PAVEMENT FRICTION SURFACE TREATMENTS

A SYSTEMIC SAFETY APPROACH FOR HORIZONTAL CURVES ON SOMERSET COUNTY ROUTES

Somerset County Engineering

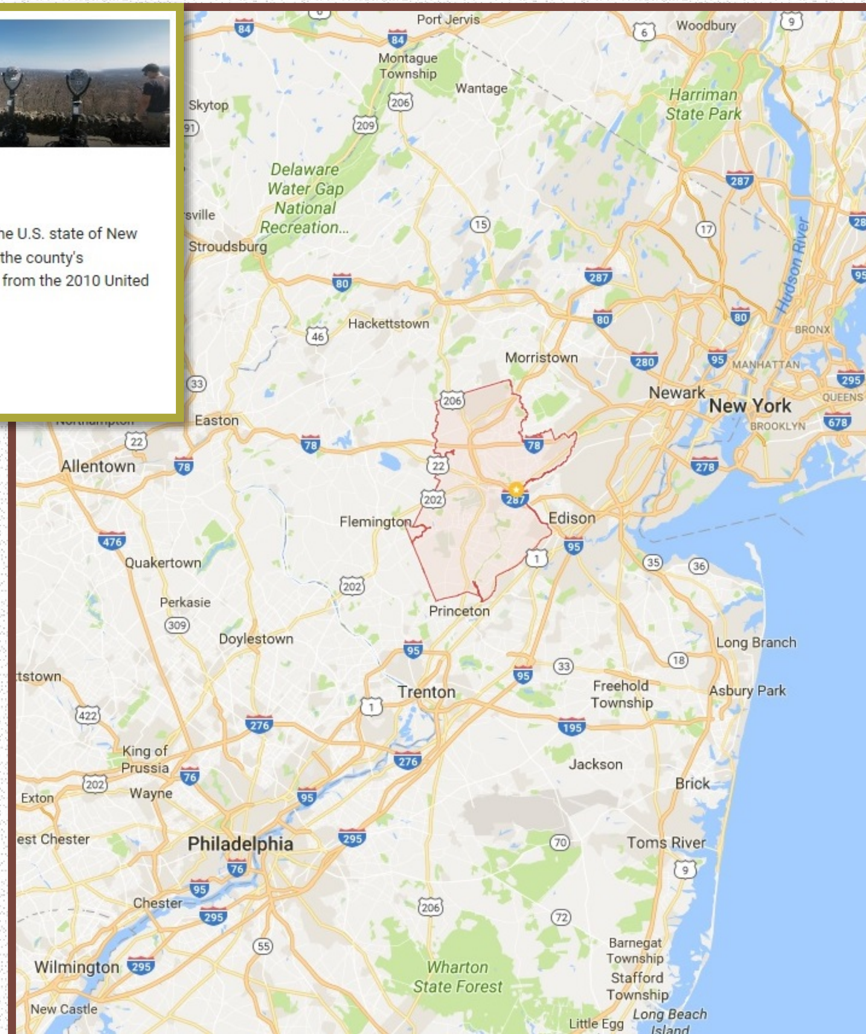
Presented by Patricia Bates Smith

Principal Engineer, Highway

SOMERSET COUNTY
EST'D 1688
MAKING VIBRANT CONNECTIONS
NEW JERSEY

Somerset – who are we?

Engineering office with:
- Staff of 36 people
- In 10 different disciplines
- Managing infrastructure including:
    - 250 miles of County Roads
    - 193 traffic signals
    - 762 bridges
    - As well as county sites, facilities and parks.



Annually, we resurface 15 miles of road, reconstruct 1.5 miles road, replace 7 bridges, install or upgrade 10 traffic signals, and replaced more than 150 ADA curb ramps.

Annual budgets for road and bridges:

$9 - $18 million, County Capital

$6 million, State Aid

$ vary, Federal Aid - based on the project

Somerset County – Local Safety Projects

Program	Project	Town	Description	Grant Amount	Length (miles)	Project Status
2010 LSP	Hamilton St (CR 514) & Franklin Blvd (CR 617)	Franklin	Traffic signal modifications and upgrade, left turn lanes, resurfacing, ADA ramps.	$190,000.00	N/A	completed
2011 LSP	Overheight vehicle detectors	Manville, South Bound Brook	Installation of 2 height detection at approaches to low railroad overpasses, 533 in Manville, 527 in South Bound Brook	$170,000.00	N/A	completed
2012 LSP	North Bridge St & Cliff St intersection	Somerville	Installation of a new traffic signal	$150,000.00	N/A	completed
2012 LSP	Easton Ave (CR 527) & Foxwood Dr.	Franklin	Traffic signal modifications and upgrade: dedicated left turn lanes, pedestrian signals	$220,000.00	N/A	completed
2012 HRRR	New Centre Rd (CR 627)	Hillsborough	Rural road safety measures including, pavement repair, resurfacing, micro-mill friction course, wet weather high visibility traffic stripes	$490,000.00	1	completed
2013 HRRR	River Rd (CR 627)	Hillsborough	Rural road safety measures including, pavement repair, resurfacing, micro-mill friction course, wet weather high visibility traffic stripes	$380,000.00	0.8	completed
2014 LSP	Promenade Blvd (CR 685)	Bridgewater	Safety measures on 4 lane urban drive: Road diet, medians, cross walks, curb ramps, sidewalk extension.	$750,000.00	0.65	completed
2014 HRRR	Bedminster Safety Improvements including Pottersville Rd (CR 512), Lamington Rd (CR 523) and Burnt Mills Rd (CR 620)	Bedminster	Rural road safety measures including pavement repair, resurfacing, High Friction Surface Course on horizontal curves, wet weather high visibility striping, pavement safety edge, driveway aprons, new signage and delineators.	$4,125,000.00	10	completed
2014 LSP	Chimney Rock Rd (CR 525)	Bridgewater	Rural road safety measures including pavement repair, resurfacing, High Friction Surface Course on horizontal curves, wet weather high visibility striping, pavement safety edge, new signage and delineators.	$400,000.00	1	completed
2015 LSP	Mountain Ave (CR 642)	North Plainfield	Local Safety suburban street including: 2 traffic signal modifications and upgrades, ADA ramp compliance, striping.	$960,000.00	1.3	completed
2015 LSP	Washington Ave (CR 529) & Greenbrook Rd (CR 634)	Green Brook	Local Safety suburban street including: traffic signal replacement, Road Diet, RCP culvert replacement, ADA curb ramp compliance.	$780,000.00	0.4	completed
2016 LSP	Main St (CR 533)	Manville	Local Safety suburban street including: 5 traffic signal modifications, 1 traffic signal replacement, Road Diet, ADA ramp compliance, resurfacing, striping.	$3,000,000.00	1.1	prelim design
2017 LSP	Easton Ave (CR 527) & Demott Lane	Franklin	Safety measures on 4 lane arterial roadway including: traffic signal modifications, barrier upgrades, ADA ramp compliance, rehabilitation of existing HMA bikepath including ADA compliance.	$1,440,000.00	0.8	consultant award
2017 round-about	Allen Road (CR 652) and Somerville Road Roundabout	Bernards	Installation of a modern roundabout at an existing 4-way stop controlled intersection that is seeing high crash rates.	-	0.2	consultant award
				$13,055,000.00		

(Shaded) Projects that applied a pavement surface treatment

Surface Friction Treatments – How did we get started?

… there was a need.

- 2006 police concern for crashes on Warrenville Hill:
- 14% grade at steepest;
- Substandard S-bend horizontal alignment;
- Driveways and side streets;
- Route 22 approach at near 10% gradient.

'Warrenville Hill', CR 651 north of Route 22.

Suddenly, safety became measurable.

The availability of crash data from the Plan4Safety crash database allowed our office, as well as our MPO, to look at crash trends around the region.

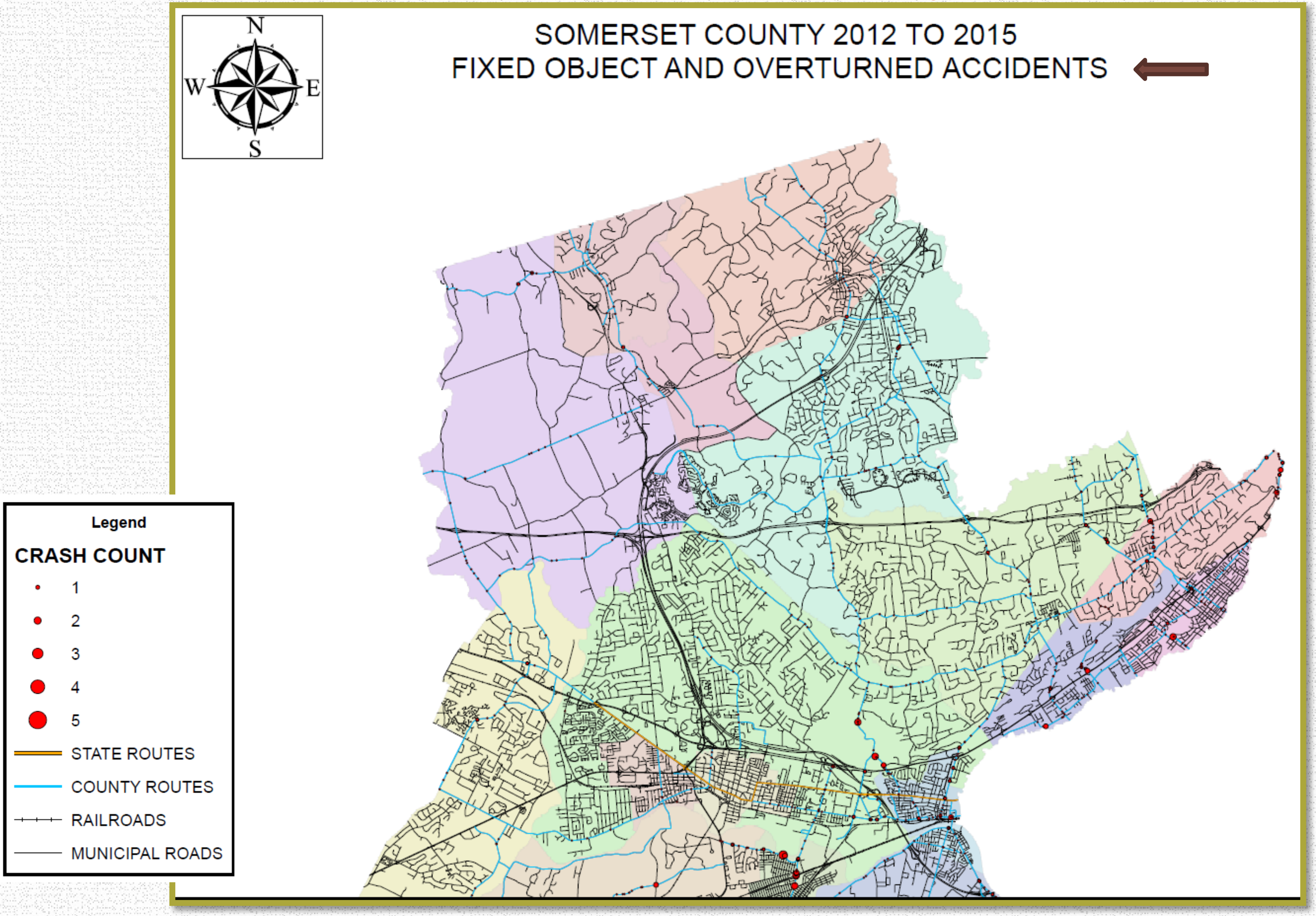
This provided us the data to start planning for infrastructure improvements based on locations of need and type of issues occurring.

DATE TEXT	CRAS	(	(	CRASH_TIME	CRASH_TYPE	CRASH_	CROSS_STREET	DIRECTION_FR	DISTANCE	I	I	ENVIRONM	I	H	INTERSECTION	I	I	LIGHT_CONDIT
1/17/08	Thurs		Ja	5:50 PM	Opposite Direc	2008	LISK HILL RD	NULL				Snow	I	N	At Intersection	I		Dark (No Street
2/8/08	Frida		Fe	6:56 AM	Animal	2008	LARGER CROSS	East	500			Clear	I	N	Not At Intersec	I		Daylight
2/13/08	Wed		Fe	8:11 AM	Fixed Object	2008	LARGER CROSS	West	1584			Rain	I	N	Not At Intersec	I		Daylight
3/8/08	Satur		M	3:00 PM	Fixed Object	2008	SOUTHFIELD D	East	1000			Rain	I	N	Not At Intersec	I		Daylight
5/20/08	Tues		M	5:30 PM	Fixed Object	2008	RT 206	East	528			Rain	I	N	Not At Intersec	I		Daylight
9/26/08	Frida		Se	6:25 PM	Fixed Object	2008	LISK HILL ROAD	East	100			Rain	I	N	Not At Intersec	I		Daylight
10/6/08	Mon		Oc	6:14 PM	Fixed Object	2008	SOUTHFIELD D	East	2112			Clear	I	N	Not At Intersec	I		Daylight
10/25/08	Satur		Oc	8:35 AM	Other	2008	LISK											
12/15/08	Mon		De	4:21 PM	Right Angle	2008	OLD											
12/22/08	Mon		De	5:11 PM	Animal	2008	LARG											
12/23/08	Tues		De	6:00 PM	Animal	2008	LARG											
12/23/08	Tues		De	2:37 PM	Fixed Object	2008	SOU											
1/17/09	Satur		Ja	10:24 AM	Animal	2009	FOW											
1/19/09	Mon		Ja	5:02 PM	Fixed Object	2009	LISK											
9/13/09	Sund		Se	1:48 AM	Fixed Object	2009	LISK											
9/21/09	Mon		Se	8:50 AM	Right Angle	2009	SOU											

SOMERSET COUNTY
LOCAL SAFETY PROGRAM
CORRIDOR RANKINGS BY WEIGHTED SEVERITY
CRASH DATA: 2010-2012

County Rank	NJTPA Region Rank	County	Municipality	SRI	Milepost Start	Milepost End	Total Crashes	Fatal	Incap
1	17	SOMERSET	Franklin Twp (Somerset Co)	527	48.08	49.08	269	0	0
2	45	SOMERSET	Franklin Twp (Somerset Co)	514	22.35	23.35	191	1	0
3	46	SOMERSET	Franklin Twp (Somerset Co)	527	49.25	50.25	220	0	2
4	77	SOMERSET	Franklin Twp (Somerset Co)	527	50.95	51.95	287	0	0
5	97	SOMERSET	Manville borough	533	27.87	28.87	228	0	2
6	113	SOMERSET	Bridgewater township	533	29.64	30.64	127	1	0
7	141	SOMERSET	Franklin Twp (Somerset Co)	18000617	0.87	1.87	112	0	1
8	212	SOMERSET	Franklin Twp (Somerset Co)	514	19.11	20.11	168	0	0
9	237	SOMERSET	Franklin Twp (Somerset Co)	514	20.46	21.46	115	0	0
10	301	SOMERSET	Franklin Twp (Somerset Co)	18000619	1.69	2.69	100	0	1
11	304	SOMERSET	North Plainfield borough	18000636	0.92	1.92	77	0	0
12	318	SOMERSET	Watchung borough	531	10.76	11.76	104	0	0
13	353	SOMERSET	Branchburg township	18000614	0	1	136	0	0
14	399	SOMERSET	Franklin Twp (Somerset Co)	18000623	2.33	3.33	73	0	0
15	408	SOMERSET	Watchung borough	18000655	0	1	114	1	0

Then, we could evaluate the whole County for crash trends



What now to do with this information? Friction treatments!

Because of County wide crash analysis we could now see which areas needed further investigation for possible safety improvements

- friction courses gave us a tool to use at horizontal curves. But, we still had questions:

- What was the correct friction treatment method?
- When is it warranted?
- How to determine the length of need on a horizontal curve?

VARIOUS LOCATIONS - KENTUCKY

Kentucky Transportation Cabinet . Automated High Friction Surfacing Treatment

BROCHURE www.dbiservices.com

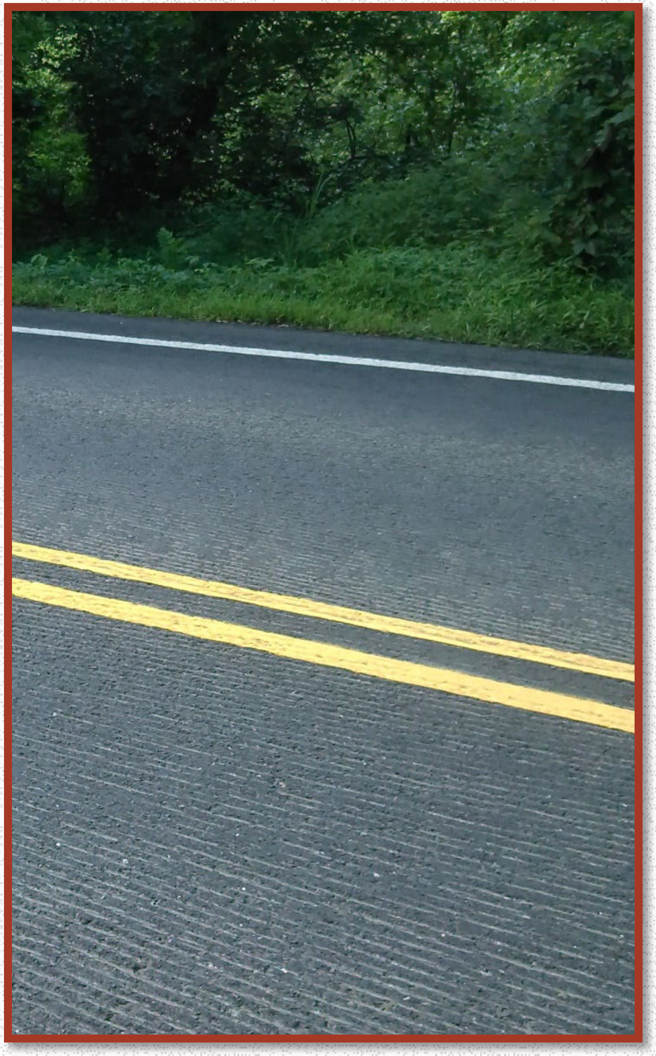
Micro milling – our initial solution.

Pros:

- Provided high friction surface which reduced 'run-off-road' type crashes
- Low cost of installation
- Installation by local pavement contractors

Cons:

- Short life expectancy with surface due to moisture penetration, oxidation, and friction loss.
- Complaints from motorcyclists and bicyclists
- Poor image portrayed to the public of milling off new pavement surface.



Next came … High Friction Surface Treatment!

PROS:
- Promoted by FHWA as proven safety measure (NCHRP Document 108)
- Safe for all vehicle types
- Longer life expectancy than micro-milling (due to microtexture of aggregate used).

CONS:
- High cost
- Specialize trade needing sub-contracting work added to paving contracts.

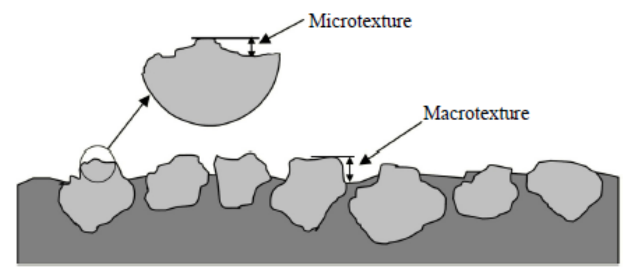
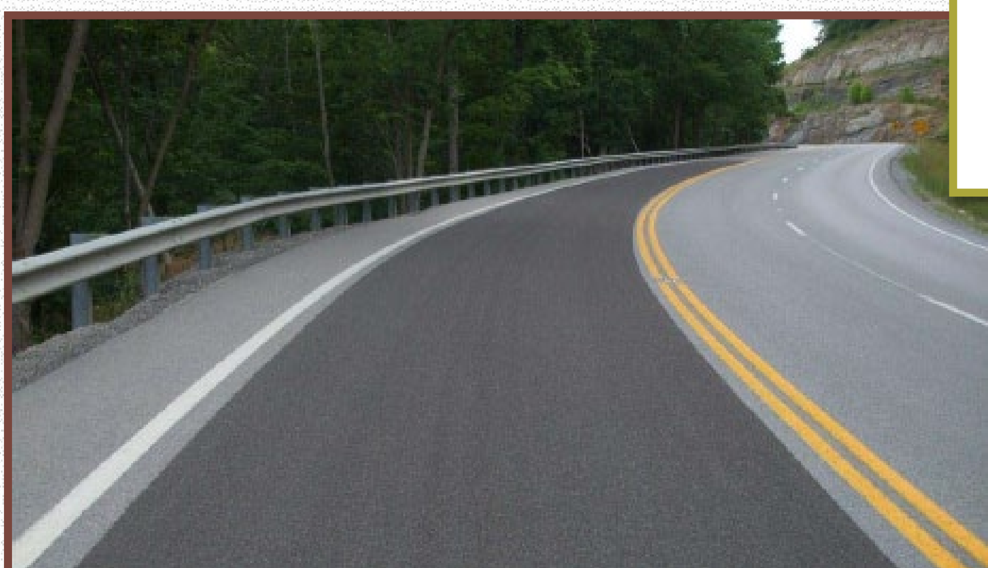
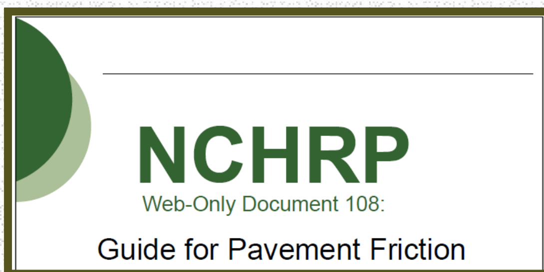


Figure 3: The relationship between different textures in pavement aggregate (*23*).

Texas Transportation Institute, July 2012,
Using High Friction Surface Treatments to
Improve Safety at Horizontal Curves.





When is a friction treatment warranted?

Assessing Curve Severity and Design Consistency Using Energy- and Friction-Based Measures

Michael P. Pratt and James A. Bonneson

Numerous published models can be used to predict curve speed based on geometric and operational characteristics like radius, superelevation rate, and approach tangent speed. Speed-based design consistency measures have also been developed to help identify which curves on a roadway are the most severe. However, the use of speed reduction alone can result in improper assessment of curve severity because drivers are more reluctant to reduce speed on roadways with higher speeds and thus accept speeds associated with higher crash risk. New measures of curve severity are suggested, based on considerations of side friction demand and kinetic energy. The increase in side friction demand above drivers' comfort thresholds is shown to be roughly proportional to the kinetic energy reduction associated with speed reduction. Agencies can use these curve severity measures to assist in identifying curves in their jurisdictions that would most likely benefit from safety improvements.

Horizontal curves are an essential part of any highway system, but they can present safety hazards to drivers. Research has consistently shown that crash rates on horizontal curves are significantly higher than are crash rates on tangent roadway segments of similar geometric design, even for curves that may appear to be relatively mild.

Numerous models published in the literature can be used to predict curve speed based on geometric factors like radius and superelevation rate, and operational factors like approach tangent speed. Models accounting for the influence of tangent speed have shown that drivers choose curve speeds that minimize their speed reduction (and travel time) while avoiding excessive amounts of side friction demand. Speed reduction is used to assess the design consistency of curves, and it is also a measure of curve severity. Larger speed reduction levels indicate that a curve is more severe, and also more inconsistent with drivers' expectations and the design of the roadway, compared with other curves. Curve severity is a measure that reflects crash risk and the effort drivers expend to avoid risk while minimizing travel time.

In this paper, curve severity measures based on side friction demand levels and kinetic energy reduction are explored. The friction-based measure is side friction differential, measured as the difference between side friction demand at the curve speed that drivers choose and their friction comfort threshold for that speed. The energy-based measure is the amount of energy reduction that must occur for drivers to decelerate from tangent speed to their chosen curve speed. It is proposed that side friction differential and energy reduction are more closely related to driver behavior and safety, and thus better suited to assess curve severity, than speed reduction is. These measures can be used by agencies to determine which curves in their jurisdictions would most likely benefit from safety improvements.

HORIZONTAL CURVE OPERATIONS

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Transportation Research Record: Journal of the Transportation Research Board, No. 2075, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 8–15.
DOI: 10.3141/2075-02

Friction-Based Curve Risk Components

Given the importance of side friction demand in drivers' curve speed choice and perception of risk, and the fact that skidding or truck rollover will occur at excessive side friction demands, it can be rationalized that curve risk can be quantified in regard to side friction comfort levels and the friction demands experienced at curve speed.

TABLE 2 Candidate Guidance for Curve Signing

Side Friction Demand, g	Suggested Signing Treatments	Side Friction Differential, g
0.19 or less	None	0.00
0.20–0.23	Curve warning sign	0.01–0.04
0.24–0.27	Curve warning sign, advisory speed plaque	0.05–0.08
0.27–0.30	Redundant curve warning signs and advisory speed plaques	0.08–0.11
0.30–0.34	Redundant curve warning signs and advisory speed plaques, chevrons	0.11–0.15
0.35 or more	Other measures to reduce speed limit, rebuild curve, etc.	0.16 or more

After much research … our take away is:
- it is about the difference in the side friction experienced by driver. This is calculated by finding the difference in the travel speeds along the tangent segment of roadway and the horizontal curve.

Our evaluation method.

Data needed:

- Centerline alignment geometry
- Roadway cross slope
- Road profile slope
- Posted speed limit
- Posted curve advisory plate speed

From the result of the evaluation, friction ranges developed giving guidance for the action to take.

Side Friction Differential	Action
0 - .009	No action
.01 - .019	Curve warning sign
.02 - .044	Curve warning with advisory speed
.045 - .074	Advance curve warnings and chevrons
.075 and above	High friction surface treatment

U.S. Customary

$$R_{min} = \frac{V^2}{15(0.01e_{max} + f_{max})} \quad (3\text{-}8)$$

Formula 3.8, AASHTO 'Green Book', utilized to provide friction rates based on horz. curve characteristics.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1				ACCIDENTS		CURVE	CROWN	L	POSTED SPEEDS		DESIGN SPEED EVALUATION				CRITICAL	FRICTION EVALUATION			
2	CURVE #	RADIUS	PC STA	ROAD	TRENDS	DIRECTION	% (+SE)	> 5%	SEGMENT	CURVE	TANGENT	FRICTION	CALC V-CURVE	CONDITION	CURVE SPEED	F-TANGENT	F-CURVE	F-CHANGE	ACTION
3	C2	3964.81	0+95.15			LEFT	-2		45	45	50	0.14	84.48	OK	45.00	[illegible]	[illegible]	[illegible]	NO ACTION
4	C4	1323.18	6+70.98			LEFT	-2		45	45	50	0.14	48.80	SUBSTNDRD	45.0[illegible]	[illegible]	[illegible]	[illegible]	NO ACTION
5	C7	2660.42	14+64.57			LEFT	-2		45	45	50	0.14	69.20	OK	45.0[illegible]	[illegible]	[illegible]	[illegible]	NO ACTION
6	C9	3827.8	17+21.84			RIGHT	-2		45	45	50	0.14	83.01	OK	45.0[illegible]	[illegible]	[illegible]	[illegible]	NO ACTION
7	C11	1231.6	20+80.9	4	3-ROR-DAY	RIGHT	-4		45	45	50	0.14	42.98	SUBSTNDRD	42.9[illegible]	[illegible]	[illegible]	[illegible]	CURVE WARNING SIGN
8	C13	906.1	28+56.03			LEFT	3		45	30	50	0.14	48.07	SUBSTNDRD	30.00	0.14	0.2	0.06	ADVANCE CURVE WARNINGS AND CHEVRONS
9	C15	352.97	30+96.3	1	ROR-ICE	RIGHT	2		45	30	50	0.14	29.11	SUBSTNDRD	29.11	0.14	0.23	0.09	HIGH FRICTION SURFACING
10	C17	691.62	35+43.65	4	3-ROR	RIGHT	-1	Y	45	35	50	0.14	36.72	SUBSTNDRD	35.00	0.12	0.18	0.06	ADVANCE CURVE WARNINGS AND CHEVRONS
11	C19	1577.67	38+64.16			RIGHT	-2		45	35	50	0.14	53.29	OK	35.00	0.14	0.18	0.04	CURVE WARNING WITH ADVISORY SPEED
12	C21	723.72	40+65.35	1	ANML	LEFT	-3		45	35	50	0.14	34.56	SUBSTNDRD	34.56	0.14	0.2	0.06	ADVANCE CURVE WARNINGS AND CHEVRONS
13	C24	477.18	58+63.73	1	ROR-ICE	RIGHT	-2		45	30	50	0.14	29.31	SUBSTNDRD	29.31	0.14	0.23	0.09	HIGH FRICTION SURFACING
14	C26	738.45	67+31.01	1		RIGHT	-2		45	35	50	0.14	36.4[illegible]	SUBSTNDRD	35.00	0.14	0.18	0.04	CURVE WARNING WITH ADVISORY SPEED
15	C28	573.46	79+94.9	5	4-ROR 1-SS	LEFT	-3.6		45	30	50	0.14	29.91	SUBSTNDRD	29.91	0.14	0.23	0.09	HIGH FRICTION SURFACING
16	C30	2235.89	102+77.81			RIGHT	-2		45	45	50	0.14	63.44	OK	45.00	0.14	0.15	0.01	NO ACTION

CURVES | LOOKUP | Sheet3

tangent friction, curve friction needed, difference between them.

Posted speed and curve advisory

Calculated curve design speed

cross slope at curve

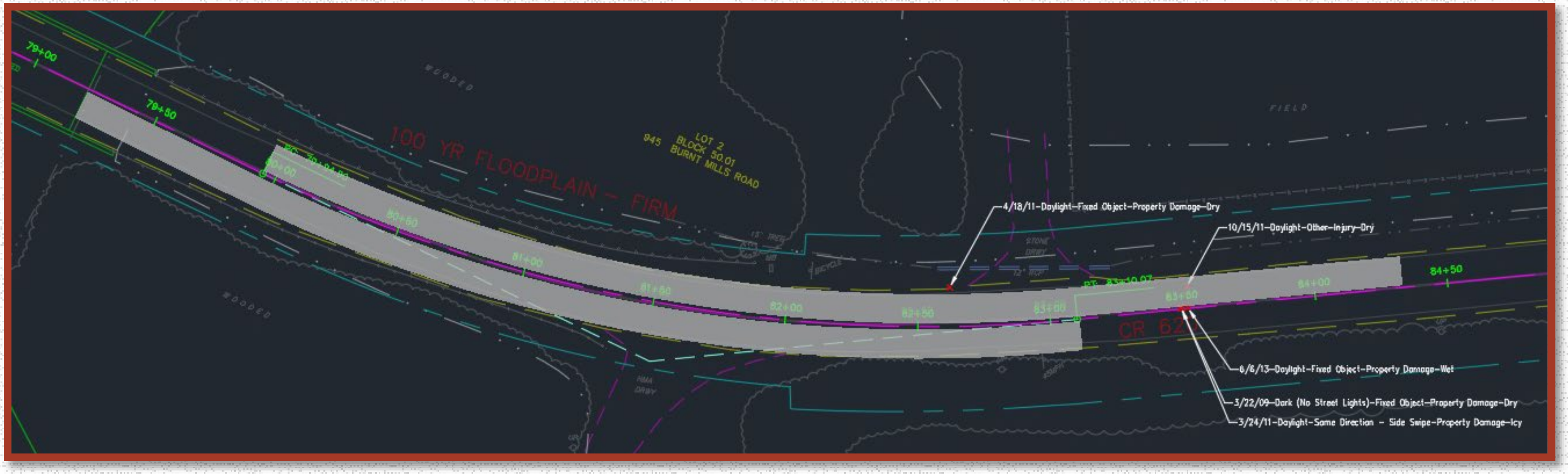
What is the Length of Need?

Friction treatment length of need determination: approach length + length of curve (PC to PT)

Table 5: Recommended Distance Upstream of the PC to Begin HFST Application

Approach Speed (mph)	Curve Speed (mph)						
	30	35	40	45	50	55	60
35	35	-	-	-	-	-	-
40	76	41	-	-	-	-	-
45	122	86	46	-	-	-	-
50	173	138	97	51	-	-	-
55	230	194	154	108	57	-	-
60	292	257	216	170	119	62	-
65	359	324	284	238	186	130	68

Texas Transportation Institute, July 2012, Using High Friction Surface Treatments to Improve Safety at Horizontal Curves.



HFST – first installation 2015

Federal Aid project Bedminster Safety
Performing test strip for friction number evaluation before installation.

ICC performed 16 tests on the road around the Test Patch of Safe-T-Grip on Lamington Rd, Bedminster NJ. The average FN40R value for the asphalt road was 55. The Test Patch numbers jumped up to a FN40R value of 86. The graphs provided show what the jump in friction looks like. It is our professional opinion that the material we tested on the Test Patch is extremely safe for roadway surface application and has a significantly higher friction value then the road it was placed on.

Statewide Striping Test Patch, Lamington Rd Bedminster Township, NJ Friction Report
7/17/2015 International Cybernetics, Largo, FL

Some results …

An in-office evaluation of crashes in the years prior to applying friction treatment and the year following.

The data utilized was distributed along the entire project corridors so the reductions shown are not solely attributed to the horizontal curve crash reductions.

County Roads	Road Segments	Year applied	Corridor - Annual avg crashes before	Corridor - crashes year after	Reduction	Treatment type
New Center Road (CR 627)	From Auten Road to Roycefield Road	2013	19	10	47%	Micro surfacing full project length
River Road (CR 625)	From Lyman Street Bridge to Roycefield Road	2014	25	5	80%	Micro surfacing full project length
Chimney Rock Road (CR 525)	From Thompson Avenue to Gilbride Road	2015	73	12	84%	HFST applied to 5 curves on 1 mile road segment (steep vertical)
Burnt Mills Road (CR 620)	From Rattlesnake Bridge Road to Country Club Road	2015	20	9	55%	HFST applied to 5 curves on 3 mile road segment
Pottersville Road (CR 512)	From Hacklebarney Road to Route 206	2015	8	7	13%	HFST applied to 4 curves on 2.4 mile road segment
Lamington Road (CR 523)	From County Line to Route 206	2015	23	17	26%	HFST applied to 2 curves on 5 mile road segment
Dukes Parkway East (CR 618)	From 6th Ave to 7th Ave, Manville	2016	4.4	1	77%	HFST applied to both travel lanes at one horz. curve

Where are we now?

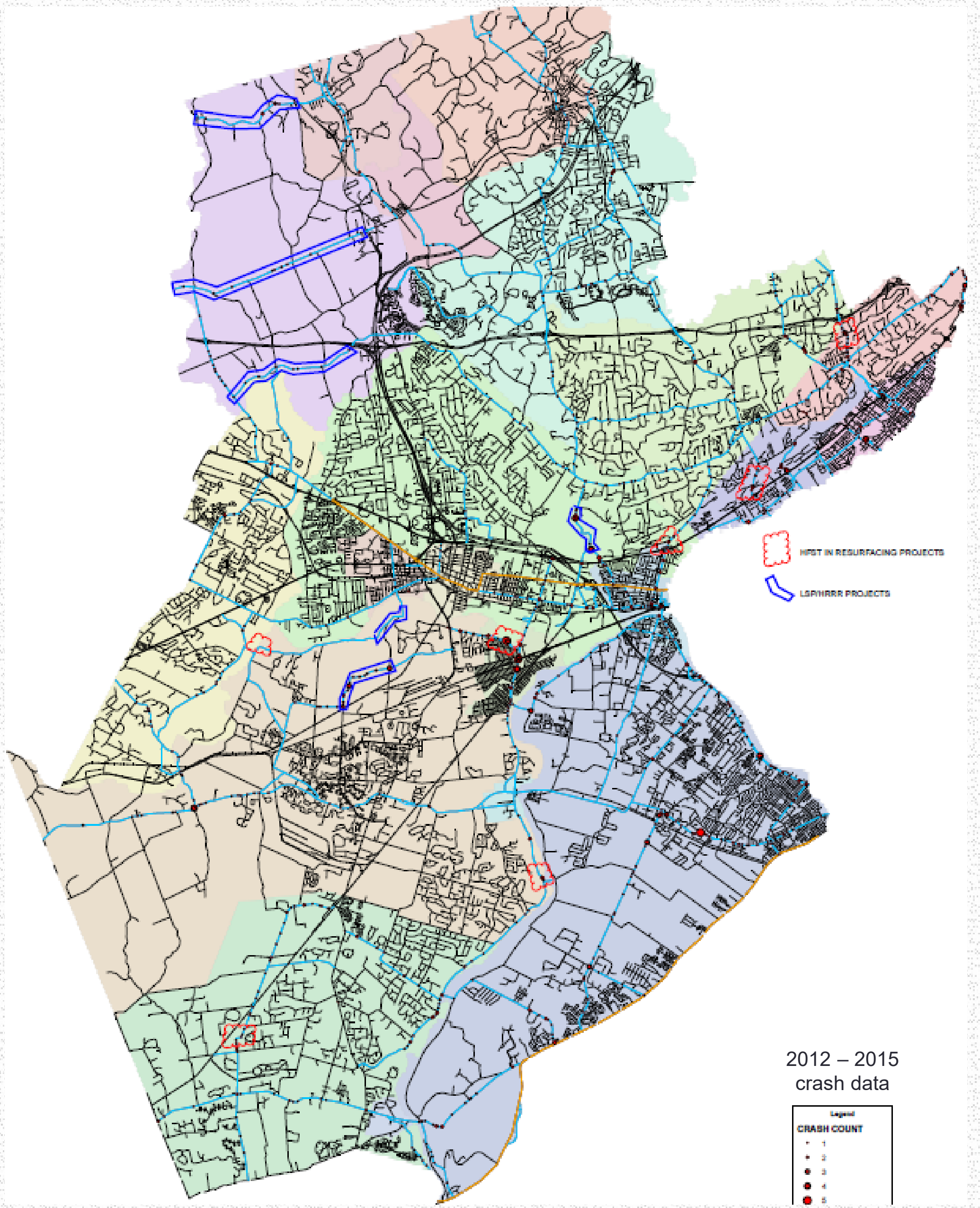
2016 and 2017, as part of our annual resurfacing program, we installed HFST treatments to locations in need. Locations to evaluate were determined from:

- Concerns expressed by Municipalities or residents
- Recent severe crashes

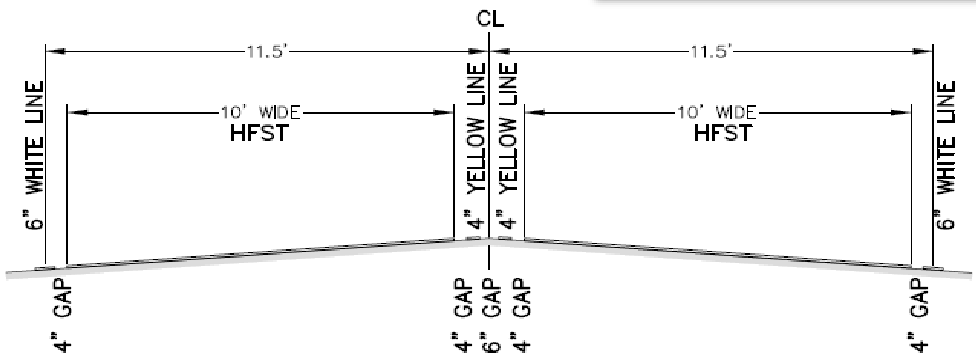
2019 performing restoration to micro-milled areas and repairs to HFST areas.

Future: prioritize high crash locations for evaluation to implement additional signage or friction surface treatments. Data sources to prioritize coming from:

- In-house GIS crash mapping
- NJ Regional Curve Inventory and Safety Assessment for the North Jersey Transportation Planning Authority (NJTPA) Region



Our HFST Installations



NOTES:
1. THIS DETAIL SHOWS THE MINIMUM LANE WIDTH AND GAP SPACING BETWEEN HFST AND THERMOPLASTIC LANE STRIPES.
2. MASK OFF GAPS AND THERMOPLASTIC STRIPING DURING PLACEMENT OF HFST TO MAINTAIN CLEAN EVEN GAPS TO THE THERMOPLASTIC STRIPING.
3. FOR INTERSECTIONS WITH TURNING LANES HOLD 4" GAP FROM YELLOW LINE OR WHITE INSIDE LEFT–LANE LINE. HOLD 10' WIDE HFST WIDTH OR AS DIRECTED BY RE.

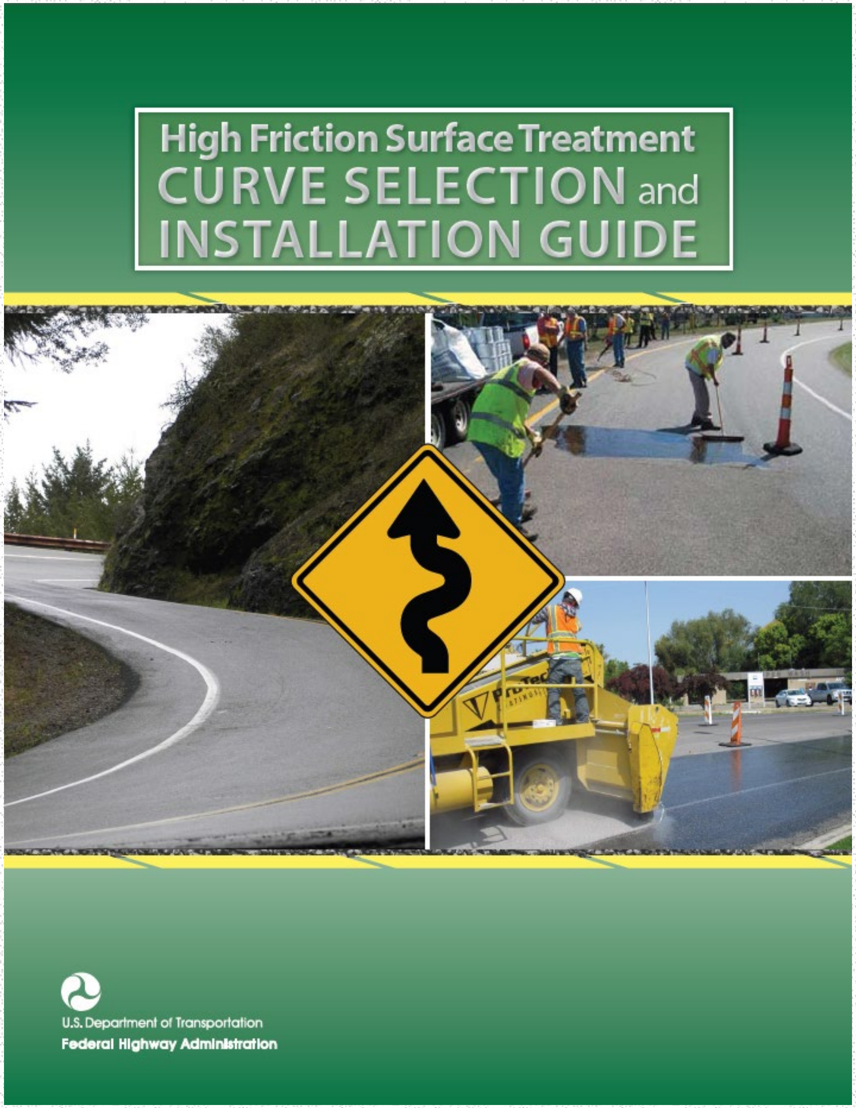
HIGH FRICTION SURFACE TREATMENT LAYOUT WITH LANE STRIPING

HFST COST: bid as square yard (SY) pay item. Bids have come in between \$35 -\$65/ SY (bid within large resurfacing contracts).

New HFST Resources

Federal Highway Administration webpage has a page of FAQs, Links, and Other Resources, General Pavement Friction Resources which includes documents of:

- May 2016 HFST Curve Selection and Installation Guide
- Guidance documents
- Fact Sheet
- Aggregate Studies
- Technical specifications
- Videos
- Other resources



Questions?

Thank You!

References:

- http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w108.pdf NCRHP Web Only Document 108, “Guide for Pavement Friction”, Transportation Research Board
- http://trb.metapress.com/content/7717239k62781311/ Pratt, Michael P. and James A. Bonneson “Assessing Curve Severity and Design Consistency Using Energy and Friction Based Measures”, Transportation Research Record No. 2075, 2008, pp 8-15.
- AASHTO “A Policy on Geometric Design of Highways and Streets 2011” Chapter 3, p3-25, Figure 3.6 Side Friction Factors Assumed for Design, and p3-31, equation 3.8 for minimum radius.
- http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2012-8.pdf Brimley, Brad & Paul Carlson, “Using High Friction Surface Treatments to Improve Safety at Horizontal Curves”, Texas Transportation Institute, July 2012, p 13.
- https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/faqs_links_other/ Federal Highway HFST FAQ webpage

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