RPUG
Road Profile Users' Group

CELEBRATING
250
RPUG
Road Profile Users' Group
YEARS OF PROGRESS
HONORING THE PAST. PAVING THE FUTURE.

2026 RPUG CONFERENCE ★ PITTSBURGH, PA ★ APRIL 28 - MAY 1

COMBINED EFFECTS OF MACROTEXTURE AND FRICTION IN FACILITY-SPECIFIC WET-WEATHER CRASHES

MD AFIF RAHMAN CHOWDHURY, NCSU
GRADUATE RESEARCH ASSISTANT

OUTLINE

- Acknowledgements
- Research Background
- Objectives
- Data Collection
- Safety Performance Function
- Results
- Conclusions

ACKNOWLEDGEMENTS

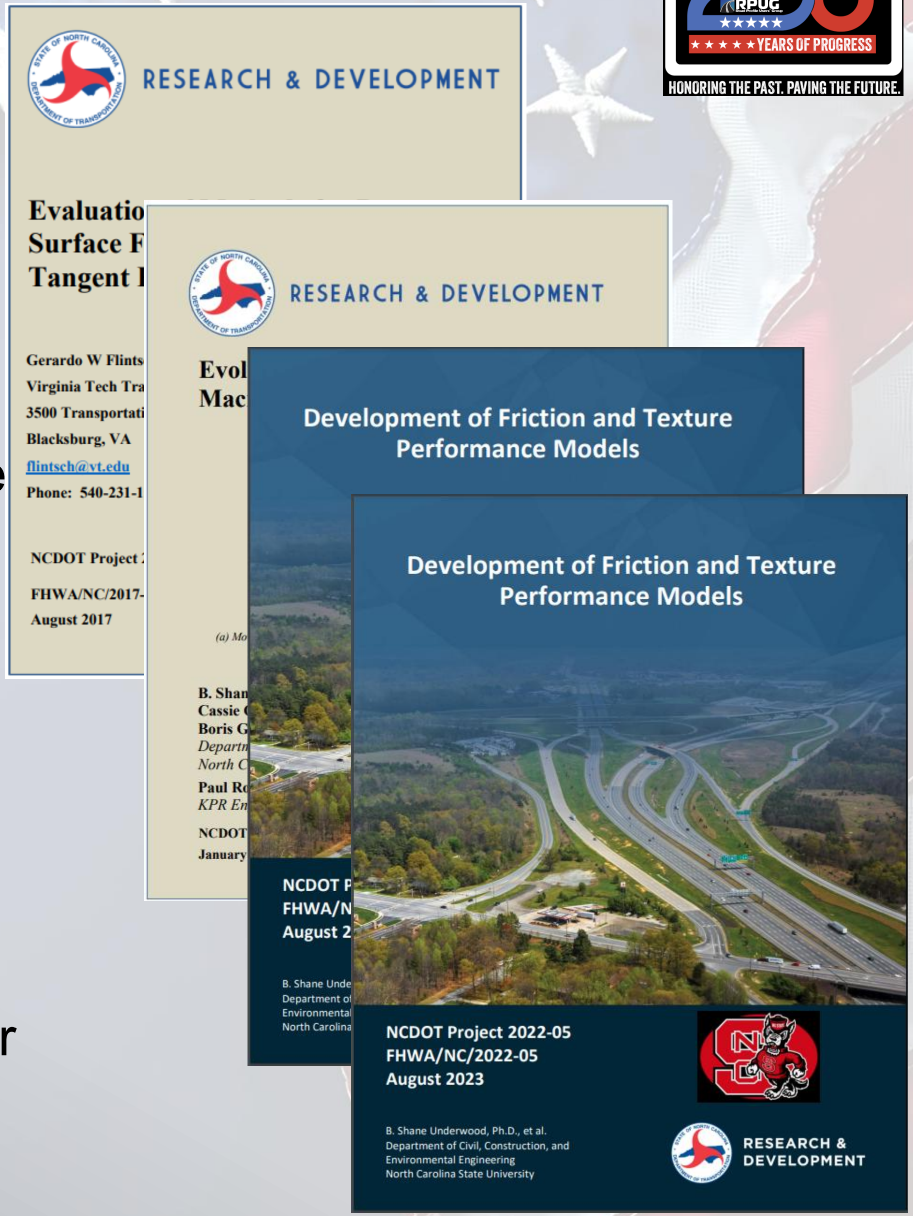
- NCSU
  - Dr. Shane Underwood – Professor
  - Dr. Cassie Castorena – Professor
  - Dr. Boris Goenaga – Former Postdoctoral Research Scholar
- NCDOT
  - Joseph Barbour, M&T
  - Shawn Troy, STU
  - Matt Hildebran, M&T
  - Andrew Wargo, M&T
  - Matthew York, Hydraulics

DISCLAIMER

This presentation represents the opinions of the author and is not meant to represent the position or opinions of the NCDOT or its employees.

RESEARCH BACKGROUND

- Internal studies on targeted sites (2017-current)
- RP2017-02 - Evaluation of Methods for Pavement Surface Friction, Testing on Non-tangent Roadways and Segments (Completed, VT)
- RP2020-11 - Evolution of Pavement Friction and Macrotexture after Asphalt Overlay (Completed)
- RP2022-05 - Development of Friction Performance Models (Completed)
- RP2024-12 - Evaluation of Macrotexture and Friction of Alternative Asphalt Surface Course Material (Completed)
- Network Data Collection (2022, 2023, 2024, 2025)
- RP2025-18 - Updating Friction/Texture Demand Categories for Improved Pavement Design Guidance (Ongoing)



CELEBRATING 250 YEARS OF PROGRESS
HONORING THE PAST. PAVING THE FUTURE.

RPUG Road Profile Users' Group

RESEARCH BACKGROUND

- Lane-departure crashes are a leading highway safety concern, particularly under wet-weather conditions.

- Wet weather greatly reduces pavement’s available skid resistance.

- Individual and combined contributions of macrotexture and friction on wet crashes have been explored previously, but how they affect in facility-specific conditions is underexplored.

OBJECTIVES

- Develop a facility-specific safety performance function (SPF) for wet lane departure crashes across the North Carolina primary road network.

- Quantify the individual influence of friction and macrotexture on wet-weather crash frequency across facility types.

- Further quantify the combined impact of friction and macrotexture on crash frequency across facility types.

DATA COLLECTION

- Continuous Friction Measurement Equipment (CFME)
  - Macrotexture, Mean Profile Depth (*MPD* in mm)
  - Side Force Friction Coefficient (*SC*)
  - Section Length (*L* in miles)

- NCDOT
  - *AADT*
  - Wet Lane Departure Crash

6 months before + surface measurement month + 6 months after

13-Month Crash Count Window

SAFETY PERFORMANCE ANALYSIS

MODEL DEVELOPMENT

Evaluating Individual and Combined Effects of *MPD* and *SC*

Model 1 $N = \exp(a + b_1 \times \ln(AADT) + b_2 \times \ln(L) + b_3 \times \boldsymbol{MPD})$

Model 2 $N = \exp(a + b_1 \times \ln(AADT) + b_2 \times \ln(L) + b_4 \times \boldsymbol{SC})$

Model 3 $N = \exp(a + b_1 \times \ln(AADT) + b_2 \times \ln(L) + b_3 \times \boldsymbol{MPD} + b_4 \times \boldsymbol{SC})$

Where;

AADT = Annual average daily traffic,

L = Section length (mile),

SC = 10^{th} Percentile side force friction value divided by 100,

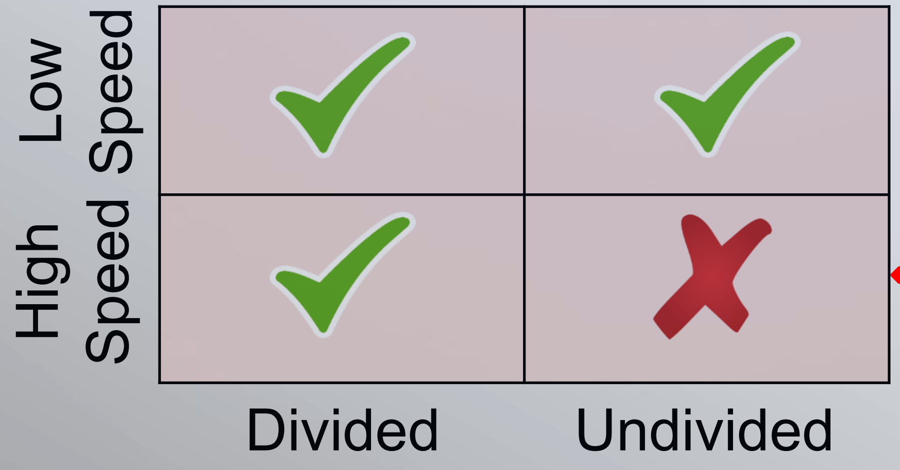
MPD = 50^{th} Percentile mean profile depth (mm), and

a, $b_{1\text{-}4}$ = Fitting coefficients determined through regression.

SAFETY PERFORMANCE ANALYSIS

FACILITY GROUPING STRATEGY

- The homogeneous sections were grouped based on the following criteria:
  - Facility Type: Divided or undivided.
  - Speed Limit: High Speed (Speed Limit ≥ 60 mph) or Low Speed (Speed Limit < 60 mph).



This facility was not evaluated because of the limited sample size.

SAFETY PERFORMANCE ANALYSIS

MODEL CALIBRATION AND EVALUATION METRICS

R^2
Coefficient of determination

- Variance explained by the model
- Higher = better fit.

MAD
Mean absolute deviation

- Difference: observed vs predicted
- Lower = better accuracy.

MACD
Moving average convergence divergence

- Detect over/under-prediction
- Indicates model bias.

Statistical significance level: $p < 0.05$. Coefficients with $p \geq 0.05$ will be highlighted in blue as not significant.

CELEBRATING 250 YEARS OF PROGRESS
HONORING THE PAST. PAVING THE FUTURE.

RPUG Road Profile Users' Group

RESULTS

UNDIVIDED – LOW SPEED FACILITIES

Model Coefficients	Name	Model 1		Model 2		Model 3	
		Value	P-value	Value	P-value	Value	P-value
a	*Intercept*	-4.986	<0.05	-5.144	<0.05	-4.677	<0.05
b1	*AADT*	0.471	<0.05	0.459	<0.05	0.466	<0.05
b2	*L*	0.944	<0.05	0.948	<0.05	0.948	<0.05
b3	*MPD*	-0.582	<0.05	-	-	-0.592	<0.05
b4	*SC*	-	-	-0.316	0.676	-0.421	0.581
R^2		0.648		0.642		0.658	
MAD		0.795		0.798		0.794	
MACD		28.231		28.739		28.265	

Results are physically consistent: *MPD* significantly reduces crashes, while *SC* shows the expected direction but is not statistically significant.

RESULTS

DIVIDED – LOW SPEED FACILITIES

Model Coefficients	Name	Model 1		Model 2		Model 3	
		Value	P-value	Value	P-value	Value	P-value
a	*Intercept*	-8.691	<0.05	-8.202	<0.05	-8.154	<0.05
b1	*AADT*	0.840	<0.05	0.811	<0.05	0.822	<0.05
b2	*L*	1.033	<0.05	1.033	<0.05	1.035	<0.05
b3	*MPD*	-0.138	0.592	-	-	-0.152	0.556
b4	*SC*	-	-	-0.543	0.561	-0.586	0.531
R^2		0.504		0.507		0.507	
MAD		1.847		1.841		1.845	
MACD		108.585		107.032		107.390	

MPD and *SC* follow the expected physical direction, but are not statistically significant.

RESULTS

DIVIDED – HIGH SPEED FACILITIES

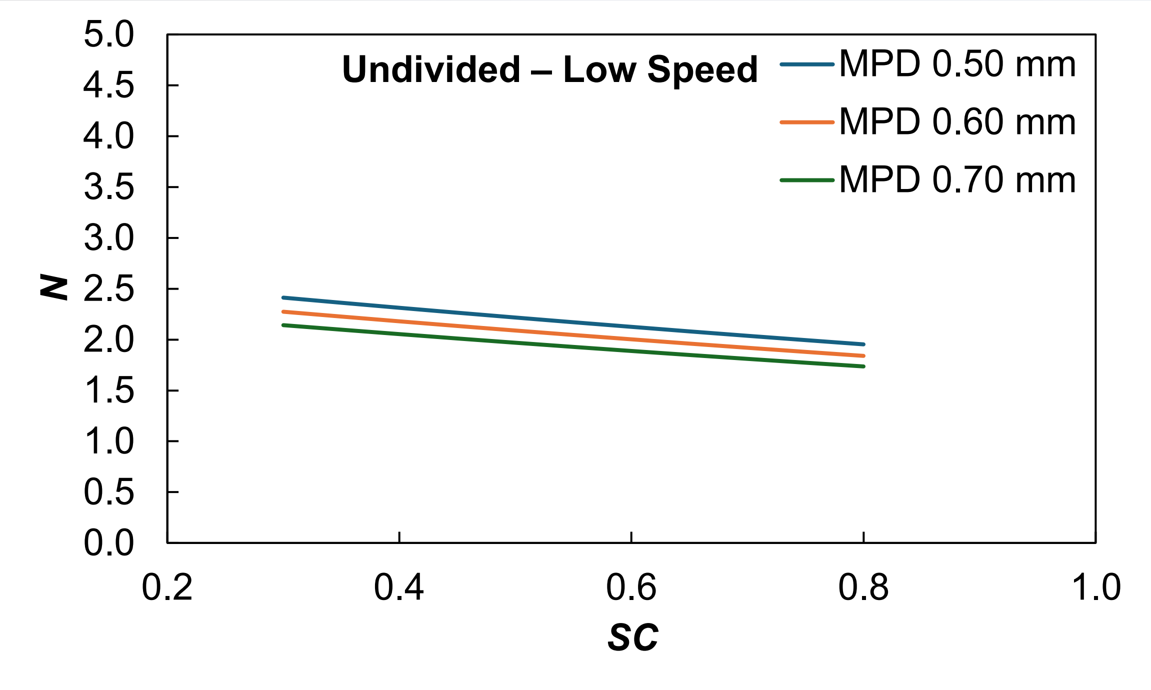
Model Coefficients	Name	Model 1		Model 2		Model 3	
		Value	P-value	Value	P-value	Value	P-value
a	*Intercept*	-6.715	<0.05	-8.288	<0.05	-6.955	<0.05
b1	*AADT*	0.734	<0.05	0.823	<0.05	0.742	<0.05
b2	*L*	0.982	<0.05	0.983	<0.05	0.982	<0.05
b3	*MPD*	-0.562	<0.05	-	-	-0.545	<0.05
b4	*SC*	-	-	1.403	<0.05	0.228	0.762
R^2		0.621		0.583		0.621	
MAD		4.735		4.887		4.736	
MACD		112.724		114.054		108.970	

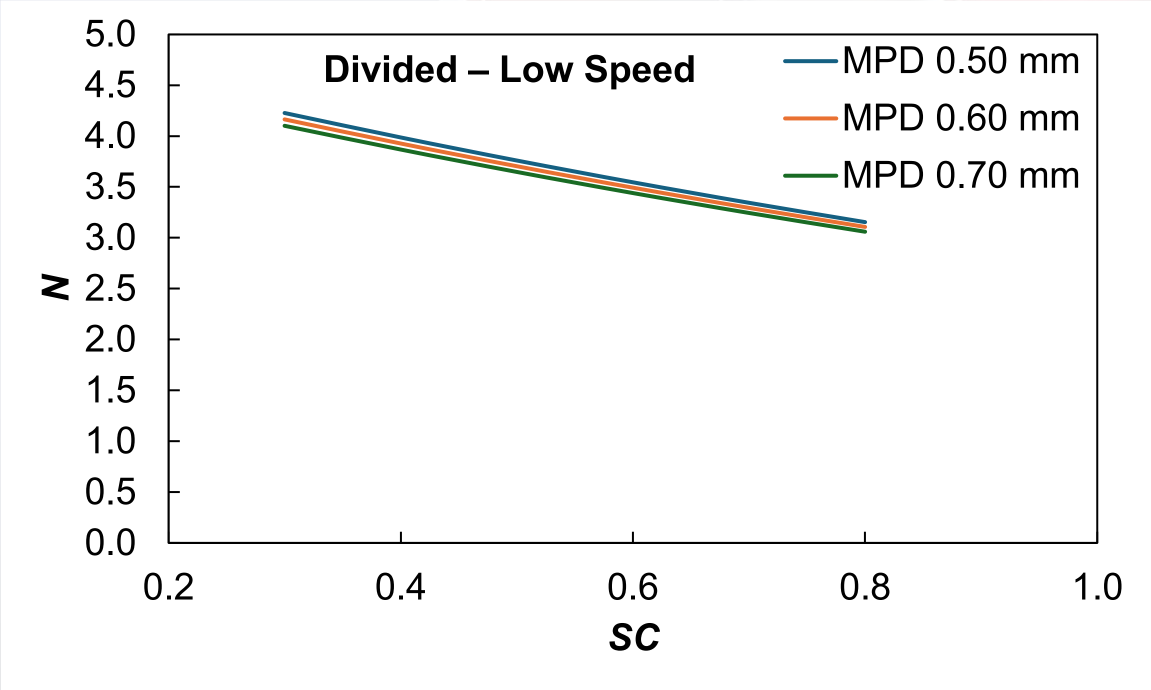
MPD is statistically significant, while *SC* is physically counterintuitive.

RESULTS

SENSITIVITY ANALYSIS FOR MODEL 3

Crash frequency (*N*) decreases with increasing *SC* and *MPD* across both facility types (at constant *AADT* and *L*).





CONCLUSIONS

MACROTEXTURE

- *MPD* shows a consistent negative coefficient with wet lane departure crashes across all facility groups.

- Statistically significant for Undivided - Low Speed and Divided - High Speed facilities.

- Even where *MPD* is not statistically significant (Divided - Low Speed, $p = 0.556$), the coefficient remains negative, physically consistent with the improved drainage and reduced crash risk.

CONCLUSIONS

FRICTION

- Friction demonstrates variable effects across facility types.

- At low-speed facilities, *SC* generally follows the expected negative direction but is often not statistically significant.

- Positive *SC* coefficient at Divide - High Speed facilities results suggest that *MPD* has a stronger influence than *SC*.

- Sensitivity analysis supports the combined role of *MPD* and *SC* in reducing wet crash risk at low speed facilities.

RPUG
Road Profile Users' Group

Thank You