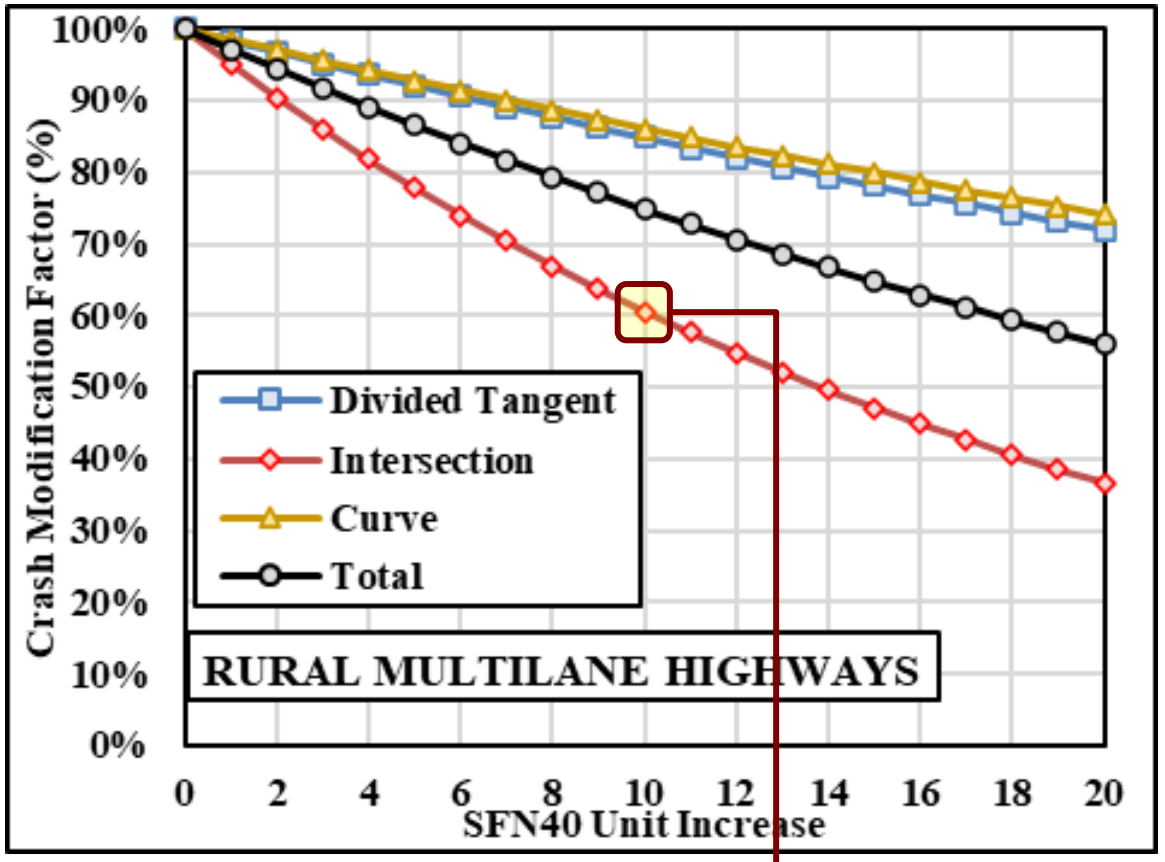
Examples of CMFuntions





Potential Crash Reduction of 5-30%

Up to 40%

Relationship of asphalt mix gradation to macrotexture and safety

Objectives

- ✓ *Develop a field-calibrated macrotexture prediction model for asphalt surfaced pavements*
- ✓ *Provide guidance for agencies and construction contractors to use in designing asphalt mixes with a required value of macrotexture*

Scope

- ✓ Assemble and review scholarly and technical work
- ✓ Develop relationship between macrotexture and asphalt mix and aggregate properties
- ✓ Develop guidelines

4. Accelerated Pavement Testing Experiment for High-RAP HMA using BMD

Virginia BMD Journey

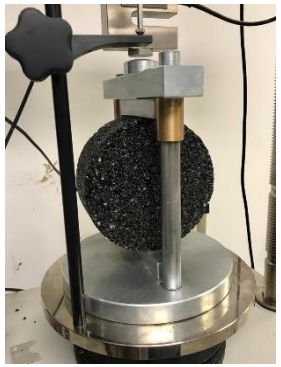
- ✓ VDOT is interested in ways to facilitate the increased durability of asphalt mixtures in an effort to make its roadway network more sustainable, longer lasting, and more economical
- ✓ Committed to the implementation of the BMD method in an effort to improve asphalt mixture performance
  - Laboratory experiment
  - APT experiment
  - Pilots with in-service monitoring
  - Full implementation

https://vtrc.virginia.gov/media/vtrc/vtrc-pdf/vtrc-pdf/21-R15.pdf

APT BMD Experiment Objectives

Primary:

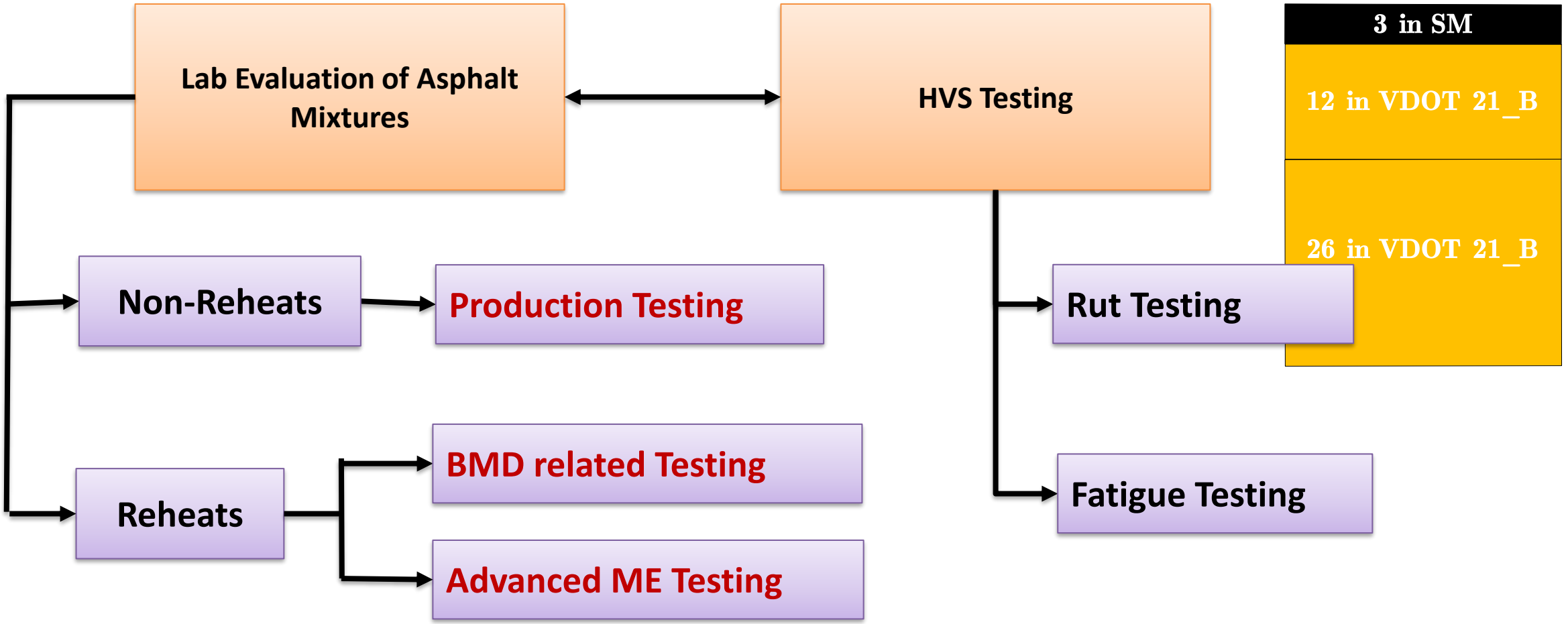
- ✓ Can we design mixes with high RAP contents using Balanced Mix Design (BMD)?



Secondary:

- ✓ Verify the validity of the simple tests and limits set for the pilot projects
- ✓ Do we need to have the three tiers?

Experimental Program



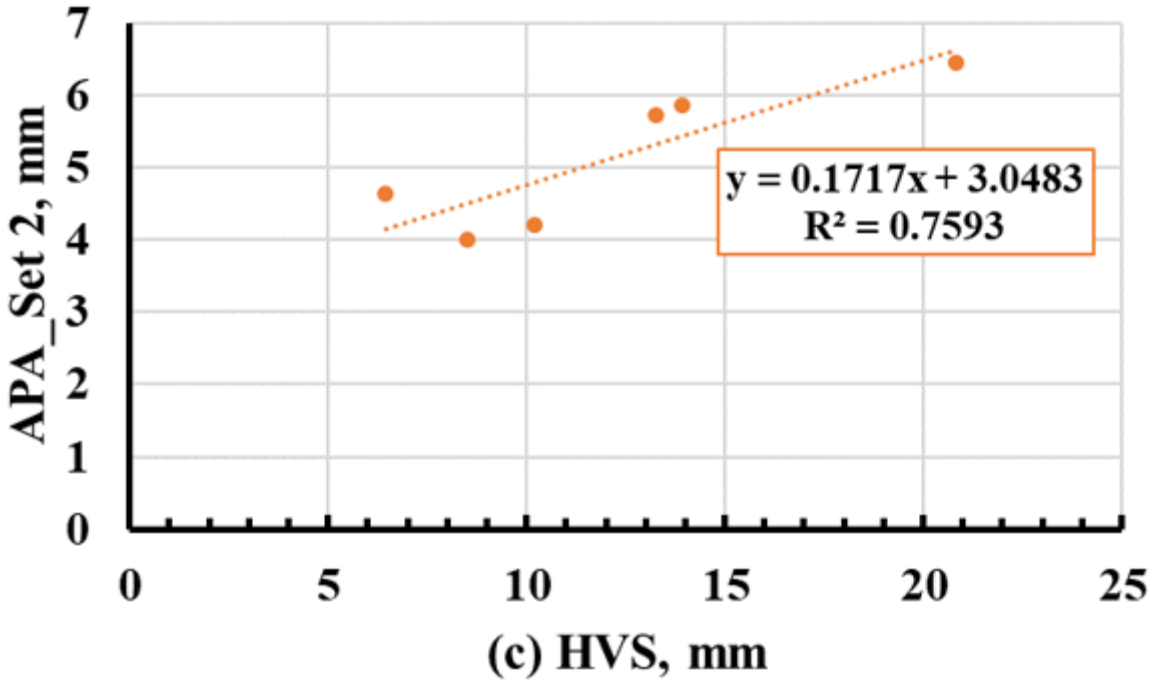
Production (VDOT)

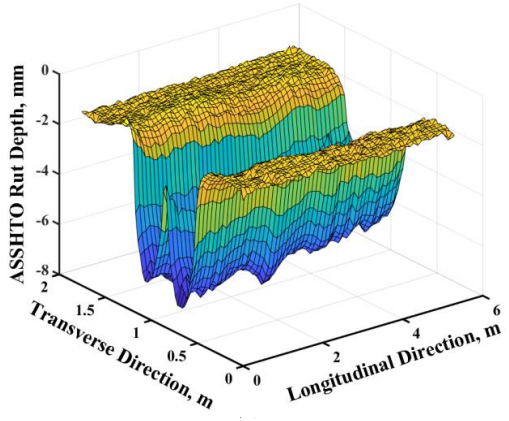
Volumetric Properties

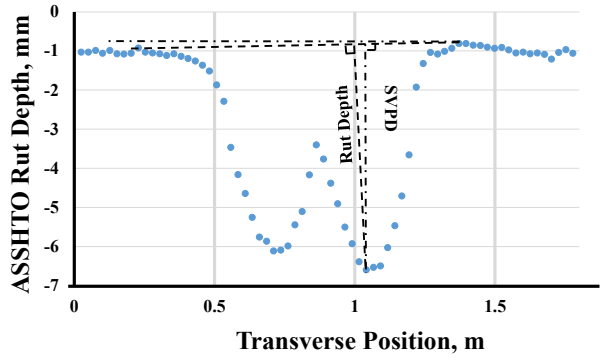
Mix ID	Mix I	Mix II	Mix III	Mix IV	Mix V	Mix VI
Composition	30% RAP + PG64-22	30% RAP + PG64-22	45% RAP + PG64-22	45% RAP + PG64-22 + RA	45% RAP + PG58-28	60% RAP + PG58-28 + RA
AC Content, %	5.6	6.1	6.8	6.2	6.1	5.9
VTM, %	4.1	6.2	0.6	2.3	2.7	1.4
VMA, %	16.9	19.8	16.4	16.7	16.9	14.9
VFA, %	75.8	69.0	96.5	86.3	84.3	91.0
FA Ratio, %	1.1	1.1	1.2	1.3	1.3	1.5
Pbe	5.4	5.9	6.5	6.0	5.9	5.6
Gmm, Rice	2.542	2.522	2.508	2.539	2.535	2.539

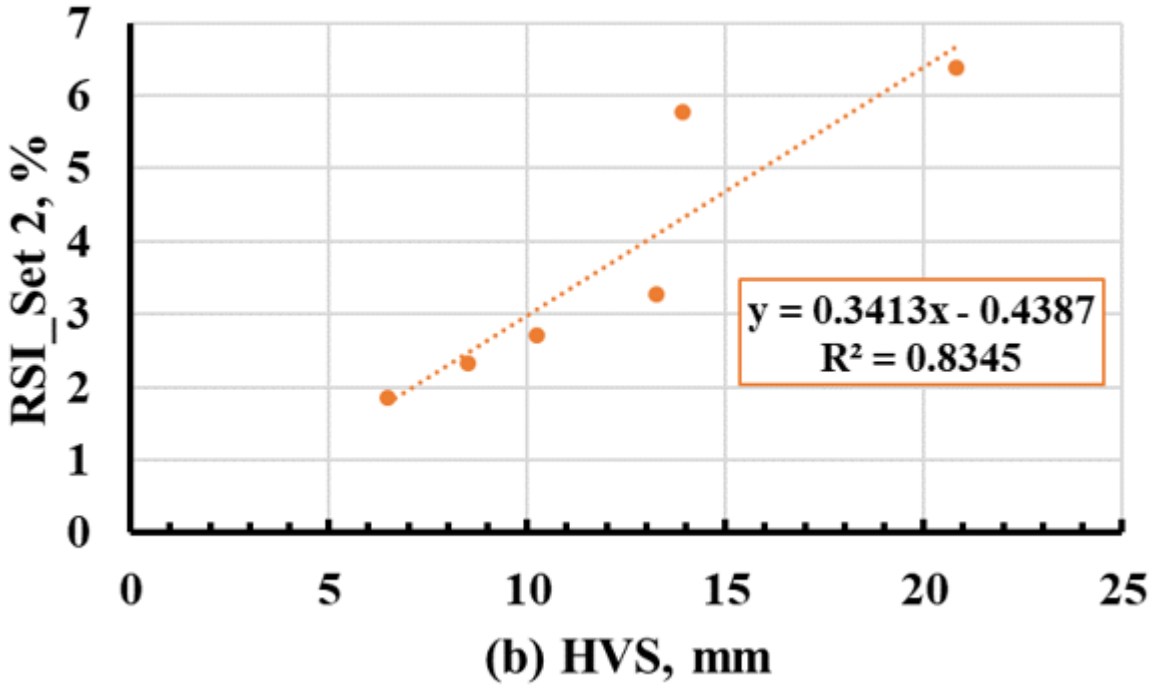
- Volumetric Properties on Production: ***by VTRC***

Preliminary Rutting Comparisons

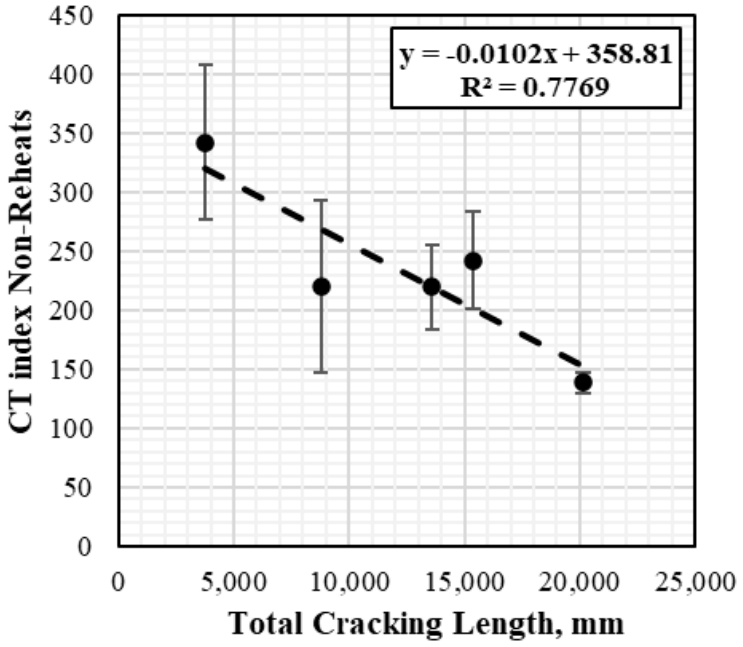


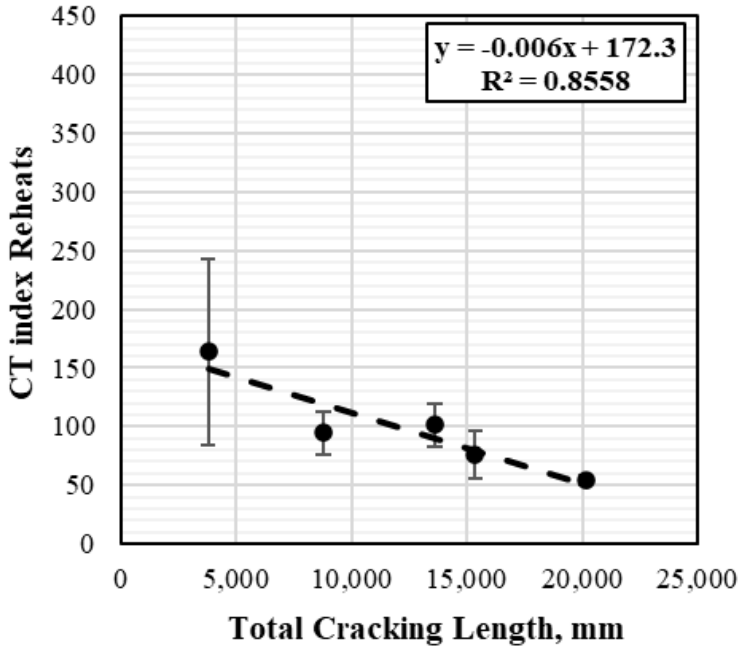


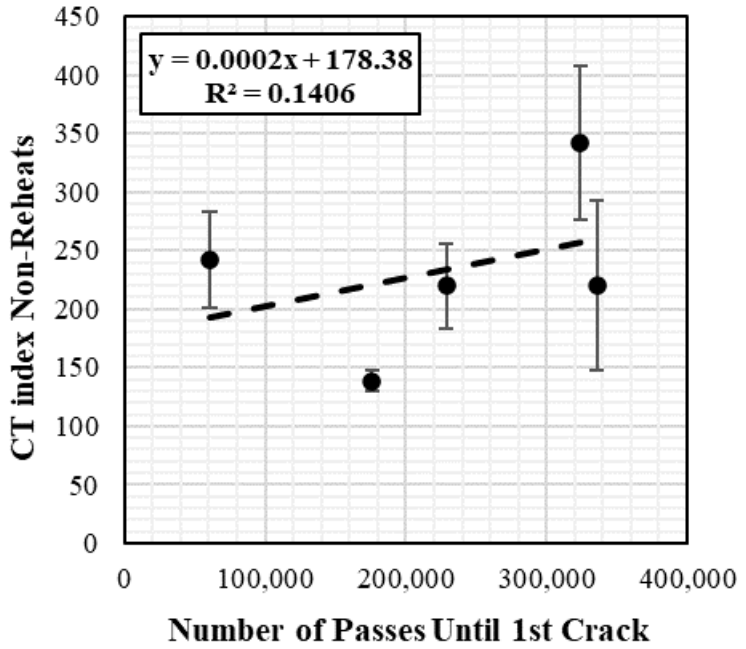




Preliminary Cracking Comparisons





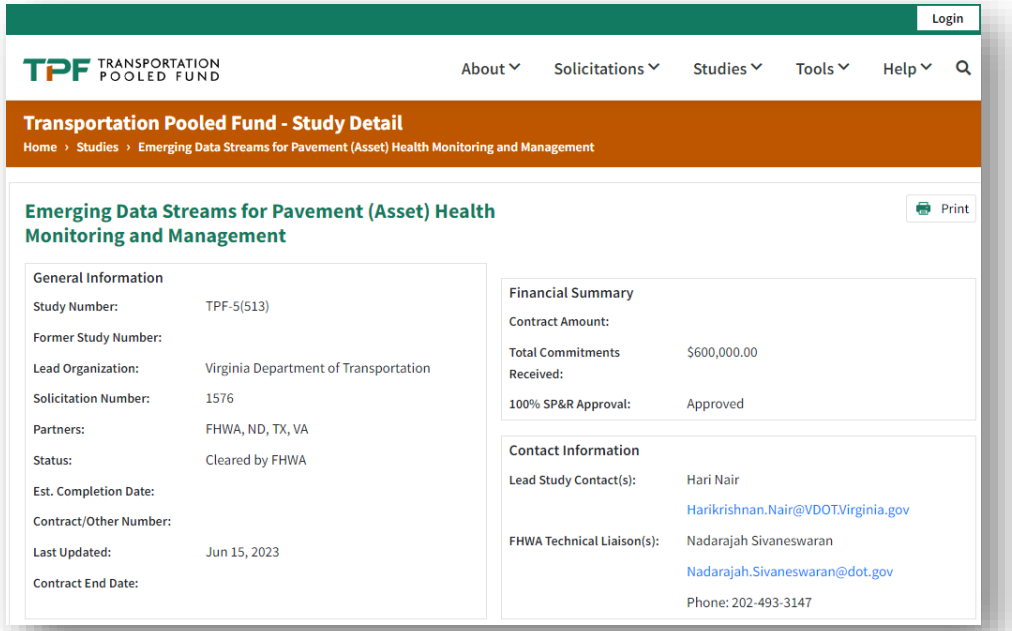


Preliminary Conclusions

- ✓ Surface Mixes with high RAP contents (45% or 60% by total weight of mixture), exceeding the conventional upper limit 30% set by the current specifications, can be designed using the current VDOT BMD special provision and can be successfully produced in the field.
- ✓ Rutting - Strong agreement was observed between the APT rut depth measurements and the APA test results collected in the laboratory. APA rut test is expected to reflect the true rutting performance.
- ✓ Cracking - Strong linear relationships between cracking and CT index were observed. Additional data from other field trials needed to reach final conclusions.

5. Examples of Starting and Future Initiatives

Vehicle-Based Data Collection



https://www.pooledfund.org/Details/Study/745

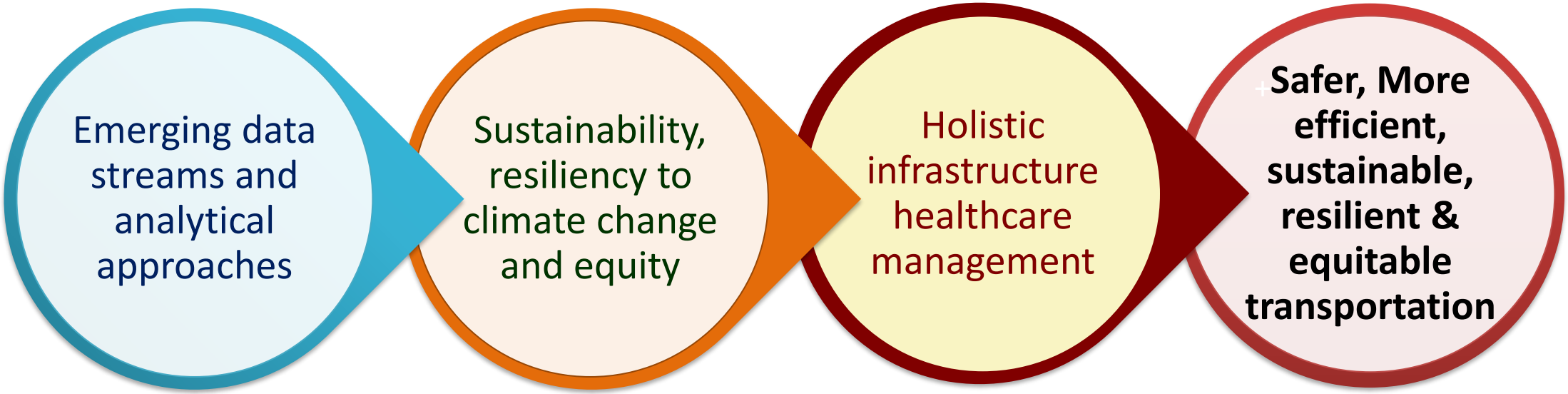
- ✓ Pooled-fund Emerging Data Streams for Pavement (Asset) Health Monitoring and Management

  Objective: Identify, test and evaluate emerging big data stream that may enhance the process we use to evaluate the performance and manage our pavement assets

  - **Vehicle response data (AV/CV)**
  - Smart infrastructure sensors (internet of things)
  - Smart construction and BIM (digital twin)

Transportation Infrastructure Healthcare Management

- ✓ Holistic healthcare approach, that leverages Big Data, Machine Learning, and Artificial Intelligence, to **better preserve and renew** our transportation infrastructure and provide **more climate resilient and equitable** solutions.
- ✓ This entails breaking down the silos that are currently pervasive in transportation agencies and promoting the activities of building a team of experts that can work as an expert team.



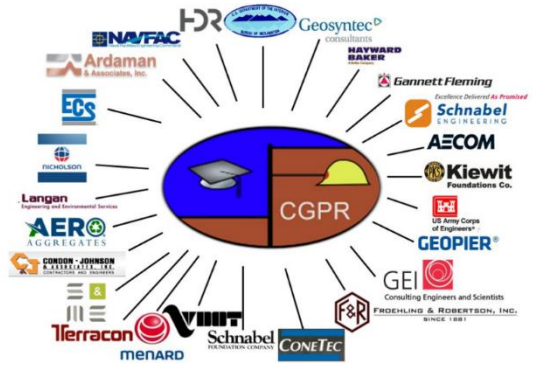
Ongoing ⇨ **Looking for Support**

Industry Affiliates

E.g.: Center for Asphalt Technology Practice and Research

- ✓ Mission (preliminary)
  - Expanded educational opportunities for students, practitioners, and others
  - Conduct research on asphalt-related problems of importance
  - Enhance the knowledge base and practice level of asphalt technology
- ✓ Examples of Potential Activities:
  - Innovative research
  - Hot topic workshops
  - Limited consulting
  - Literature searches
  - Distinguished Lectures
  - Endowed Laboratory
  - Endowed Chair
  - Periodic Seminars
  - Knowledge-sharing website

Funded by Donations



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VTTI Research Spotlight

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