Development of High Friction Surface Treatment (HFST) Prescreening Protocols and an Alternative Friction Application

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Northeastern States Materials Engineers Association (NEAMEA)
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(Somewhere from my house)

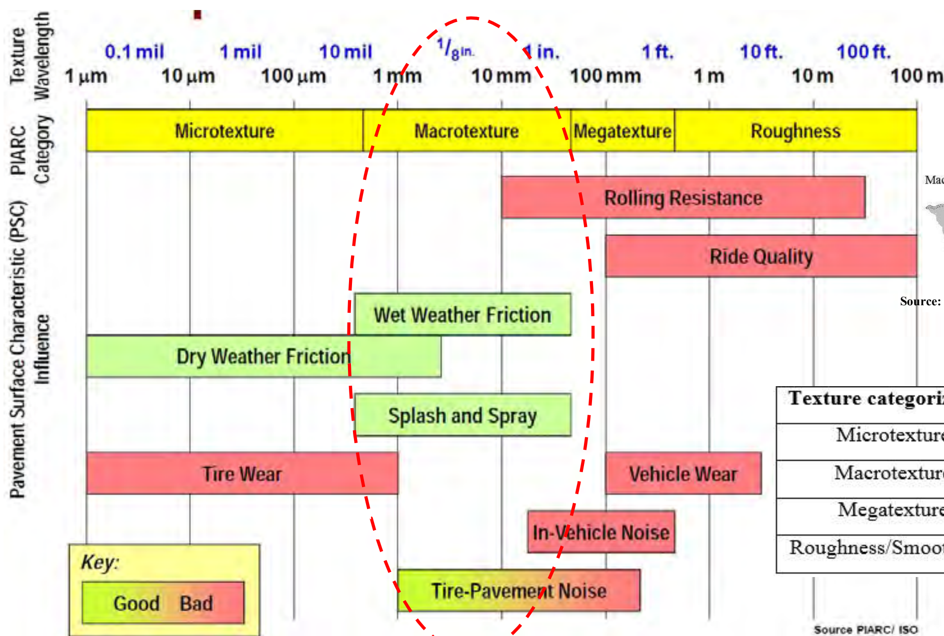
High Friction Surface Treatment (HFST)

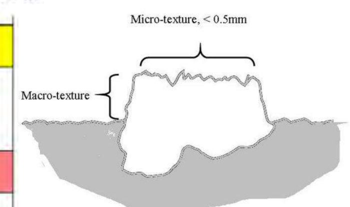
- Typically consists of calcined bauxite (polish resistant) bonded to pavement with polymer resin
- HFST installed as a thin overlay (< ½ inch)
- Applied as a single "surface"
- Used to improve frictional characteristics of pavement surfaces

Creating Pavement Friction Through Texture

Center for Sustainable Transportation Infrastructure

Texture Wavelength Influence on Pavement Surface Characteristics





Source: http://www.mto.gov.on.ca/

Texture categorization	Texture Wavelength (λ)
Microtexture	λ < 0.5 mm
Macrotexture	0.5 mm < λ < 50 mm
Megatexture	50 mm < λ < 500 mm
Roughness/Smoothness	0.5 m < λ < 50 m

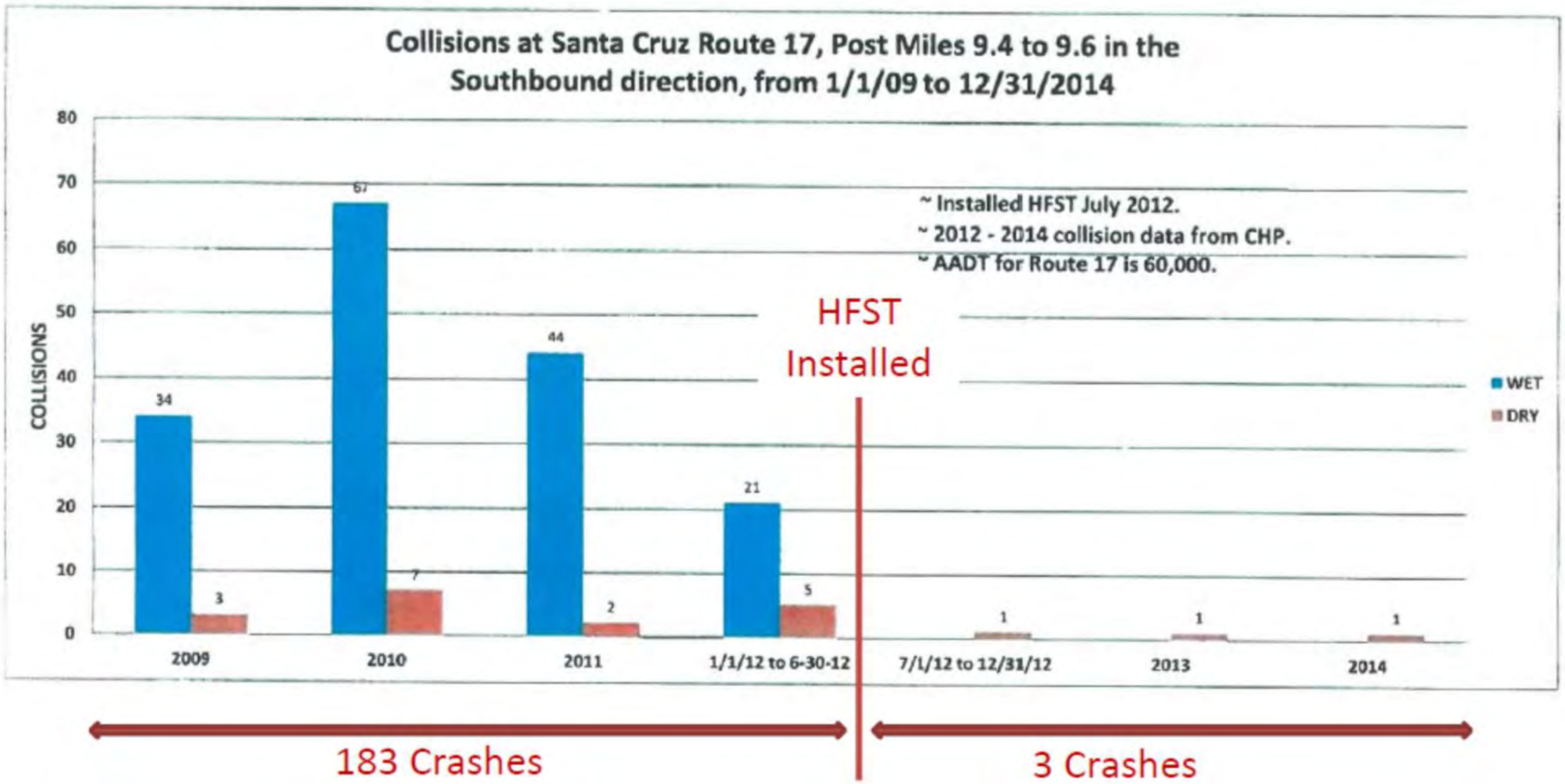
VirginiaTech Transportation Institute

Recommended Locations of HFST

- Horizontal curves*
- Intersections
- On and Off Ramps*
  - Elevation changes (loops ramps)
- Steep grades
- Line of Sight problem locations
- High speed connectors/merge locations
- High crash clusters, roadway departures or poor roadway friction conditions

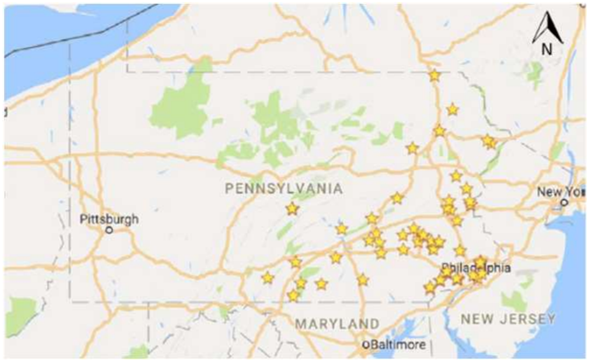
HFST Safety Benefits

CA Highway 17 at Laurel Curve



PennDOT Study (Musey et al., 2017 TRB)

- 74 sites across the state
- HFST reduced accident related injuries significantly, including NO FATALITIES



	Before	After	Crash Reduction	% Reduction
Simple Before-After Analysis				
Fatal	6	0	-6	100.0
Major Injury	9	4	-5	55.6
Moderate Injury	29	8	-21	72.4
Minor Injury	98	9	-89	90.8
PDO	265	37	-228	86.0
Unknown Injury	72	6	-66	91.7
Total	**479**	**64**	**-415**	**86.6**
Average Crashes Per Year				
Fatal	3	0	-3	100.0
Major Injury	6	3	-3	48.9
Moderate Injury	22	5	-17	79.3
Minor Injury	70	8	-62	89.0
PDO	171	41	-130	76.0
Unknown Injury	44	6	-38	86.6
Total	**315**	**62**	**-253**	**80.3**

State Agency HFST Studies

- Kentucky

The Kentucky Transportation Cabinet installed HFSTs at selected locations with a history of wet roadway departure crashes.

HFSTs were one of the eight countermeasures identified when the Kentucky Transportation Cabinet implemented a statewide Roadway Departure Safety Plan to address problem curve sites. They identified a list of the 30 worst curves: 15 for wet crash and 15 for total crash. Additionally, 10 of the worst ramps were also selected. One such location is Oldham County, KY 22. Through a 4-year before-and-after (August 2007 to August 2011) study period, lane-departure crashes were reduced from 47 crashes in the 2 years before to only 5 crashes in the 2 years after.

Oldham County, Kentucky, KY 22

- Washington State

HFST at the intersection of Forest Drive and Cole Creek Parkway in Bellevue, Washington results in 78 percent fewer accidents per year

Associated accident costs dropped by 83 percent

The City of Bellevue in Washington State installed the HFST 'Tyre-grip' on the westbound approach of Forest Drive at its intersection with Cole Creek Parkway in Bellevue in October 2004 (resurfaced again in May 2007 due to a surface water issue). This is a downgrade intersection approach often affected by icy weather conditions. Approximately 35,000 vehicles use the westbound approach weekly. Bellevue tried several countermeasures, including installing a large flashing warning sign at the bottom of the grade, additional road markers, new street lights, and raised pavement buttons, but did not achieve the desired result. After applying HFST, accidents at this intersection dropped 78% and costs associated with accidents declined by 83%.

HFST Roadway Applications Do's and Don'ts (FDOT, 2016)

Pavement condition	
• Dense-graded asphalt or concrete. • Pavement condition rating of "Good" and higher. • Polished surface. • Highly oxidized. • Few low-severity cracks. Very few cracks greater than 0.25 inch Wide. • Minor rutting ≤ 0.25 inch. • No structural damage.	• Open-graded asphalt (OGFC) • Asphalt pavements with 6+ percent of cracking in or outside the wheel paths. • Widespread rutting > 0.25 inch deep. • Raveling surface. • Bleeding pavement. • Areas where layer debonding or subsurface stripping is suspected. (Verify with coring and other pavement forensics.) • Concrete single slab with moderate or severe distress, patching, or shattered in more than 3 pieces.
Where to Use	**Where Not to Use**

What is a “Good” Pavement for HFST?

- A prerequisite for HFST application is a “good” pavement
- Pavement screening extremely important in success of HFST
  - How do you define “good”?
    - No cracking
    - No rutting
    - Fairly “new”
    - Can a “new” or “visually good” asphalt pavement actually be “old” or prone to durability issues?

What is a "Good" Pavement for HFST?

- Asphalt mixture factors that accelerate aging, cracking, and raveling in asphalt pavements
  - Low asphalt contents
  - High dust content
  - Excessive production temperatures
  - Recycled asphalt
    - Recycled Asphalt Pavement (RAP)
    - Recycled Asphalt Shingles (RAS)

NJ County Roads SR511 & SR700

Our Story Begins in North Jersey…

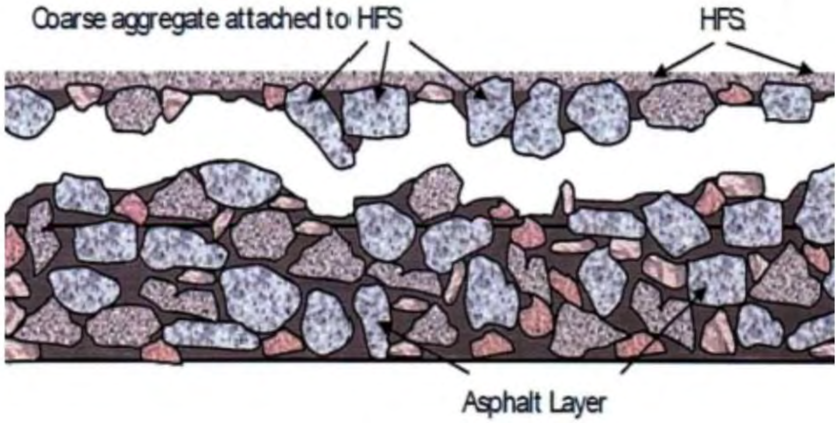
- Both county roads received HFST application in 2017
  - CR511:
    - 8 to 13 inches of HMA over gravel base;
    - Recent HMA overlays from 2012 to 2015;
    - Visual distress survey showed pavement in "relatively good" condition (some deterioration near shoulder areas due to poor drainage)
  - CR700:
    - 8 to 9 inches of HMA over gravel base;
    - Recent HMA overlays from 2013 to 2015;
    - Visual distress survey showed pavement in "relatively good" condition

NJ County Roads SR511 & SR700

- Late Winter/early Spring 2018, pavement distress began showing up

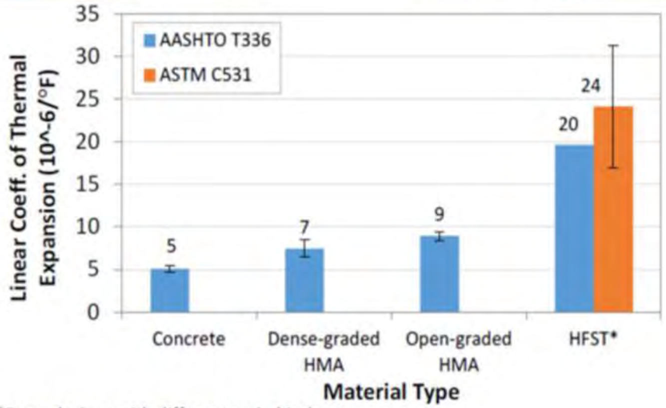
HFST Distresses and Possible Causes

- Substrate Failure – Top-down & Shallow Horizontal Cracking
  - Due to weak substrate
  - Areas of extreme stopping & slow turning
  - Thermally induced stress
  - Excessively thick & stiff HFST layer (epoxy)



HFST Distresses and Possible Causes

- Substrate Failure – Top-down & Shallow Horizontal Cracking
  - Typically ¼" to ½" deep
  - Epoxy and asphalt mixtures are thermally incompatible
    - Epoxy has an expansion/contraction rate 3 to 4 times greater than asphalt mixtures
    - Worst situation – cool/cold temperatures with a quick, large temperature decrease



*From designs with different resin binders

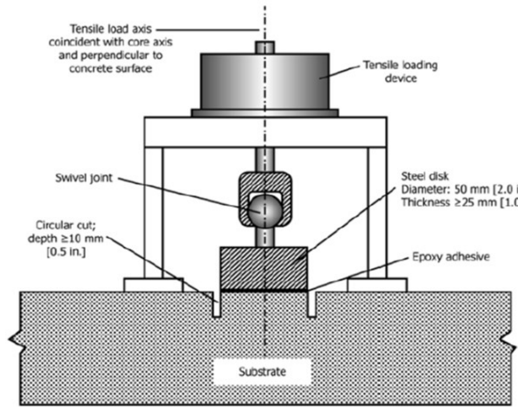
Need for a Prescreening Protocol

- The current guidance of “good condition” for asphalt pavements is not adequate for such an investment
  - Immediate need for a method to characterize existing asphalt pavements prior to HFST application
  - In addition, if the pavement is shown to not be a candidate, is there a similar “system” compatible with the existing pavement?

Proposed Testing Protocols for HFST Prescreening

Proposed Prescreening Methods

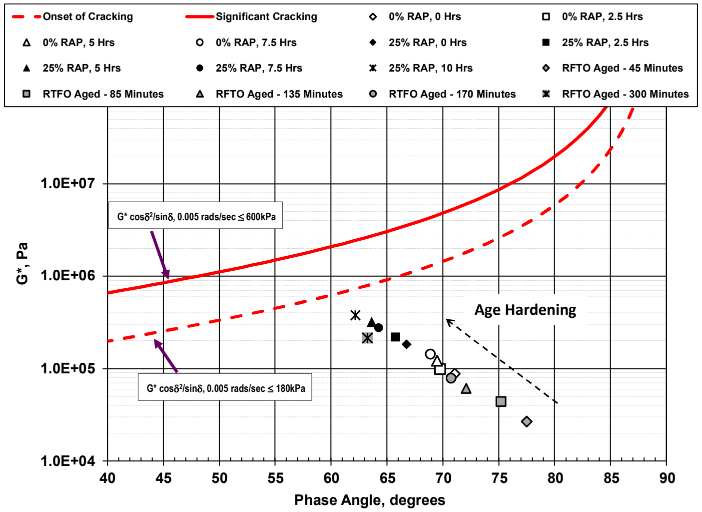
- Test methods selected;
  - ASTM C1583 – testing pull-off strength of existing substrate tested at 25°C
    - 6 inch field cores work well
  - Asphalt binder characterization from upper ½" to ¾" of existing asphalt pavement for "durability"
    - Glover-Rowe Parameter
    - ΔTc (Difference in critical low temperature cracking)



Glover-Rowe Parameter (G-R)

- Rowe (AAPT, 2011) proposed the DSR master curve analysis to calculate the "Glover-Rowe" parameter
  - As G-R parameter increases, the binder is more prone to fatigue cracking
  - Correlates very well to ductility of asphalt binder
    - G* = shear modulus (stiffness of asphalt binder)
    - δ = phase angle (relaxation of asphalt binder)

$$\frac{|G*|(\cos\delta)^2}{\sin\delta}$$

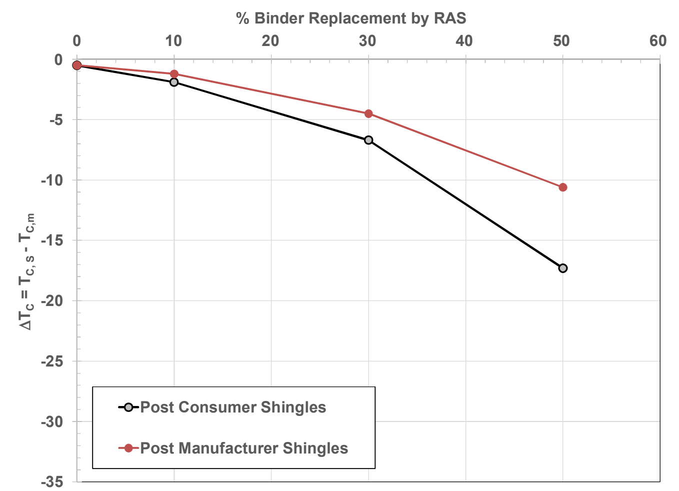


ΔT_c from BBR Testing

- As asphalt binders age, the relaxation properties (m-value) are negatively affected at greater rate than the stiffness (S)
- The difference between the low temperature cracking grade of m-value and S is defined as the ΔT_c

$$\Delta T_c = T_{c,\,S} - T_{c,\,m\text{-value}}$$

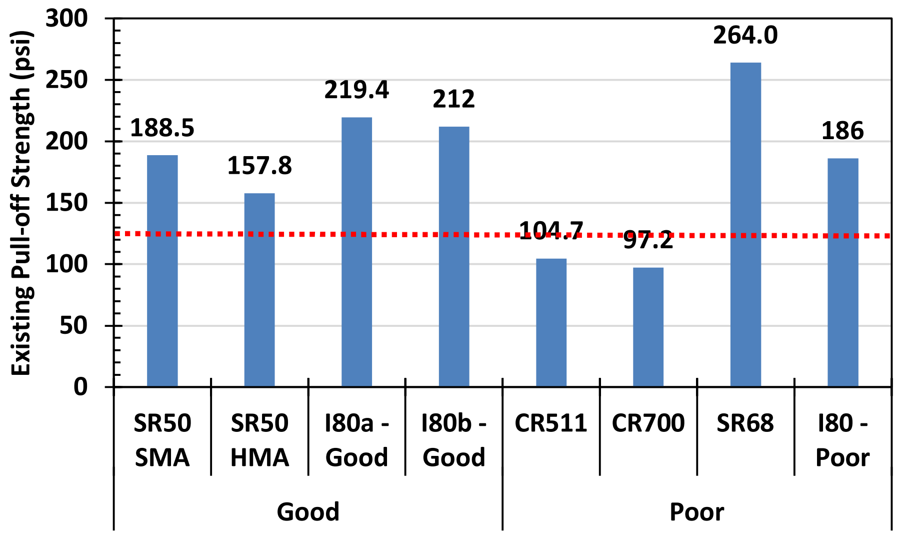
- Anderson et al. (2011) showed that the ΔT_c correlated to non-load associated cracking on airfields (i.e. – cracking due to lose of ductility from aging)
  - The more negative value, the more aged the asphalt binder



HFST Prescreening Test Results

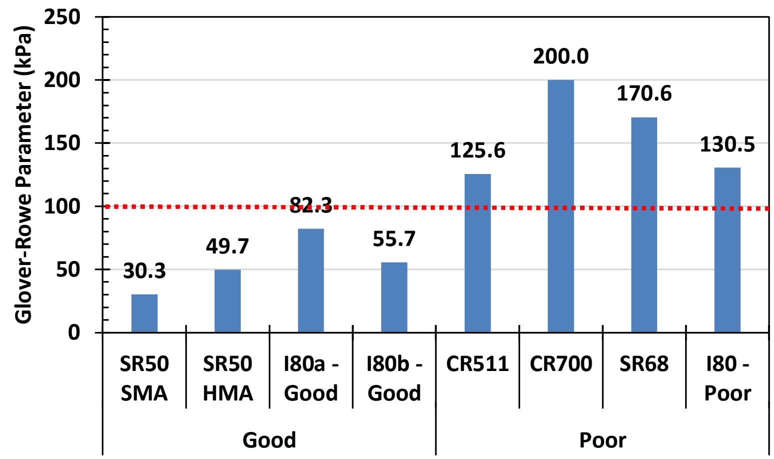
HFST Performance and Testing in NJ

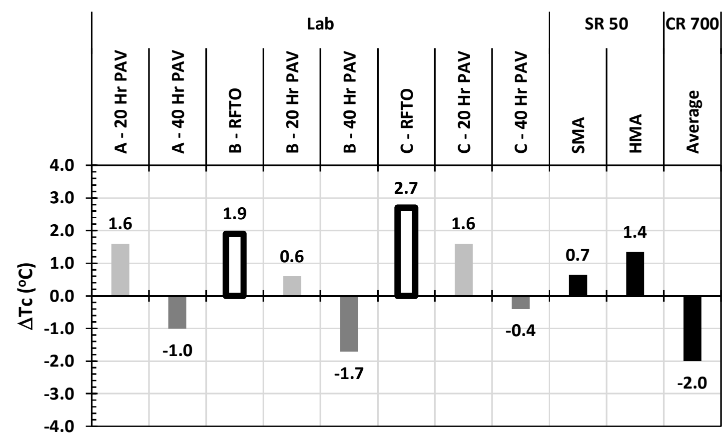
- Substrate testing of 5 different pavement sections (8 different performing areas)
  - Results indicate that pull-off testing alone may not be able to predict suitability of substrate for epoxy resin-based HFST
  - For CR511 and CR700, there was noticeable lower strength compared to other sections



Failed HFST Sections – Asphalt Binder Characterization

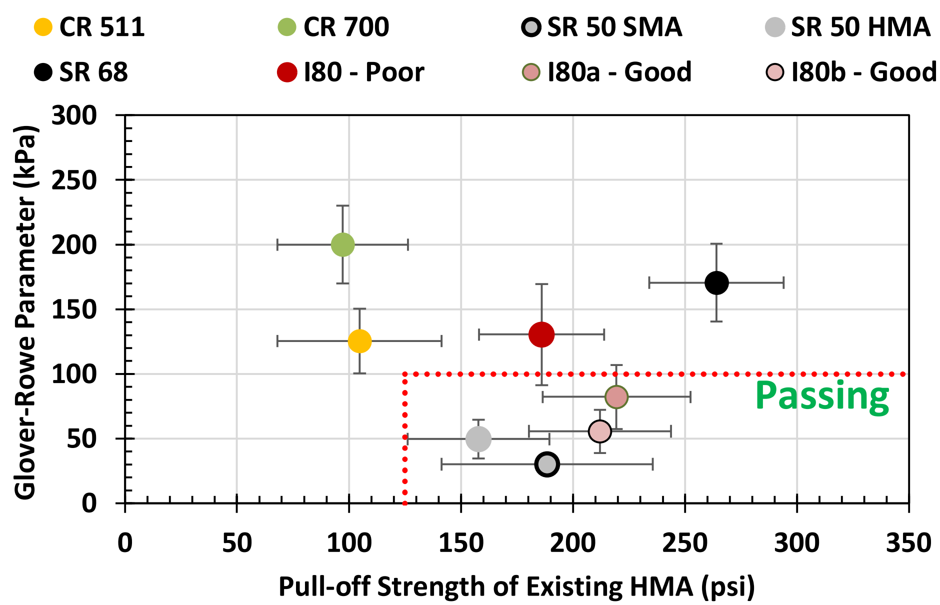
- Recovered the asphalt binder for ½" to ¾" of surface
  - "Good" HFST performance was identified with Glover-Rowe < 100 kPa
  - ΔTc indicated values "warmer" than 0°C
    - Some projects not able to be tested due to limited material





Preliminary HFST Prescreening Criteria

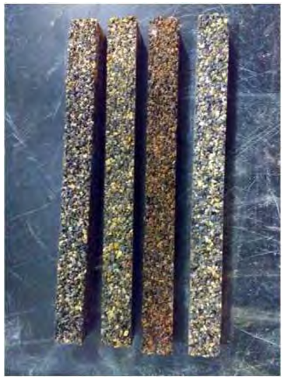
- Even though a pavement is visually in “good condition”, asphalt may still be prone to raveling/durability issues of “aged” asphalt
  - Binder testing to address quality of asphalt binder in existing pavement surface
  - Mix testing to address quality of mix strength properties in existing pavement surface

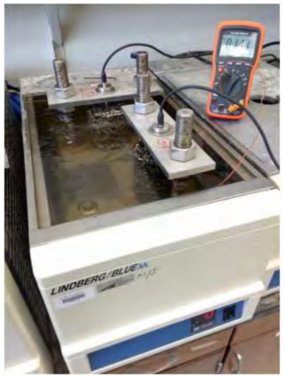


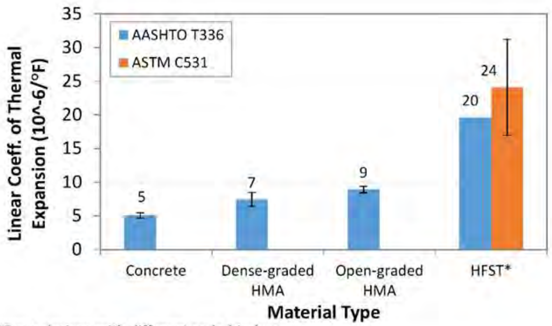
Potential Alternative to HFST – NJDOT High Friction Chip Seal (HFCS)

Route 68 High Friction Chip Seal (HFCS) Case Study

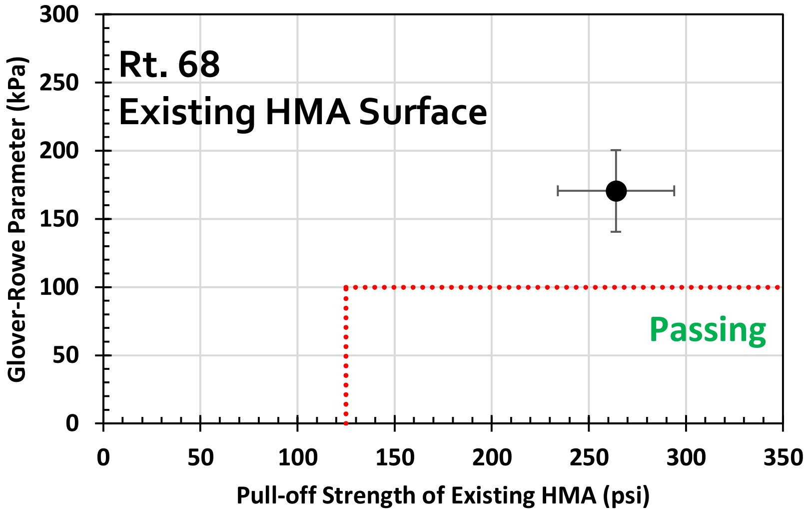
- What if we tried high friction aggregate with a highly modified asphalt binder?
  - Asphalt-based binding system more thermally compatible than epoxy resin
  - High PG to maintain stiffness in hot temperatures
  - Low PG properties to aid in thermal contraction movements





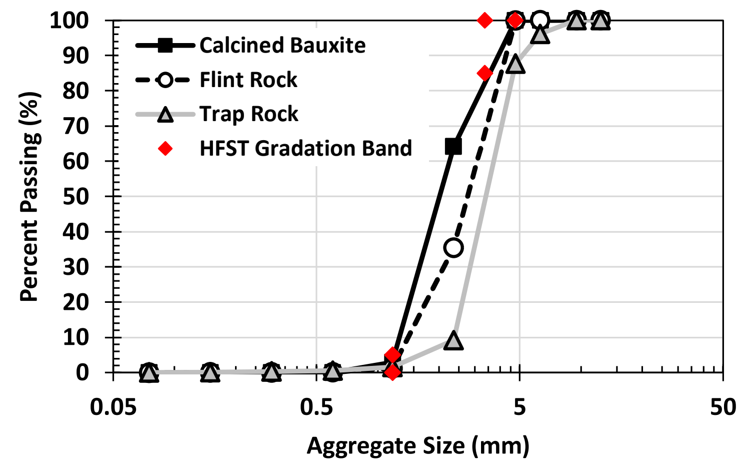


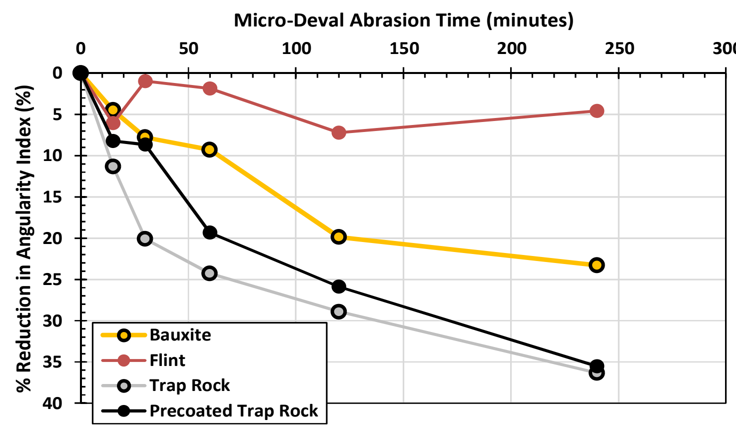
*From designs with different resin binders



Route 68 High Friction Chip Seal (HFCS) Case Study

- Looked at using a chip seal process using hard, angular stone
- Evaluated different aggregate sources
  - Diabase (NJ) – Lane 1
  - Calcine Bauxite – Lane 2
  - Flint Rock (OK) - Shoulder
- Compared aggregate “polishing” resistance
  - Utilized micro-deval & Aggregate Imaging to assess polishing resistance (Masad et al., 2011)





HFCS Materials and Application

- Asphalt binder met the requirements for FAA P404, *Fuel Resistant (FR) Asphalt Mixture*
  - PG88-22 with Evotherm applied hot 0.3 to 0.38 gal/yd^2
- Aggregate “chips” spread at 14 to 18 lb/yd^2
- Rubber wheel rollers to seat aggregate & loose aggregate swept



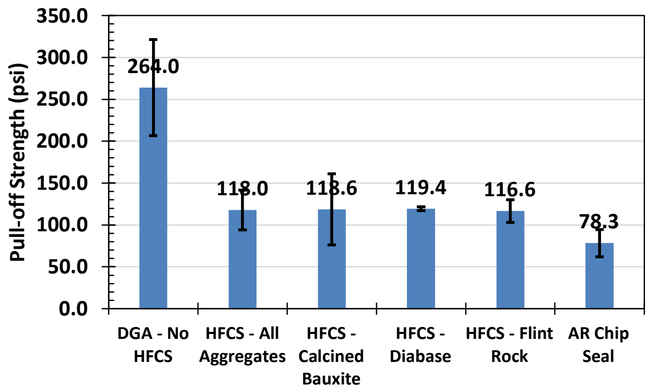
NJ Route 68 High Friction Chip Seal (HFCS)

Diabase Aggregate

Calcine Bauxite

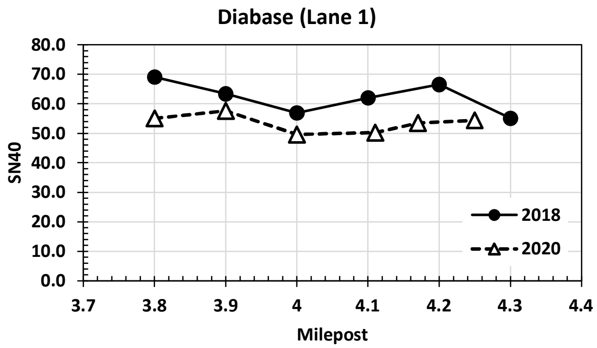
Pull-off Strength of HFCS

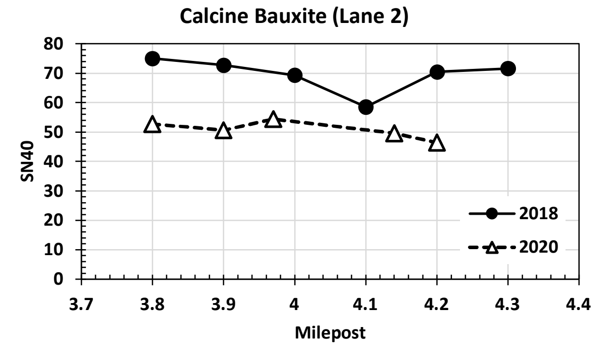
- Looked at pull-off strength of HFCS applied to Rt. 68 surface
  - Could aggregate get pulled out of HFCS binder?
- Results were consistent for aggregate (Average ≈ 118 psi) and failures occurred between binder and pavement surface
  - Pull-off strength statistically greater than adjacent asphalt rubber chip seal



Skid Resistance, SN40 (ASTM E274)

- Skid Testing was conducted in accordance to ASTM E274
  - Initial results looked good (SN40 Ave > 60)
  - After 2 years, values dropped around 10 to 20%
    - Skid friction influenced by bleeding of adjacent asphalt rubber chip seal major issue





Conclusions

- HFST surfaces can provide significant improvement in surface friction to reduce lane departure accidents
  - However, lack of quantifiable prescreening criteria may result in premature HFST failures
- Proposed prescreening would utilize recovered field cores to evaluate pull-off strength and relative asphalt binder aging prior to HFST placement
  - More information required to "fine tune" and validate proposed criteria
- High Friction Chip Seal (HFCS) possible alternative for existing pavements with marginal substrate conditions
  - Thermally compatible and provides high level of friction
  - Similar systems being evaluated at NCAT test track

Thank you for your time!

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