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ABSTRACT

The frictional properties of pavement surfaces play an important role in highway safety. Pavement surfaces must ensure an adequate level of friction at the tire pavement interface to provide safe operation of vehicles.

The Maryland State Highway Administration (MDSHA) routinely measures friction on State highways to assist with decision making associated with road maintenance management and to monitor network health against road condition targets detailed in the system preservation report published annually.

The MDSHA uses the Friction Tester to monitor the micro-texture of the pavement aggregate during the service life of the pavement surface. Micro-texture is a measure of the degree of polishing of a road aggregate and is the main factor in determining the peak level of dry and wet friction provided by a pavement surface.

Initial analysis of past friction information indicates a relationship between geometry, AADT, polish stone value and Friction Number. The MDSHA is attempting to better understand surface frictional requirements at approach to pedestrian crossing, traffic lights, etc during wet weather and to establish minimum friction levels for different types of roadways based on accident data.

This paper describes the MDSHA process in developing a design policy to improve pavement surface friction.

INTRODUCTION

The MDSHA is responsible for Interstate, US and State (MD) Highways. Skid resistance is routinely measured on the outer lane every 1/3 of a mile (1760-ft). The choice of Polish Value (PV) for aggregates used, controls surface friction design. Skid resistance is defined in ASTM Standard E 274 *(1)* as the retarding force generated by the interaction between a pavement and a tire under locked, non-rotating wheel condition.

To ensure measurements made at various places and times can be compared, a standardized tire and a specific amount of water are applied to dry pavement ahead of the tire. Results are reported as the friction number (FN) formerly referred to as skid number (SN). FN is computed as 100 times the force required to slide the locked test tire (at a stated speed, usually 40 mph or 64 km/h) divided by the effective wheel load as shown in FIGURE (1).

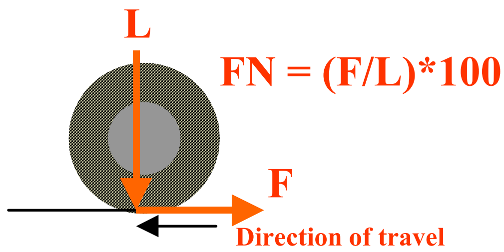


FIGURE 1 FN Computation

Minimum requirements for friction levels will depend on a variety of conditions including traffic volume, roadway geometry, climate and economics. As a result, the Federal Highway Administration (FHWA) *(2)* has resisted specifying a minimum friction level. The FHWA believes that every state is best qualified to determine the necessary level of friction in each given situation.

FACTORS AFFECTING WET SKID RESISTANCE

According to the National Transportation Safety Board and the FHWA reports *(2)*, approximately 13.5% of fatal accidents and 25% of all accidents occur when pavements are wet. According to the MDSHA Traffic & Safety Analysis Division reports *(3)* approximately 18% of fatal accidents and 24.3% of all accidents occur when pavements are wet. The following factors affect the friction levels of a wet pavement surface:

- Micro-texture and Macro-texture
- Age of the road surface
- Seasonal variation
- Traffic intensity
- Aggregate properties
- Road geometry

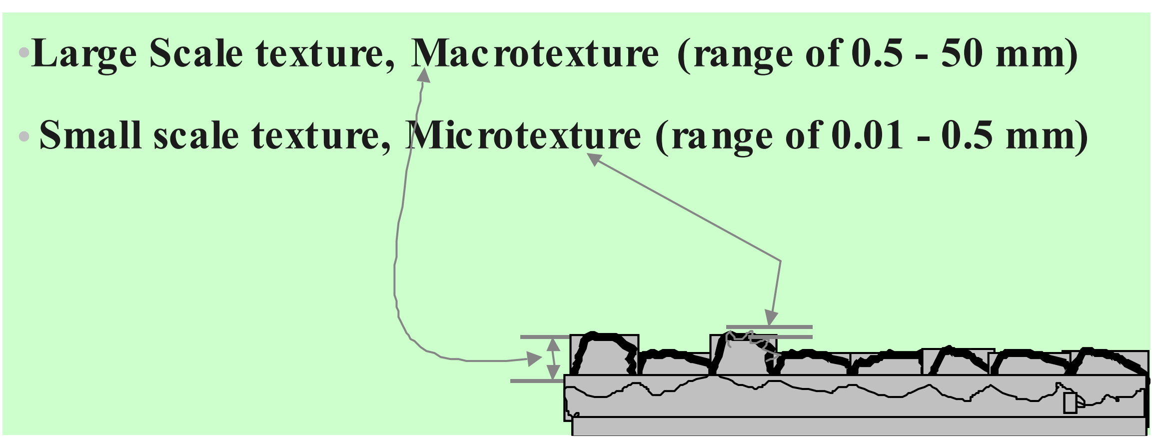


FIGURE 2 Macro-texture and Micro-texture

Micro-texture and Macro-texture
(Skid resistance is influenced by texture at two levels as shown in FIGURE (2) - large-scale texture or macro-texture (range of 0.5 – 50 mm) and small-scale texture or micro-texture (range of 0.01 - 0.5 mm)). Macro-texture is of primary importance at high speed to remove excess water. Studies have shown that the deterioration of skid resistance with speed as macro texture increases. Micro-texture is important at all speeds to penetrate the remaining water film on a road surface and to provide 'dry' contact with the vehicle tire.

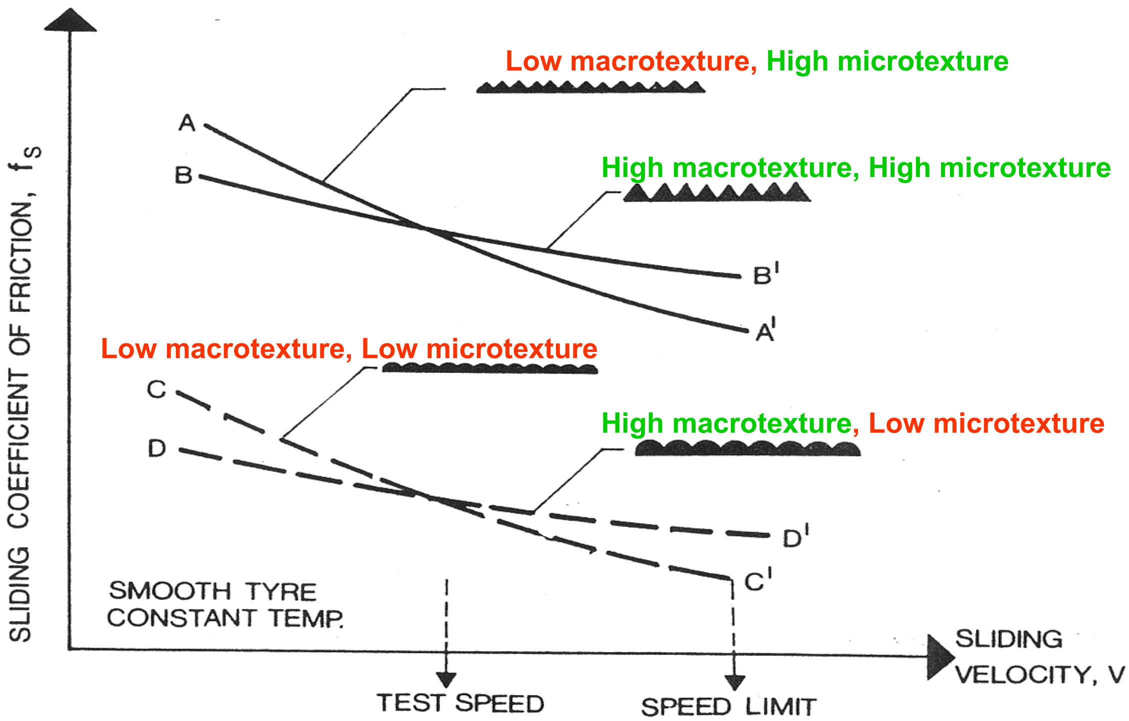


FIGURE 3 Change in Friction vs Change in Speed and Texture

The chart in FIGURE (3) the difference in friction for different speeds and texture. An international standard for terminology in road surface texture has been set by the Technical Committee on Surface Characteristics of the World Road Association's "Permanent International Association of Road Congress" (PIARC). This is:

Micro-texture<0.5 mm (0.02 in)
Macro-texture 0.5 mm to 50 mm (0.02 to 2 in)
Mega-texture 50 mm to 500 mm (2.0 to 20 in)

Age of Surface
Almost all-new road surfaces have high skid resistance. Road surfaces will attain their peak skid resistance condition after a few weeks of traffic action. Under traffic action, skid resistance will deteriorate and gradually reach an 'equilibrium' level. Only small deviations in skid resistance are experienced while traffic levels are constant and no structural deterioration is evident. It will take about two years to reach equilibrium.

Seasonal Variation

There are distinct seasonal patterns in skid resistance levels. Summer months have the lowest levels of skid resistance. A variation of approximately 30% of skid resistance has been observed between a minimum in summer to a peak during the winter *(4)*. The chart in FIGURE (4) shows the generalised pavement-polishing model.

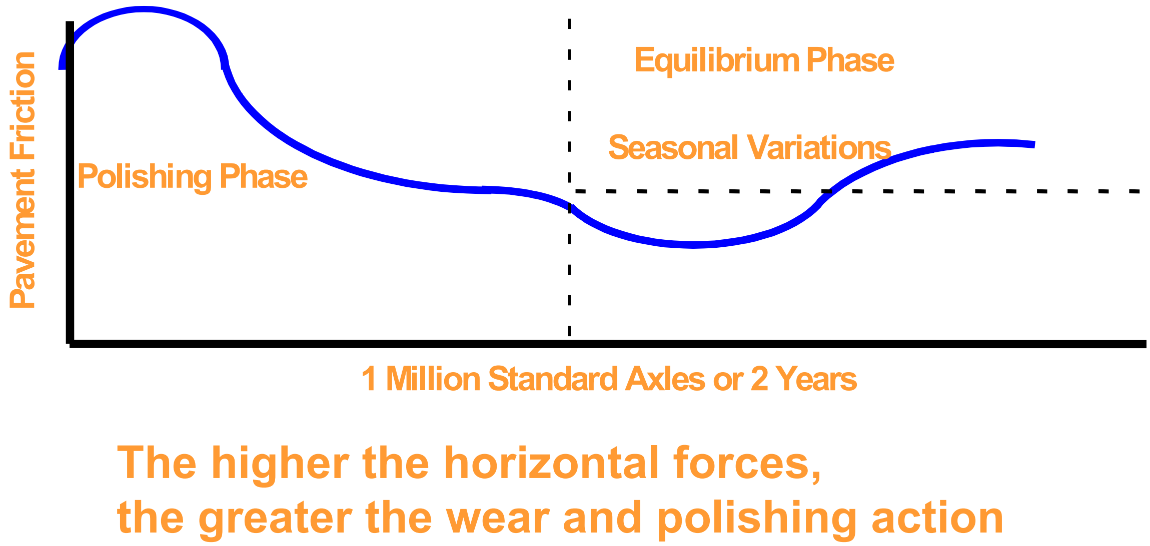


FIGURE 4 Generalised Pavement Polishing Model

Traffic Intensity

Polishing of aggregates relates to traffic intensity, commercial vehicles contribute to most of the polishing. The geometry of the road also contributes to polishing. Polishing relates to traffic volumes as shown in the chart in FIGURE (5) where high volume areas require a higher design FN. Our analysis has shown that there is a good correlation between daily traffic volume, skid resistance and the polishing value of the aggregate.

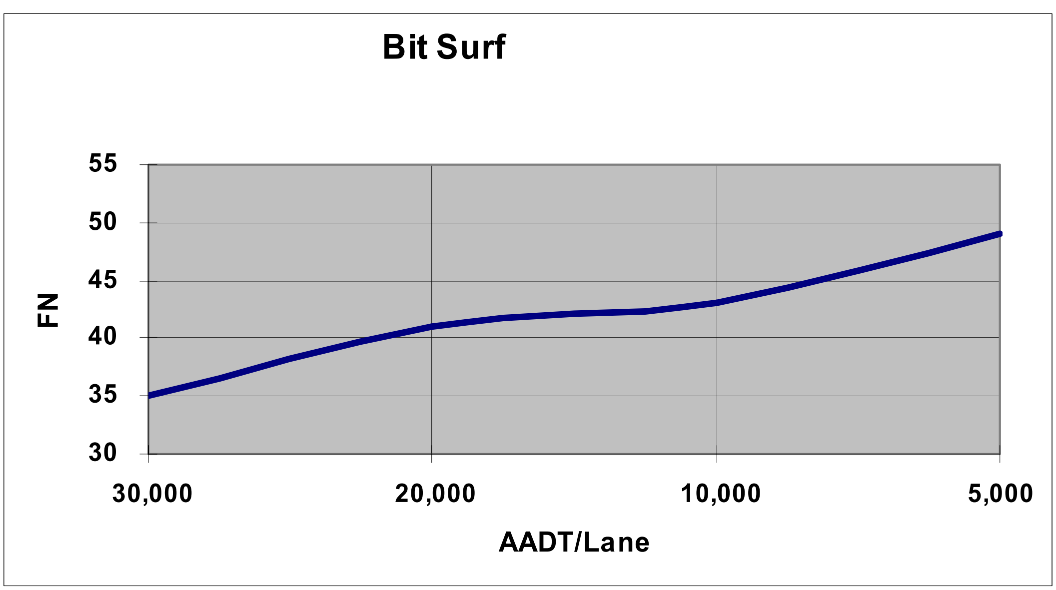


FIGURE 5 FN vs AADT for Pavement with Similar Surfaces

Aggregate Properties

Polishing resistance of the aggregate is measured in the laboratory. Fourteen specimens are clamped around a circular track (British wheel PV tester) and subjected to a fixed number of revolutions of polishing by a loaded wheel with a rubber tire. Two of the fourteen samples are of control stone.

The degree of polish of the specimens is then measured by means of the portable skid resistance tester (using a special narrow slider, shorter test length and supplementary scale) under carefully controlled conditions. Control specimens are used to condition and check the slider before the test. A pair of control specimens is also included in each test run of fourteen specimens to check the entire procedure that allows for adjustment of the result to compensate for minor variations in polishing and friction testing. Derived results are expressed as 'Polished Values' (PV) and calculated as the mean of the four test specimens of each aggregate.

The MDSHA tests for PV of aggregates from surrounding quarries every 3 years. In the UK and New Zealand, PV is checked every year with results showing that marginal source aggregates change quickly. Extensive research has also shown that it is not possible to predict polishing qualities of natural road stone from petrologic data. However, some indicators have emerged.

Rocks composed of minerals of widely different hardness, and rocks that wear by the pulling out of mineral grains from a relatively soft matrix had relatively high resistance to polishing. Conversely, rocks consisting of minerals with nearly the same hardness wore uniformly and tended to have a low resistance to polishing.

The gritstone group is excellent, with resistance to polishing being always high while the limestone and flint groups yield the lowest resistance. Other groups such as the basalt, granite and quartzite, yield intermediate resistance. Polishing of samples from the basalt group yielded high resistance due to their softer minerals composition and the proportion and hardness of secondary minerals. In-groups of indigenous rocks, the petrologic characteristics that most readily affect resistance to polishing are variation in hardness between the minerals and the proportion of soft minerals. Rocks with cracks and fractured minerals are of higher resistance, whereas finer-grained rocks tend to polish more readily.

Aggregate polishing is affected by:

- Aggregate size
- Highway geometry
- Commercial vehicles (Truck AADT/Lane)

Larger aggregates attract higher stress, which tend to polish the surface faster. Analysis of past pavement performance has shown that Super pave 12.5 mm polishes more than Super pave 9.5 mm for the same traffic intensity and aggregate source. But we are not certain, whether that has more to do with the aggregate gradation or the local conditions. We are including these mixes in our test track to compare the results under similar conditions.

International studies have shown that gradients, curves, pedestrian crossings, roundabouts, Stop and Give-way controlled intersections attract high stresses and result in more polished surfaces that do not have any geometrical constraints influencing frictional demand. Commercial vehicles tend to impose high stress on pavement surfaces. International studies have also shown that increase in truck traffic tends to polish the surface more.

BACKGROUND

The MDSHA has been monitoring wet surface accidents and its correlation to surface friction. It is extremely complex to relate wet surface accidents only to surface friction. The Office of Material & Technology (OMT) measures friction every year and tests the PV of the source aggregate every 3 years. Every year, the performance of the MDSHA highway network is reported in the System Preservation Report. The Office of Traffic & Safety (OOTS) has been recording and monitoring wet surface accidents researching their relationship to surface friction. The statistics indicate that in the past two years, there has been an increase in wet surface accidents in Montgomery and Prince George's counties. The OOTS was concerned and requested the OMT to investigate.

An accident is usually the result of combination of several factors. It is difficult and nearly impossible to attribute an accident solely to poor surface friction. However, research and analysis at the MDSHA are indicating that that surface friction is a contributing factor to the increased number of accidents during wet weather. Efforts are currently underway at the MDSHA to evaluate the cause of wet accidents and the potential effect of friction levels on reducing accidents.

In the recent past, there have been a number of Torte claims against highway agencies in the USA, UK, Australia, and New Zealand. Many of these have been upheld in court as the responsible authorities have not maintained a wet skid *safe* roadway or warned the driving public of possible danger at reasonably anticipated speeds. Highway Authorities globally will have to implement remedial actions to provide wet skid safe highways. When wet friction measurements and wet surface accidents data are collected systematically, highway authorities are in position to analyze the information and come up with sound solutions to improve the driving conditions thus improving skid resistance and minimizing Torte claims to the highway agencies in the future.

The MDSHA has just begun to investigate the links between wet friction (FN), wet surface accidents, average annual daily traffic (AADT), truck traffic (truck AADT) and surface aggregate PV. The one critical remedial action, we at the MDSHA will be carrying out is the improvement of surface friction. This significant project started in February 2002.

DATA ANALYSIS

Use of MD's Geographical Information System (GIS) helped to analyze a large amount of data significantly easier by creating information rich maps of roadway systems that include wet accident records, friction condition (FN), traffic volume (AADT) and types of pavement surfacing (PV). Friction is measured every 1760 ft on the outer lane and wet accidents are recorded at the log mile. The FN at a wet accident location is assigned as the closest measured FN to the location of the accident, which can be up to 1 mile off. For network level analysis this accuracy is adequate. For project level it is essential to measure every 100ft for accurate results.

Measuring friction at smaller intervals can optimize cost of surface treatment. AADT is only reported for the road section as such analysis was carried out for the road sections and then for the lanes. Distribution of AADT per lane was assumed to be equal for this analysis.

Identifying Potential Wet surface skid accident sites - Black Spots

Candidate safety improvement locations are selected by the OOTS by preparing a three-year listing of wet surface accidents on half-mile sections that exhibit a minimum of 10 accidents in three years and experiencing a percentage of wet surface accidents greater than or equal to twice the statewide average percent of wet surface accidents. These sites are then compared with OMT friction test results to identify potential resurfacing locations.

Proposed Method for Identifying Potential Wet Surface Skid Accident Sites - Black Spots
An annual listing of wet surface accidents should be developed by the OOTS referenced by log mile and compared with all accidents occurring on State and County roadways. This listing should be presented as half-mile sections, pedestrian crossing, signalized intersections and intersections. The listings should then be merged with the OMT 's AADT, FN, surface treatment type (PV), and date of last surface treatment.

Any section exhibiting greater than 24% wet surface accidents or had more than 3 accidents in the last 5 years should be selected for further analysis based on the following:

Design traffic:
Design AADT should be calculated based on the service life of the surface treatment.

Design AADT/lane = $((1+GF)^{SL} - 1)/GF)*(AADT)$ (1)

AADT/lane = Annual average daily traffic
%Truck AADT/lane = %Annual average daily truck traffic (any vehicle that has a weight of 3.5 tons or more)
GF = Traffic growth factor
SL = Service Life of the surface treatment

Example:
AADT/lane = 10,000
% Truck AADT/lane = 20%
GF = 2.3%
SL = 10 years
Design AADT /lane = $((1+0.023)^{10} - 1)/0.023)*(10,000)$ = 11,101
Design Truck AADT= 11,101* 20%= 2,220

Site category:
VIC ROADS Australia developed site categories concept from past performance and developed a Skid Resistance Guide *(3). The proposed* MDSHA site categories are based on the same concept modified to suit US traffic conditions and testing methods. Sites are categorized based on how much shear stress the pavement surfacing attracts. Sites without any geometrical constraints will be categorized as low frictional demand sites. Sites with geometrical constraints such as railroad crossings, traffic lights, pedestrian crossings, roundabouts, Stop and yield controlled intersections, curves, expressway/highway on/off ramps will be categorized as high frictional demand sites. TABLE (1) illustrates the different site categories.

TABLE 1 Site Category vs Truck AADT vs PV

		PV of aggregate							
		Traffic in Heavy Commercial Vehicles per Lane per Day							
Site Category	Site Description	250	1000	1750	2500	3250	4000	Design FN	Demand Category
1	Approach rail road crossings, traffic lights, pedestrian crossings, roundabouts, Stop and Give Way controlled intersections (SH only).	7	7	8	8	9	9	55	High
2	Curves with radius=<250m, downhill gradients > 10% and > 50m long Freeway/highway on/off ramp	6	7	7	8	8	9	50	High
3	Approch to intersections, downhill gradients 5 to 10%	6	6	7	7	8	8	45	High
4	Undivided highways without any other geometrical constraints which influences frictional demand.	5	6	6	7	7	8	40	Low
5	Divided highways without any other geometrical constraints which influences frictional demand.	5	5	6	6	7	7	35	Low

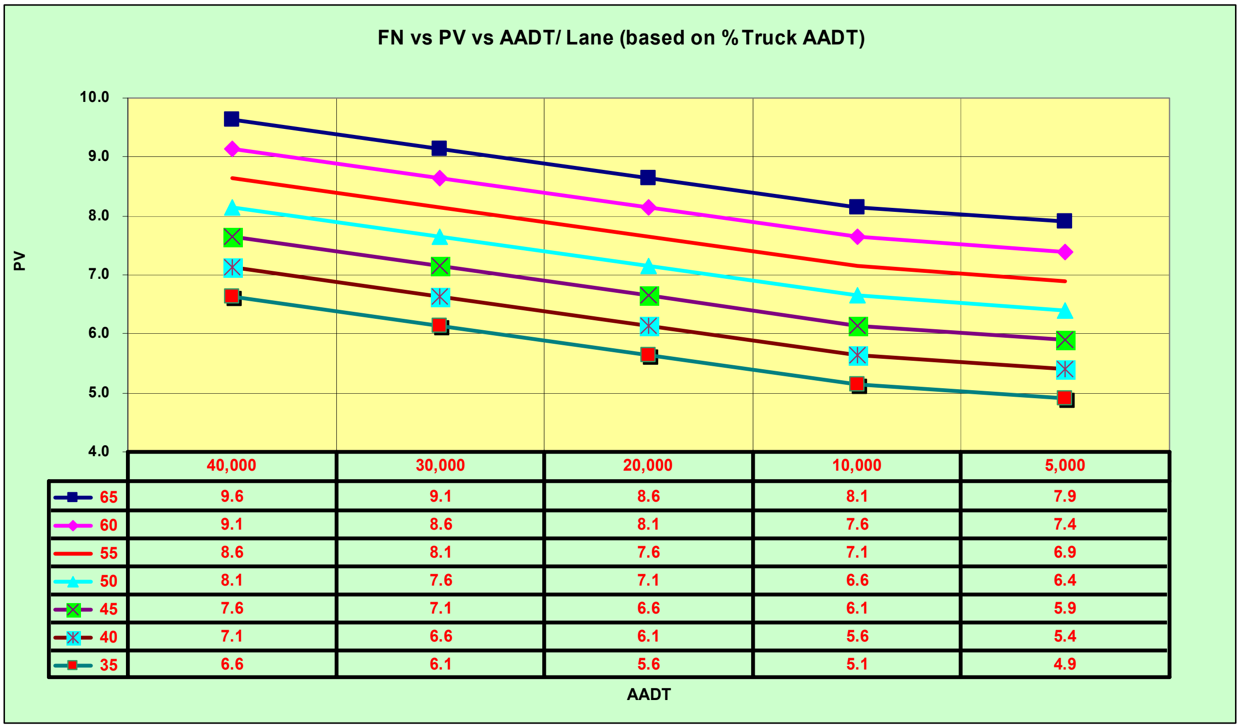
Design friction:
High demand category surfaces (FN = 45 to 55) will be able to maintain the design frictional characteristics through their service life. Wet Frictional characteristics are easily lost if:

- Water ponds on the road surface due to rutting, shoving or poor drainage.
- Asphalt surface flushes and submerges the aggregate.
- The wrong type of aggregate (which polishes easily) was used in the asphalt surfacing.

Unfortunately, the same forces which demand high friction can also cause the rutting and shoving of the pavement surface that make the surface slippery when wet. Designing for reduced rutting and shoving during the same design process of improved skid resistance will make economic sense. Rideability or roughness does not effect the skid resistance. How ever, on very rough roads greater skid resistance is required to be able to maneuver successfully at anticipated speeds. TABLE 1 has 5 site categories for selecting the Design Friction Value.

The national roading authority in New Zealand (Transit NZ) *(4)* developed a relationship between Truck AADT, FN and PV based on past performance information. The proposed MDSHA relationships are based on the same concept but modified to suit past information trends and US environment and traffic conditions.

The chart in FIGURE 6 shows an approximate relationship between AADT (based on 10% Truck AADT), FN, and PV. There is not a robust relationship between PV and FN that will work on all sites. Using engineering common sense and relationships, it is possible to provide a wet skid safe pavement surface at an anticipated maximum speed.



	40,000	30,000	20,000	10,000	5,000
65	9.6	9.1	8.6	8.1	7.9
60	9.1	8.6	8.1	7.6	7.4
55	8.6	8.1	7.6	7.1	6.9
50	8.1	7.6	7.1	6.6	6.4
45	7.6	7.1	6.6	6.1	5.9
40	7.1	6.6	6.1	5.6	5.4
35	6.6	6.1	5.6	5.1	4.9

FIGURE 6 FN vs PV vs AADT

Design PV can be selected in FIGURE 6 or can be calculated as shown below

Design FN = 10*(PV-0.000663*Truck AADT-1.15) **(2)**

Design FN = the required skid resistance at an anticipated maximum speed.
PV = the required PV to achieve the Design FN
Truck AADT = the >3.5 ton weight commercial vehicles/lane/day

Example:
Truck AADT = 2,000
PV = 7
Design FN = 10* (7- (0.000663*2,000) -1.15) = 45.24 = 45
Design FN can be selected from site category table or calculated from stopping distance and anticipated speed. Chart in FIGURE 7 shows stopping distance v FN v speed.

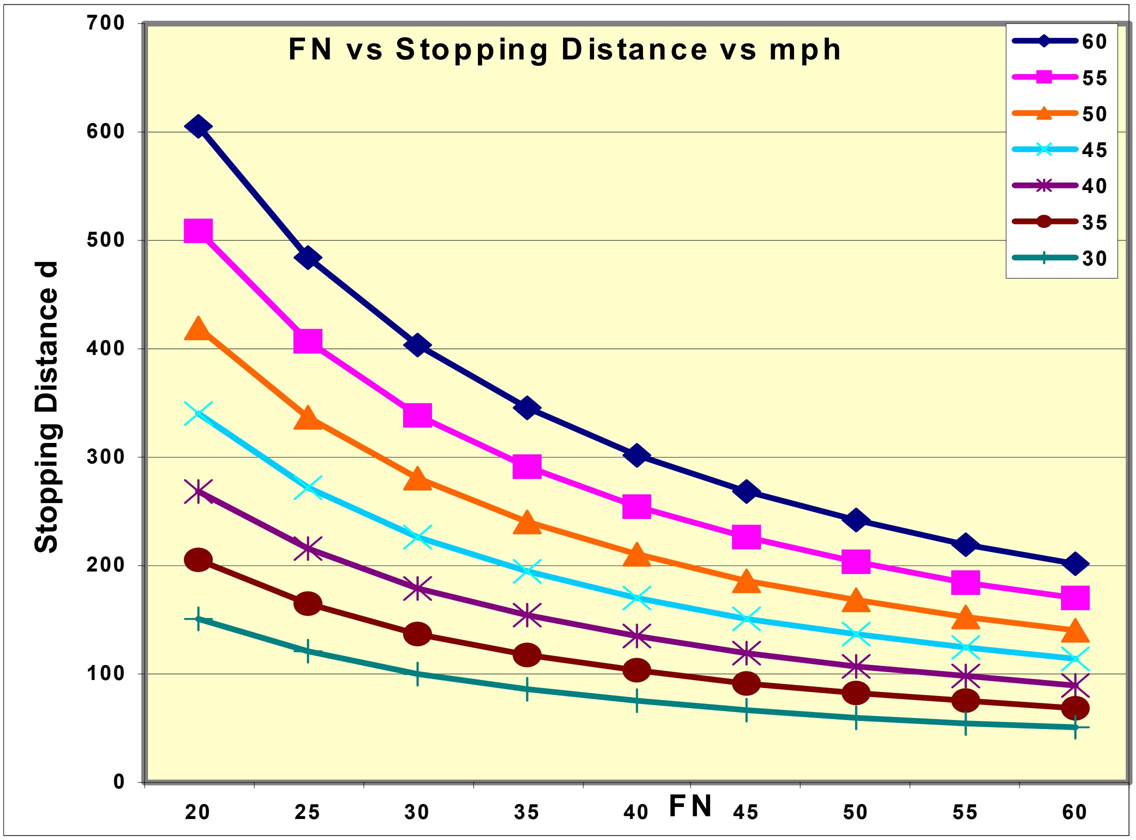


FIGURE 7 FN vs Stopping Distance vs mph

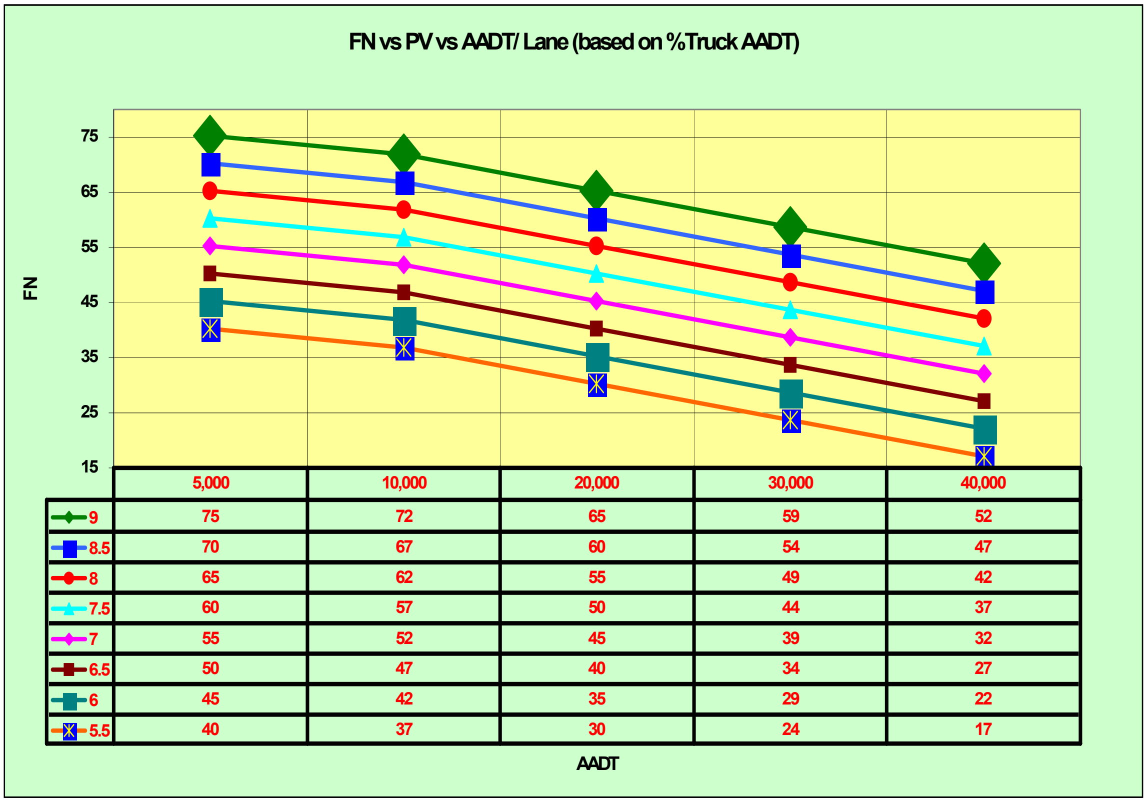
Design PV can be selected in FIGURE 7 or can be calculated as shown below

Design FN = (V ^{2} /(2* D * G * 24.545)) * 5280 **(3)**

Design FN = the required skid resistance at anticipated maximum speed
D = distance in feet
V = anticipated speed miles/hour
G = gravitational acceleration feet/ sec^2

Example:
V = 55 mph
D = 290 ft
G = 32/ft/sec ^{2}
Design FN = (55 ^{2} /(2* 290 * 32 * 24.545)) * 5280 = 35

Design polish value:
TABLE (1) has 5 site categories and 6 truck AADT values for selecting Design Polish Value. There is no robust mechanistic relationship between PV, FN and truck AADT. But analysis of past information has shown that increase in truck AADT (in this case 10% of AADT) polishes the aggregate faster. FIGURE (8) illustrates this relationship.



	5,000	10,000	20,000	30,000	40,000
9	75	72	65	59	52
8.5	70	67	60	54	47
8	65	62	55	49	42
7.5	60	57	50	44	37
7	55	52	45	39	32
6.5	50	47	40	34	27
6	45	42	35	29	22
5.5	40	37	30	24	17

FIGURE 8 PV vs FN vs AADT

Design PV can be selected in FIGURE 8 or can be calculated as shown below:

Design PV = (FN/10) + (Truck AADT*0.000663) +1.15 **(4)**

Example:
FN = 45
Truck AADT = 2000
Design PV = (45/10) + (2000*0.000663) + 1.15 = 6.976 = 7

When in doubt, it is advisable to select a higher polish value but using limestone, marble or serpent aggregates should be avoided. The requirement for 7 or higher PV may involve importing aggregates from outside the region. When the cost of wet accidents is compared to the initial cost outlay of importing aggregates, the latter will be a much more economical option.

Treatment selection:
Selection of treatment type involves a complex interaction of number of factors, including pavement type, traffic stresses, required operating characteristics, maintenance requirement and the life cycle costs.

While selecting a surface treatment consideration should be given to the following:

- Structural integrity of the pavement layers *(5)*.
- Rutting and shoving resistance of the surface treatment.

- Cracking resistance of the surface treatment.
- Skid resistance of the surface treatment.
- Noise level due to the surface treatment.
- Effect of water spray on visibility due to the surface treatment.
- Cost of the surface treatment.

Super pave asphalt mixes are most commonly used to provide a structural, durable mix that will resist cracking and rutting. The Superpave design procedure does not directly address skid resistance. In general, Super–pave asphalt mixes have provided an improvement in noise reduction through improved ride quality.

Other type of mixes like Stone Mastic Asphalt has maintained their skid resistance characteristics under high traffic stresses and geometric constraints. Open graded mixes (OGM) reduce water spray and noise and increase skid resistance, but have low surface shear resistance, as such should not be used at heavily trafficked intersections. Macro-surfacing like chip seals are generally used in rural highways where cost of treatment is an important consideration.

Chip seals have been successfully performed in the UK, France, Australia, New Zealand and several other countries as a durable, crack resistant, skid resistant and cost effective surface treatment. The FHWA's Long Term Pavement Performance (LTPP) Study found that chip seal treatments performed very well. Specialized chip seal macro-surfacing is a single pass surface treatment developed for cost-effective pavement preservation. It features quick traffic return, reliable surfacing and low risk of vehicle damage. It is suitable for use on high traffic volume highways in good condition but with minor surface distresses.

Micro-surfacing (slurry) is a thin, uniform fine textured surface suitable as a maintenance re-treatment on sound stiff pavements with low to medium traffic levels. Micro-surfacing lacks cracking, rutting, and shoving strength, however, past performance of micro-surfacing has shown that skid resistance increased from about FN = 30 to 55.

Benefit Cost (B/C) Analysis

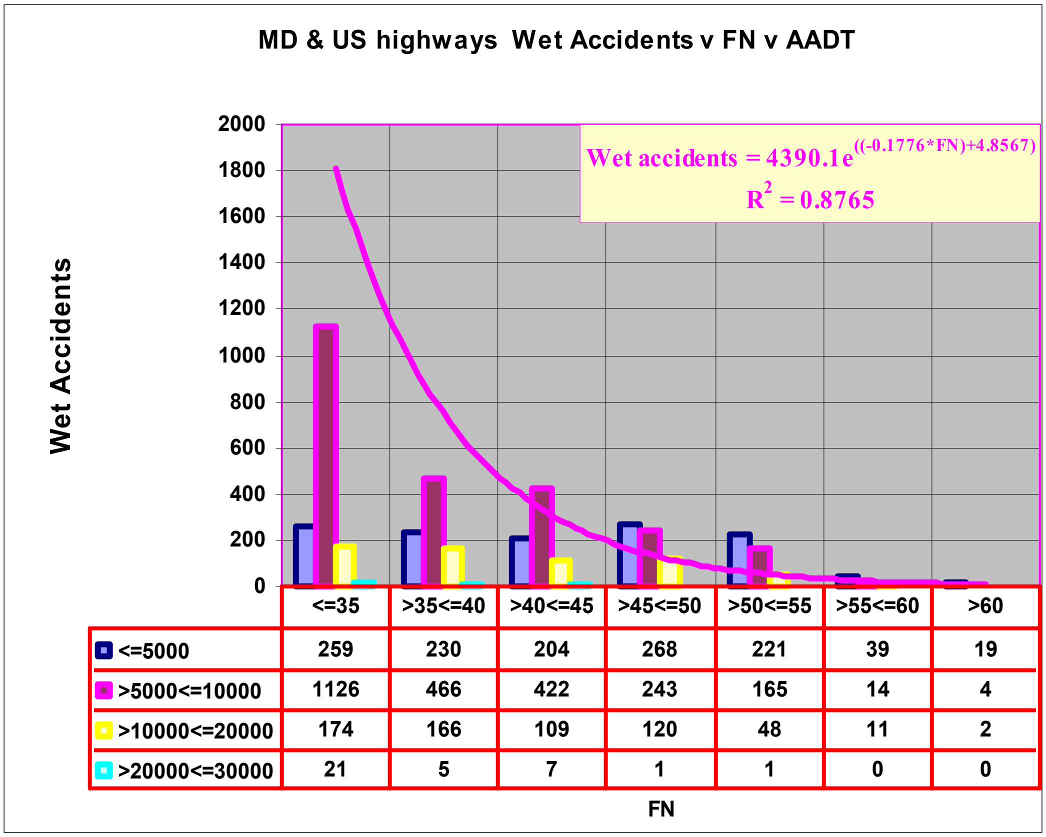
Alternative treatments can be compared using B/C calculations based on:

- Expected life
- Accident Reduction
- Construction costs
- Accident costs

Expected life: Expected life of surface treatment to improve skid resistance can vary from 3 - 5 years for micro-surfacing and from 7 - 10 years for macro-surfacing and overlays.

Accident Reduction: B/C is calculated by developing an empirical model to predict wet accidents from FN. Percentage reduction in wet accidents is calculated for a particular site category and truck AADT.

One model was developed for AADT levels ranging from 5,000 to 10,000 to predict the level of wet accidents from measured friction levels. This model, shown in FIGURE (9), was developed using all wet accident data occurring in 2001. It is important to note that the wet accidents used to generate this model could had been caused by factors other than poor skid resistance. Therefore, the accuracy of the model shown below is still unknown. MDSHA will be placing trial sections to improve friction levels in high need areas to verify and adjust the model.



	<=35	>35<=40	>40<=45	>45<=50	>50<=55	>55<=60	>60
<=5000	259	230	204	268	221	39	19
>5000<=10000	1126	466	422	243	165	14	4
>10000<=20000	174	166	109	120	48	11	2
>20000<=30000	21	5	7	1	1	0	0

FIGURE 9 FN vs Wet Surface Accidents vs AADT

Wet Accidents/year = ((4390.1)*EXP ((-0.1776*FN)+4.8567) (5)

Example:
Assume 100 % wet accidents @ FN = 35
Wet Accidents/ year = ((4390.1)*EXP ((-0.1776*FN)+4.8567)= 1128
If Design FN = 45
Wet Accidents/ year = ((4390.1)*EXP ((-0.1776*FN)+4.8567)= 288
% Reduction in wet accidents = ((1128 – 191)/1128) * 100 = 83%

Accident costs:
Cost savings per accident/ year:
Fatal accident = $3,923,000 *(3)*
Injury accident = $126,000 *(3)*
Property damage accident = $26,000 *(3)*
From past data analysis, we assumed an average % distribution of type of accident:
Fatal accident = 0.9% *(3)*
Injury accident = 47.3% *(3)*
Property damage = 51.8% *(3)*

Construction costs:
Cost per 100,000 sq. yd resurfacing with a life of 10 years = $435,000

Example:
Say No. of wet accidents 4
Reduction in wet accidents = 4 * 0.83 = 3.3
Present Value B/C = ((Present value @ 4% interest rate 3.44*($3,923,000*0.009 + $ 126,000* 0.473 + $ 26,000* 0.518)-($435,000))/ $ 435,000 = 6.72
B/C = 6.72
B/C > 1 is enough to get approval for the project if funds are available.

The calculations are automated in the Excel spreadsheet, shown in TABLE (2).

TABLE 2 Benefit Cost Calculations Excel Spreadsheet

Benfit/Cost Analysis for Improving Pavement Surface Skid Resistance										
Benefit/Cost	**6.72**	Years After Rehab	Interest rate%	Fatal Accidents/ Year	Fatal Accident Cost	Injury Accidents/ Year	Injury Accidents Cost Rate	Property Damage Accidents /Year	Property Damage Accidents cost rate	Total Accident Cost
NPV	$2,920,933	1	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Total Cost	$434,880	2	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Rate/sq yd	$ 4.35	3	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Rehab Life in Years	10	4	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Area in sq yd	100,000	5	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
PV	7.12	6	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Design %Truck AADT\Lane	20%	7	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Design AADT\Lane	11,101	8	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
Growth factor	2.3%	9	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
%Truck AADT\Lane	20%	10	4%	0.0299	$ 3,923,000	1.572	$ 126,000	1.72	$ 26,000	$ 360,125
AADT\Lane	10,000	11	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -
Design FN	45	12	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -
Existing FN	30	13	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -
Reduction in wet Acc/Year	3.3	14	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -
% Reduction/Year	83%	15	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -
Total wet acc/ Year	4	16	4%	0.0000	$ 3,923,000	0.00	$ 126,000	0	$ 26,000	$ -

CONCLUSIONS

Pavement sections built at the same time, with same material and with the same geometrical constraints can have different skid resistance over time because of the varying traffic volumes. On the other hand, pavement sections built at the same time that have the same traffic volume and same geometrical constraints can have different skid resistance over time because they are built with different materials. Our research has shown that there is a potential for increased number of wet weather accidents on pavements with low skid resistance. The correlation between skid resistance and wet surface accidents are illustrated in FIGURE (10) note the significantly high number of wet surface accidents and low FN. sites in county 15 compared to 16.

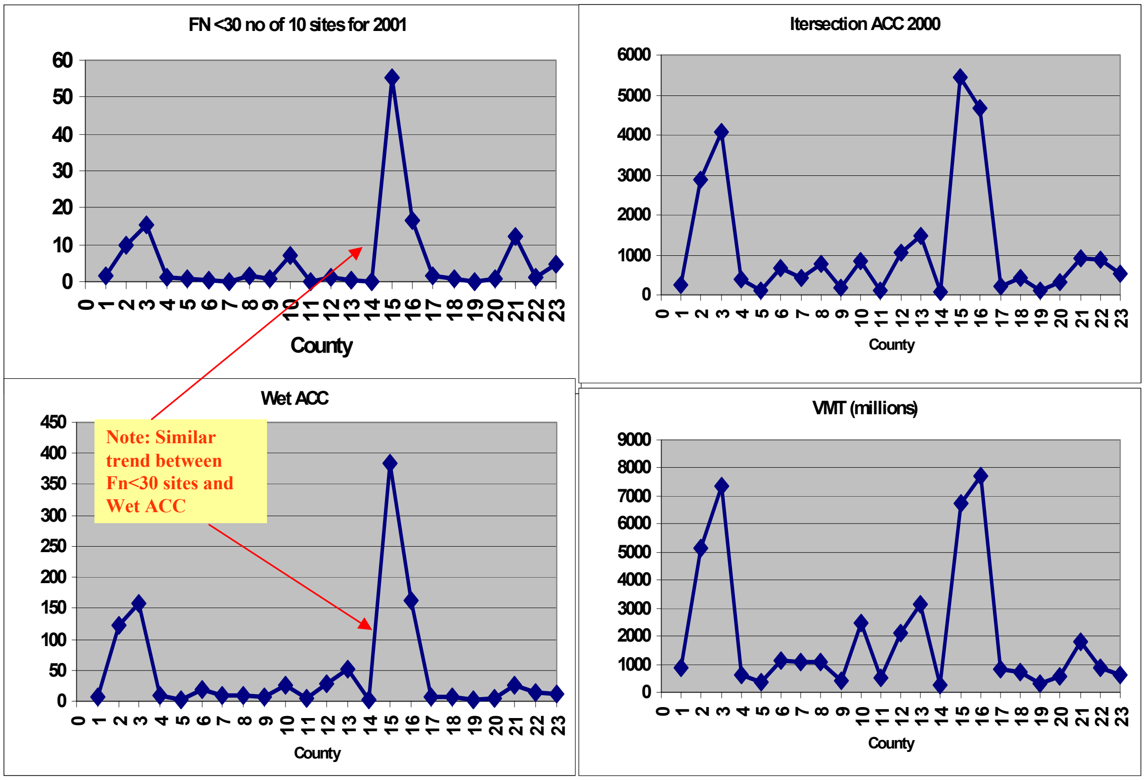


FIGURE 10 FN <30 no of 10 sites vs Vehicle Mile Traveled (millions) vs Wet Accidents vs Total intersection accidents for 23 counties of Maryland

The primary reason for collecting friction data is to prevent or reduce wet surface skid accidents. The friction requirements for a particular site must be known, to provide a potentially skid safe roadway at anticipated speeds. The site category table (TABLE 1) developed by the MDSHA is a good start. By improving skid resistance and reducing wet surface accidents, it will be possible to prevent future wet surface skid accidents at anticipated speed.

The ultimate goal at the MDSHA is to provide safe driving conditions on our highways avoiding injuries, fatalities and economic shortfalls to the public. Our goal directly contributes towards the avoidance of Tort claims for the state. It is in MDSHA's best interest to insure that roadways are safe to be driven on.

The following are proposed recommendations to potentially minimize wet surface accidents in Maryland.

REMEDIAL ACTIONS PROPOSED FOR CONSIDERATION BY THE MDSHA

- Monitoring wet surface accident sites and identifying poor skid resistance locations.
- Sites that have developed a low skid resistance for whatever reason are identified and dealt with quickly by a suitable remedial treatment. If this cannot be done - "*Slippery When Wet* " signs are to be prominently displayed to inform the driving public.
- Measuring skid resistance every 100 ft. for low FN (FN<40) sites and optimizing treatment selection and establishing a relationship with aggregate Polish Value.
- Testing for PV annually and avoiding the use of aggregates that polish easily (e.g. limestone, marble, serpent).

- Implementing a skid resistance policy to select a (design FN) and PV for anticipated maximum speeds for all future SHA pavement projects.
- Establishing a three-year program to eliminate poor skid resistance sites and monitoring the reduction in skid accidents.
- Including skid resistance improvement and the reduction of wet surface skid accidents as a key performance measure *(6)* for the system preservation program *(7)*.

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The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Maryland State Highway Administration.

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