Network Level Friction and Texture in the US

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Research Scientist, VTTI

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PFMP Research Group

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Outline

- Introduction
- History of US Texture Measurements
  - Part 1: 1958 – 1967
  - Part 2: 1968 – 1987
  - Part 3: 1988 – 2017
- NCHRP 10-98 and Tire Pavement Noise
- PE 2019 and SaferRoads 2020

Introduction

- Currently, no AASHTO standard for Network Level Texture data collection.
- NCHRP 10-98: Network Level Protocols
  – Assess adequacy and determine corrective actions of pavement surface
  – Identify factors and equipment, develop methods, specifications, and practices
- Hydroplaning, Noise and Texture, Tire…

History of US Texture, Part 1

- 1958 –Tilton E. Shelburne, 1st International Skid Prevention Conference in Charlottesville, VA, genesis of ASTM E-17 Committee on Skid Resistance (est.1962)
- 1962 – Major skid-test correlation in Tappahannock
- 1964 – First E-17 Standards:
  - E-249-64T, Ribbed Tire (E-501),
  - E-274-65T, Locked-wheel skid tester
  - E-303-65, British Pendulum
- 1967 – Highway Research Board NCHRP Report 37

(Tentative Skid-Resistance Requirements for Main Rural Highways).

E17 EXECUTIVE COMMITTEE (1962 Annual Meeting):
M. D. Graham, N. Y. State Department of Public Works; H. J. Litchfield, FAA (2nd Vice Chairman); T. H. Boone, NBS; C. L. Flooding, 3-M Co.; E. A. Whitehurst, Tennessee Highway Research Program (Chairman); J. H. Dillard, University of Virginia (Secretary); T. E. Shelburne, Virginia Department of Highways; R. H. Sawyer, USAF.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGR
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HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 37

TENTATIVE SKID-RESISTANCE REQUIREMENTS FOR MAIN RURAL HIGHWAYS

H. W. KUMMER AND W. E. MEYER
DEPARTMENT OF MECHANICAL ENGINEERING
THE PENNSYLVANIA STATE UNIVERSITY

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION
OF STATE HIGHWAY OFFICIALS IN COOPERATION
WITH THE BUREAU OF PUBLIC ROADS

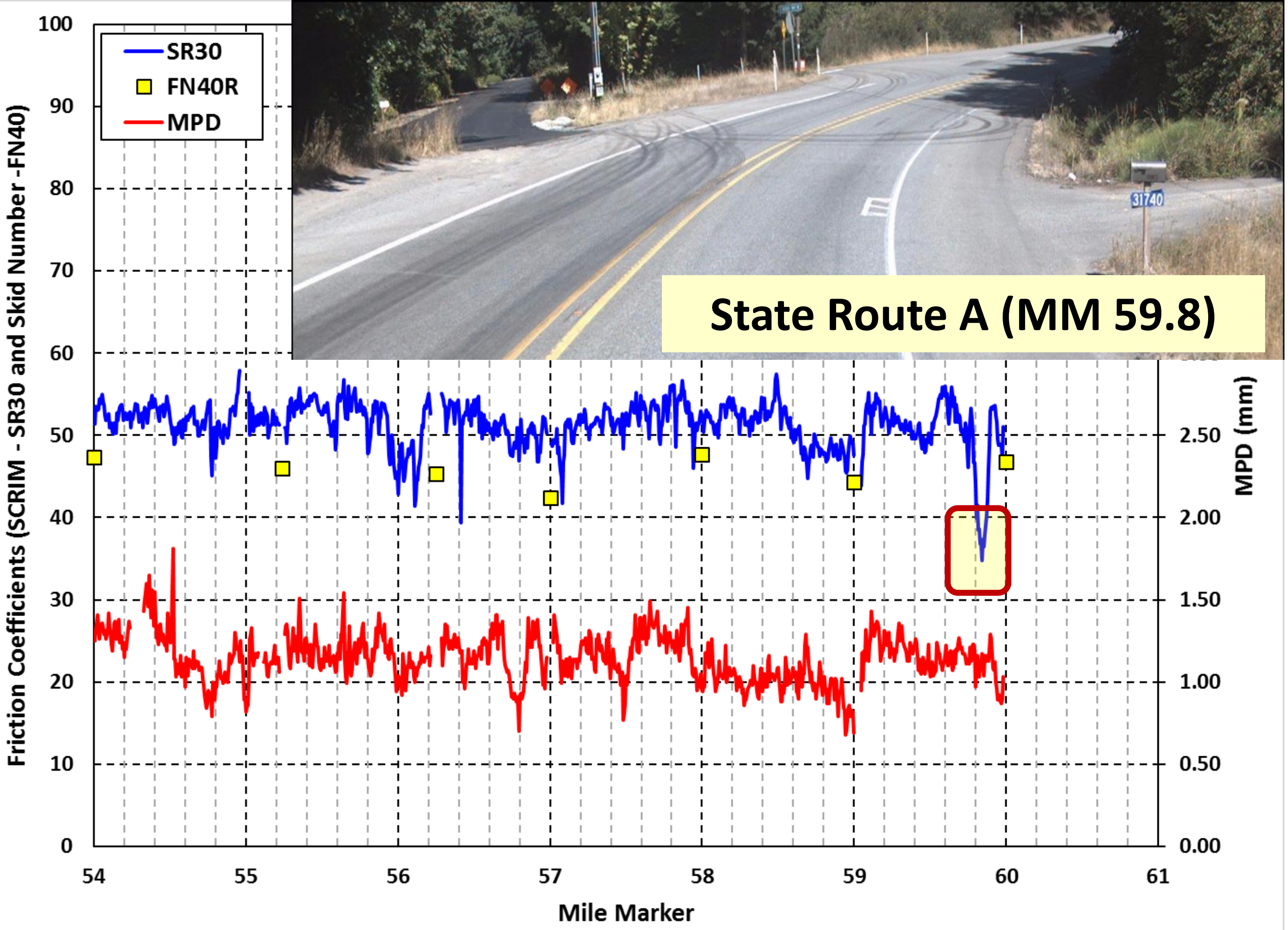
SUBJECT CLASSIFICATION:
PAVEMENT PERFORMANCE
HIGHWAY SAFETY

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING 1967

H. W. Kummer and W. E. Meyer

First test runs of the Brake Test Trailer with the Boeing Antilock System Installed

Mech. Eng. Lab PSU 1959



"Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on **high-speed roads, curves, and approaches to intersections**; in short, in locations at which high friction values are needed most."

NCHRP Report 37, 1967

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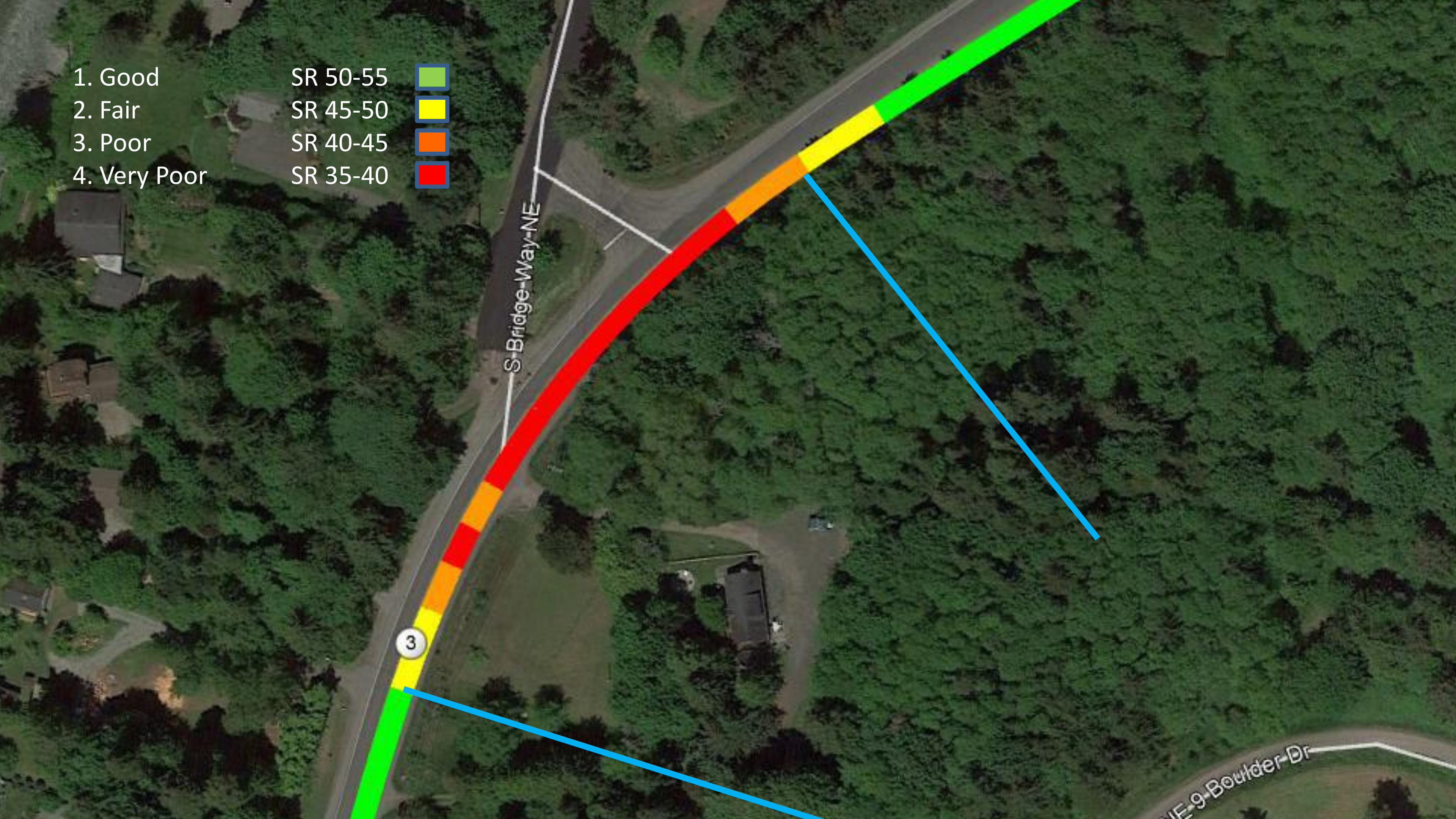
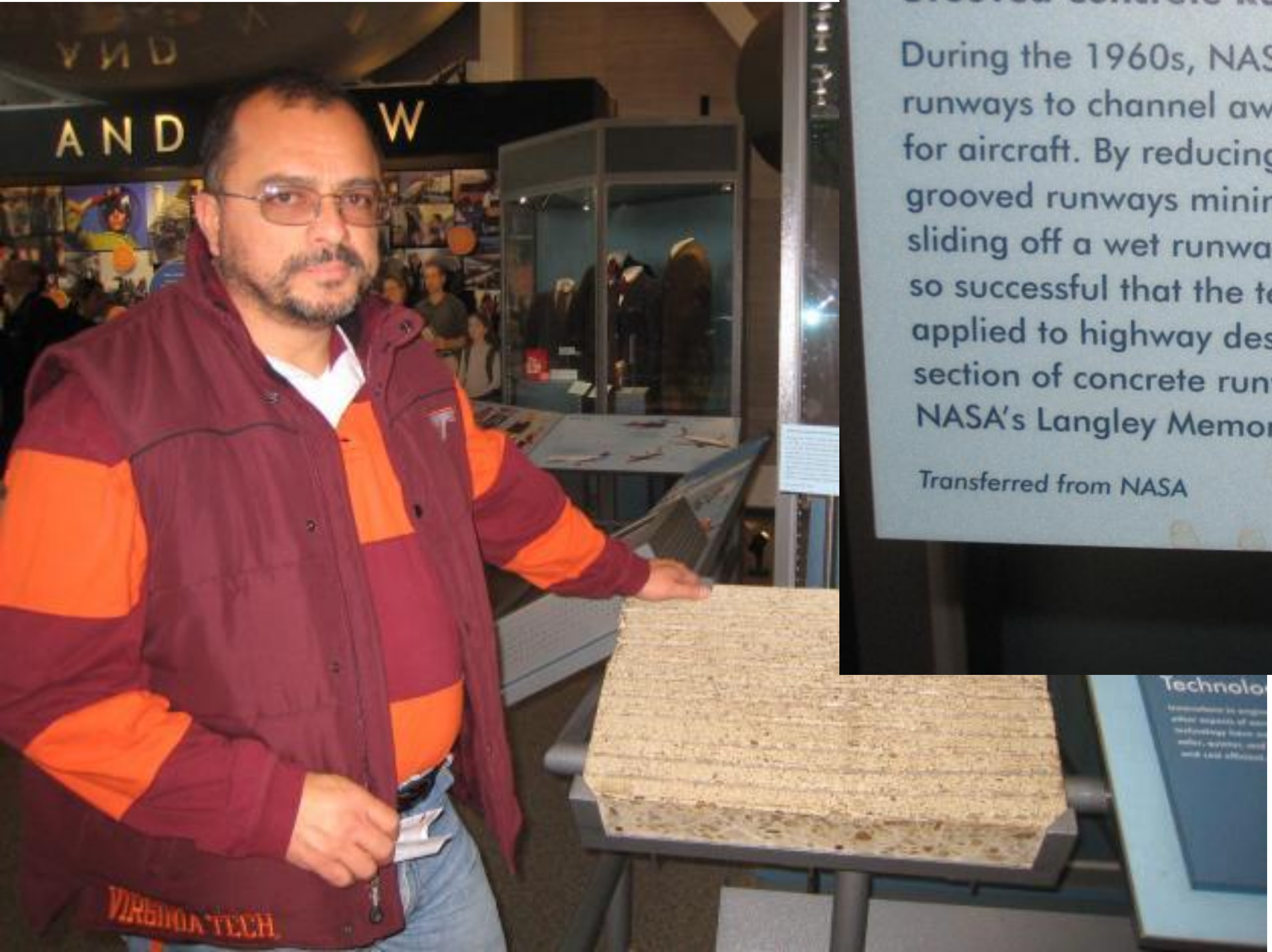
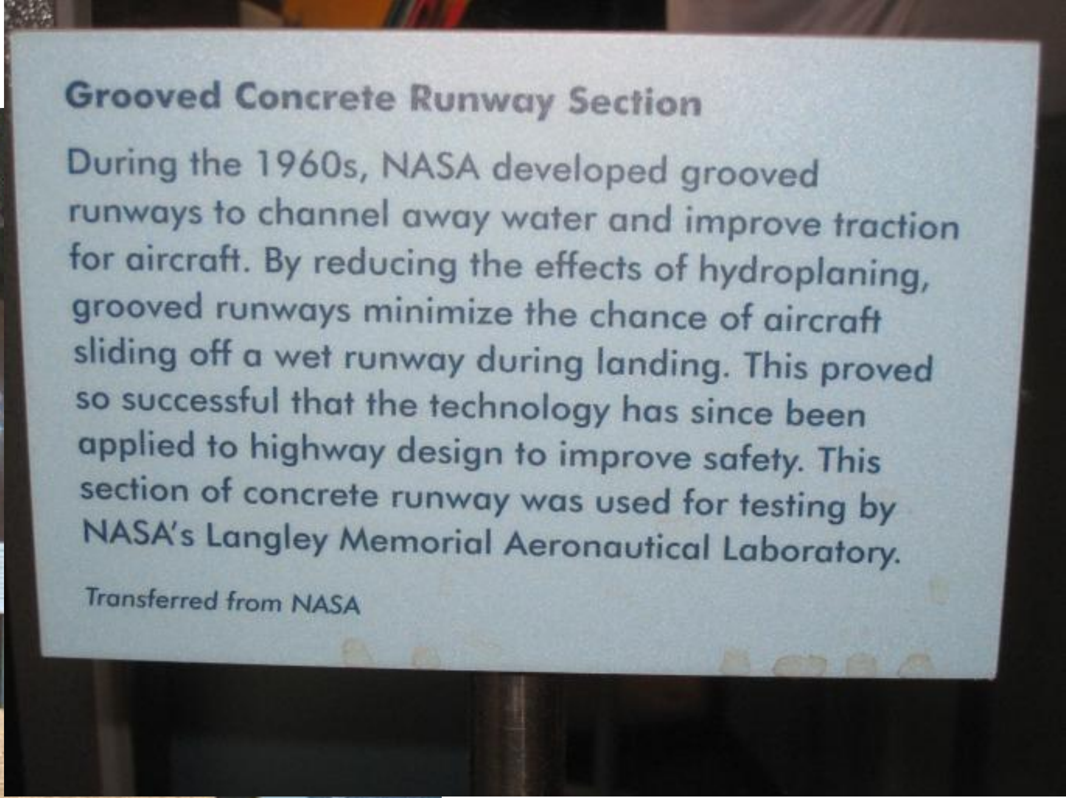

1. Good
2. Fair
3. Poor
4. Very Poor
SR 50-55
SR 45-50
SR 40-45
SR 35-40
S Bridge Way NE
3
NE 9 Boulder Dr

History of US Texture, Part 2

- August 8, 1968 –
Tilton E. Shelburne & Hartwig W. Kummer
- 1968 – At NASA, pavement grooving is developed




Grooved Concrete Runway Section
During the 1960s, NASA developed grooved runways to channel away water and improve traction for aircraft. By reducing the effects of hydroplaning, grooved runways minimize the chance of aircraft sliding off a wet runway during landing. This proved so successful that the technology has since been applied to highway design to improve safety. This section of concrete runway was used for testing by NASA's Langley Memorial Aeronautical Laboratory.
Transferred from NASA

History of US Texture, Part 2

- August 8, 1968 –
Tilton E. Shelburne & Hartwig W. Kummer
- 1968 – At NASA, pavement grooving is developed
- 1970 – The Kummer Lecture Award (33)
- 1981 – The Tilton E. Shelburne Award (21)
- 1987 – PIARC Road Congress Brussels proposes texture wavelength categories. (Also lasers & friction seasonal variations and restoration)

XVIII[th] WORLD ROAD CONGRESS

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13-19 SEPT. 1987

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REPORT No 1

SURFACE CHARACTERISTICS

PERMANENT INTERNATIONAL ASSOCIATION
OF ROAD CONGRESSES

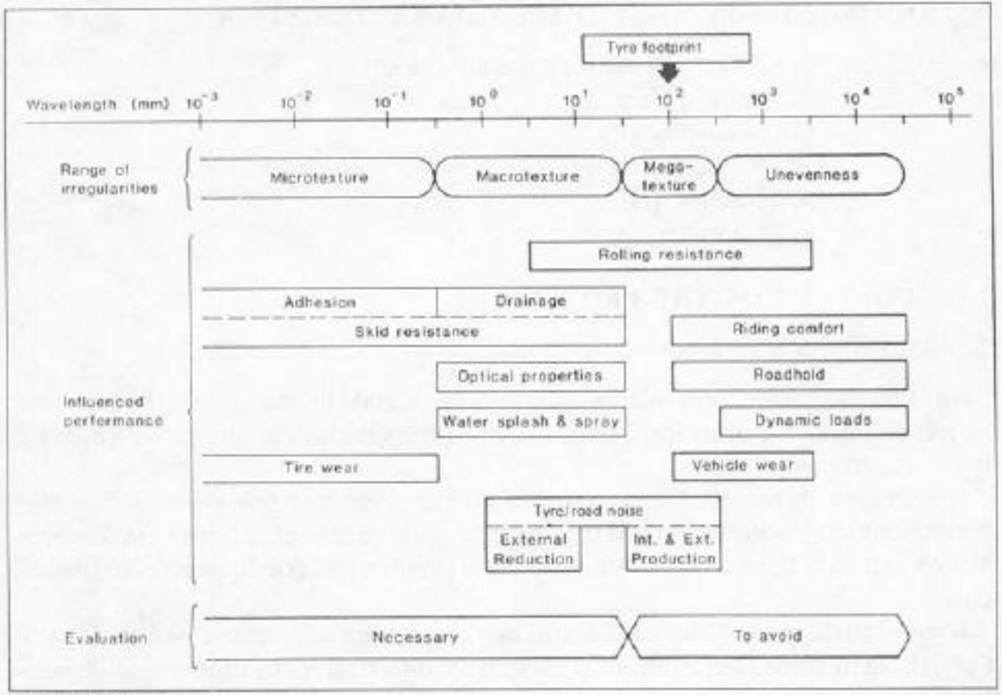

Table 1

a new range of irregularities called "MEGATEXTURE", situated between "macrotexture" and "evenness" which reveals itself as the determining factor as regards noise and driving resistance among other phenomena.

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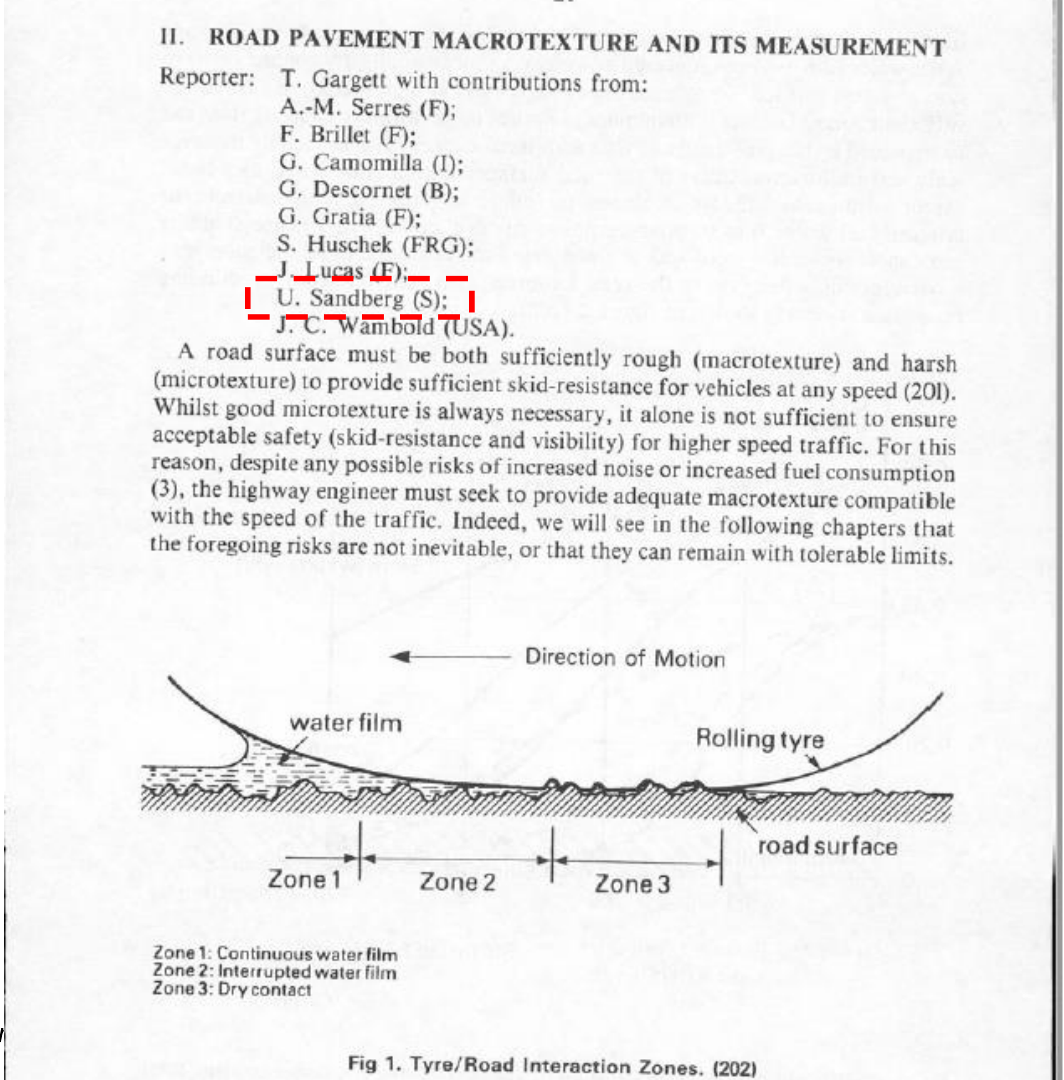


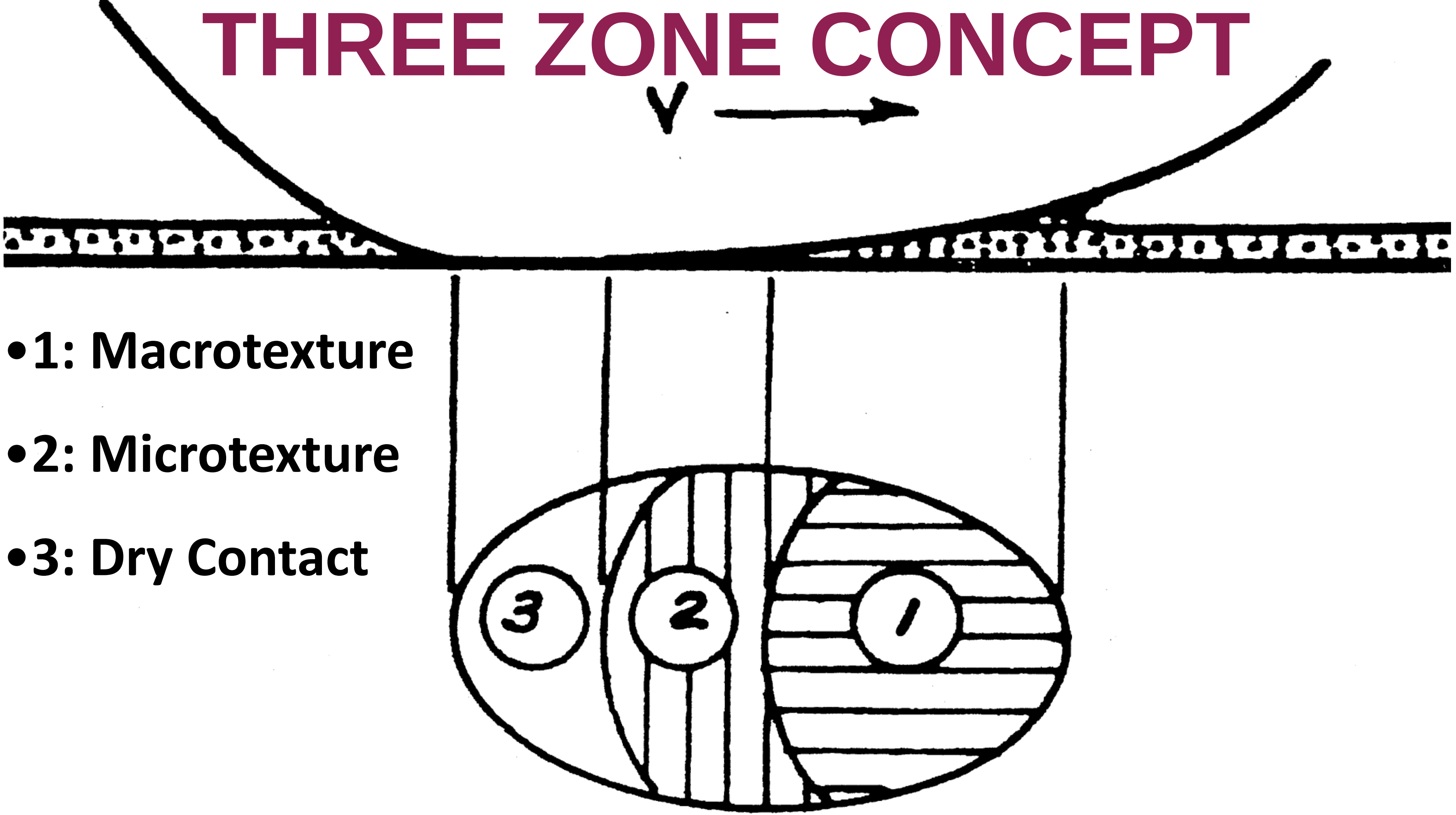
II. ROAD PAVEMENT MACROTEXTURE AND ITS MEASUREMENT

Reporter: T. Gargett with contributions from:
A.-M. Serres (F);
F. Brillet (F);
G. Camomilla (I);
G. Descornet (B);
G. Gratia (F);
S. Huschek (FRG);
J. Lucas (F);
U. Sandberg (S);
J. C. Wambold (USA).

A road surface must be both sufficiently rough (macrotexture) and harsh (microtexture) to provide sufficient skid-resistance for vehicles at any speed (201). Whilst good microtexture is always necessary, it alone is not sufficient to ensure acceptable safety (skid-resistance and visibility) for higher speed traffic. For this reason, despite any possible risks of increased noise or increased fuel consumption (3), the highway engineer must seek to provide adequate macrotexture compatible with the speed of the traffic. Indeed, we will see in the following chapters that the foregoing risks are not inevitable, or that they can remain with tolerable limits.

Fig 1. Tyre/Road Interaction Zones. (202)

THREE ZONE CONCEPT



- 1: Macrotexture
- 2: Microtexture
- 3: Dry Contact


BRUXELLES 13-19.9.1987 BRUSSELS
XVIII CONGRES MONDIAL DE LA ROUTE
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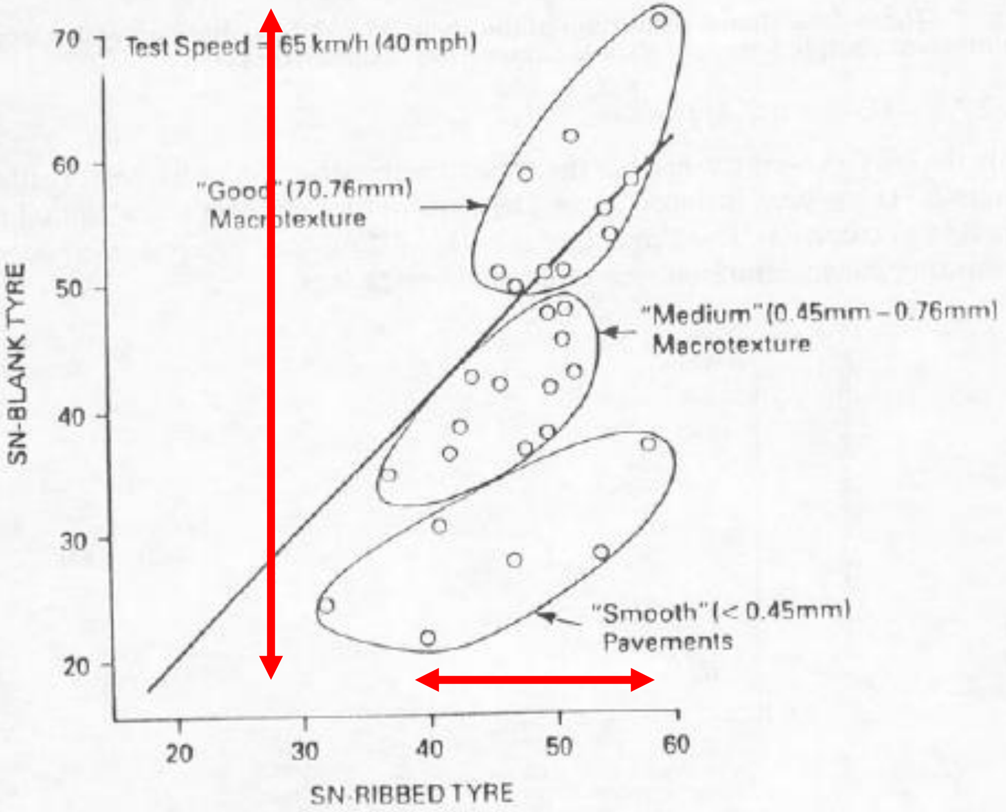
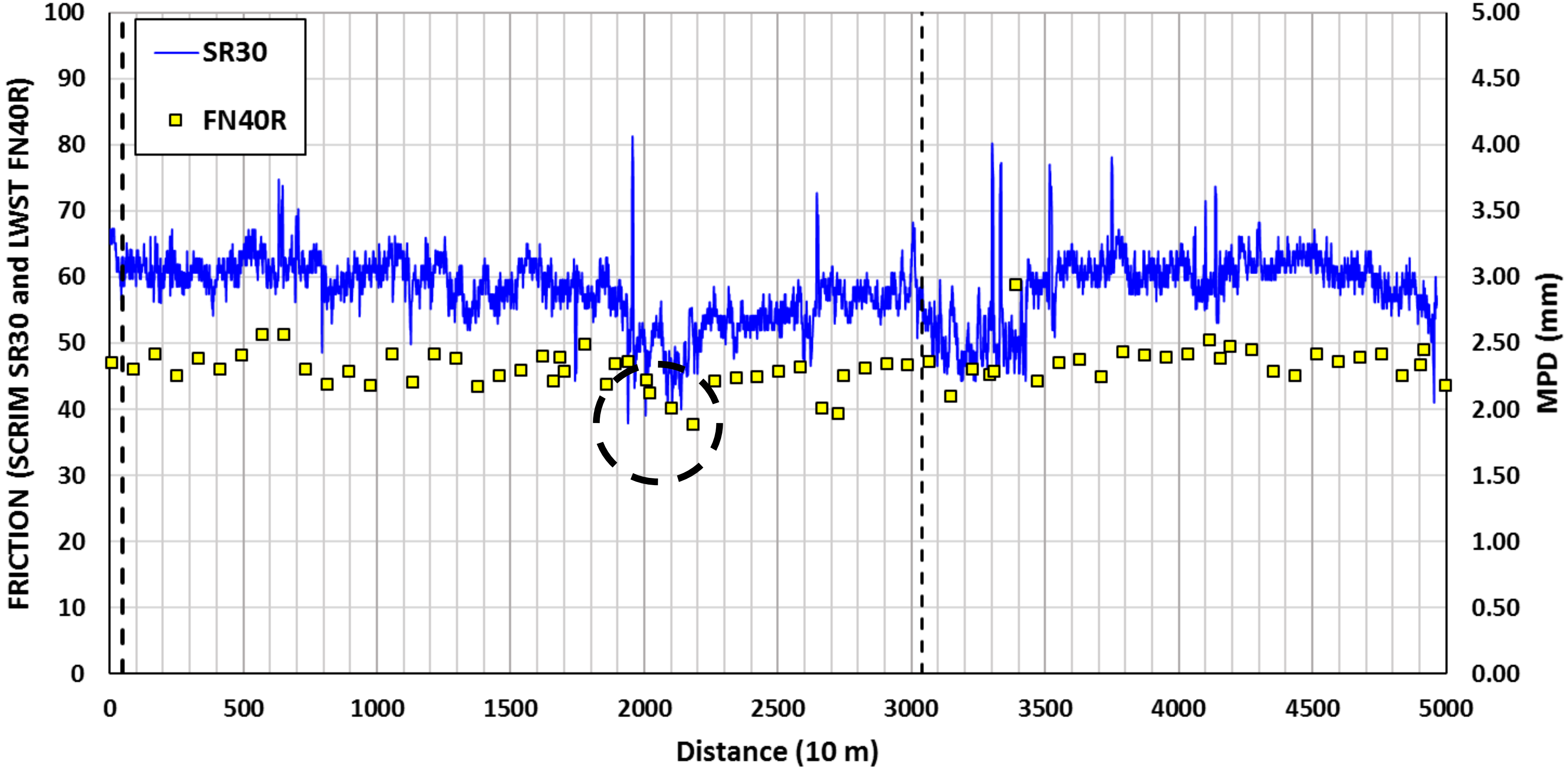


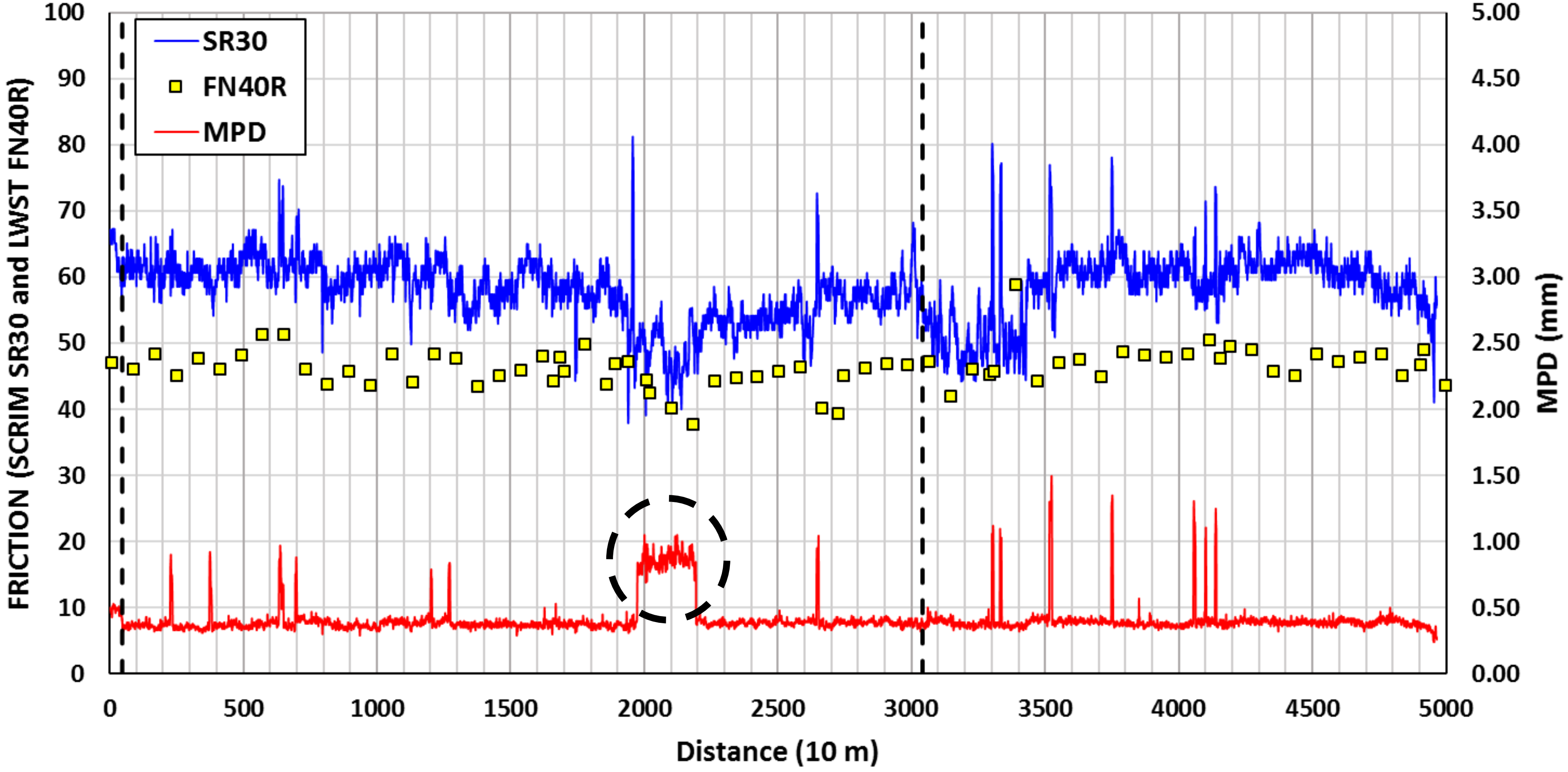
Fig. 12. Relationship between SN^{R}_{40} and SN^{B}_{40} on pavements in Virginia. (9)

LOOP Q


SR30
FN40R
FRICTION (SCRIM SR30 and LWST FN40R)
MPD (mm)
Distance (10 m)
100
90
80
70
60
50
40
30
20
10
0
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

LOOP Q

0.4 mm vs. 2/32 inch (1.6 mm)



Route Summary

- **Section 3, 4, and 6 – 55 MPH**
  - **9.09 Miles** (years before – 3.00, years after – 1.21)   ADT = 15,000-18,000
  - Total Crashes   before = 119   after = 72
  - Wet Crashes   before = 33 *(28%)*   after = 21 *(29%)*
  - Wet/Year/Mile   before = 1.21   after = 1.91 *(58% +)*
  - S9.5C (2015)   SR 30 = 51.3-57.1   MPD = 0.37-0.40

- **Section 2 and 7 – 70 MPH**
  - **24.10 Miles** (years before – 3.00, years after – 1.21)   ADT = 15,000-18,000
  - Total Crashes   before = 269   after = 234
  - Wet Crashes   before = 112 *(42%)*   after = 157 *(67%)*
  - Wet/Year/Mile   before = 1.55   after = 5.38 *(248% +)*
  - S9.5C (2015)   SR 30 = 60.4-60.5   MPD = 0.38-0.40

History of US Texture, Part 3

- **1990 – ASTM STP 1031:**
  - Skid Resistance Policy in UK IL’s for different categories (1988)
  - **Measurement of Skid Resistance and Texture**
  - **New-Generation Skid Testers for the 1990s**
  - Macro and Megatexture influence on fuel consumption (Ulf)
- **1992 – PIARC International Harmonization Experiment**
  - Friction Workshops Wallops 1993 – 2008, 2009 PSU, 2017+ FRA
- **2000 –E-274 39 states**, 33 ribbed, 5 smooth + AZ. 50 % use data for accidents, macrotexture only 5 states.
- **2009 –E-274 17 states**, “network level” 1 test/mile, 2-4 yr.

James C. Wambold,[1] Wolfgang E. Meyer,[1] and John J. Henry[1]

New-Generation Skid Testers for the 1990s

What is needed is a tester that can obtain the skid number as a function of speed **in a single pass.**

ABS can be expected to become **standard on all cars and trucks**. The locked-wheel number (64 km/h) provides only **approximate information of the friction coefficient**. Another improvement would be the possibility to **calibrate the tester without taking it to a calibration center.**

The vertical load on the tires of a tester is **constant on a smooth tangent road**. **On curves,** the test tire does not remain perpendicular to the road surface, and load shifts occur between the two wheels of the tester.

The results of these tests support the validity of the two methods: The use of the ribbed and blank tire method is recommended for existing designs, and the spin-up method is recommended as the basis for a new tester design.

It must be realized, however, that these tests were carried out under controlled conditions designed to obtain clean data. The determination of the correlations which should be obtained in actual field use **remains to be investigated**.

Christopher K. Kennedy,[1] Arthur E. Young,[2] and Ian C. Butler[2]

Measurement of Skidding Resistance and

Conclusions

1. The operation of a system for the routine monitoring of the wet-road skid resistance of a highway network and the implementation of a skid-resistance improvement program can be highly cost-effective and can substantially reduce accident rates. Skid-resistance improvements at **2000 accident sites in London reduced the number of wet-road accidents by 35%, giving a net economic return of 540%.**

2. **Both microtexture and macrotexture need to be monitored. Microtexture is important at all speeds; macrotexture is particularly important at high speeds.**

3. Equipment is now available which enables surveys to be carried out rapidly and intensively. **SCRIM can measure the microtexture (sideway-force coefficient) of 200 lane-km per day. The laser-based High-Speed Texture Meter can measure the macrotexture of up to 500 lane km per day.**

4. **Computer-based systems** have been developed to process rapidly the large quantities of data generated by the test vehicles; the results can be presented in various forms which **enable substandard sections of road to be identified readily**.

Crash Costs vs. Treatments

Crash Category	Virginia Crashes [1]	Category %	Cost ($1,000) [2]	Total Cost ($1,000)
PDO	77,941	63.1%	$6.1	$473,570
Injury	44,924	36.4%	$167.5	$7,525,803
Fatality	714	0.6%	$9,146.0	$6,530,243
Total	123,579			$14,529,615

Notes:

1. Year 2,010
2. NHTSA Cost Report, 2,010

Average cost: $117,573

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Crash Costs vs. Treatments

Friction Treatment	Treatment Cost [2]	Treatment cost per one-crash	Treatments of 0.1-mile sections per one-crash	CR per $0.5 million of savings per 0.1-mile section
DGAC O/L	$15,000	0.10	9.7	3.5
OGFC [1]	$22,500	0.15	6.5	3.6
CDG	$7,000	0.05	20.8	3.5
HFS	$40,000	0.27	3.6	3.7

Notes:

1. 1.5 cost of DGAC (18/12)
2. For 0.1-mile, 12 foot-lane

Conclusions (First Part)

Hurdles to overcome:

- **INMP syndrome (Cooperation with Safety)**
- **Financial vs. Economic Considerations**
- **Act today, commit, and do it**
  - **Special Task Force**
  - **Interdivision Cooperation**
  - **Consider other ideas**

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30 Years On The Road To Progressively Better Data

Rapid City September 18-21

Protocols for Network Level Macrotexture

By

Vincent Bongioanni, P.E.

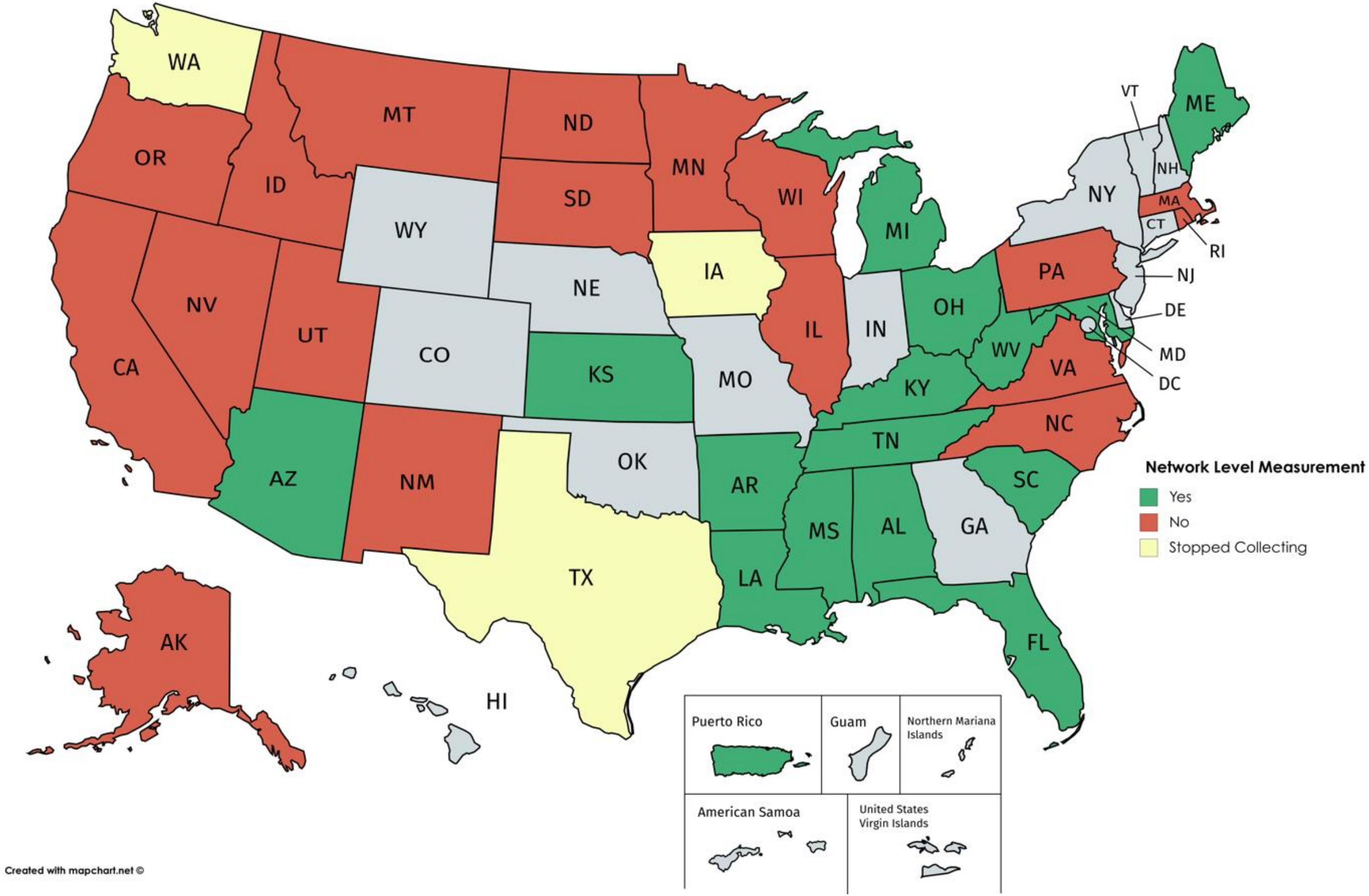
VIRGINIA TECH

Virginia Tech Transportation Institute

NCHRP 10-98 Objective

Develop recommended protocols for test methods, equipment specifications, and data quality assurance practice for network-level macrotexture measurement

1. Identify the equipment, environmental, and operational factors that influence macrotexture measurement and the macrotexture characterization parameters used for representing the macrotexture,
2. Develop improved methods for network-level macrotexture measurement that address these factors and parameters, and
3. Prepare recommended test procedures, equipment specifications, data quality assurance practices, and implementation guidelines to facilitate use of these methods



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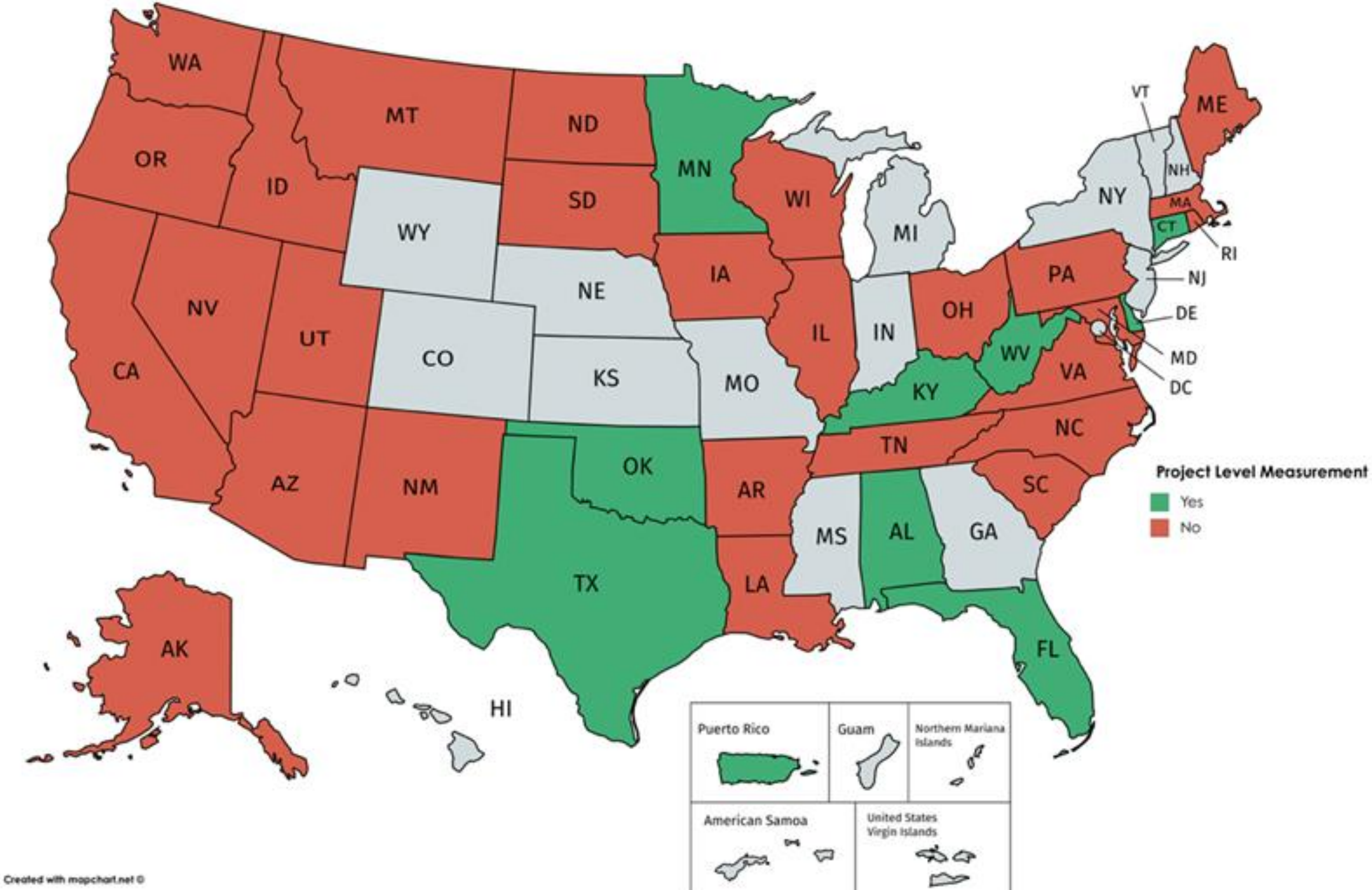

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Experiment 1 - Equipment Comparison

- **The Virginia Smart Road**

Surfaces:

- Dense-graded asphalt concrete
- Stone-matrix asphalt (SMA)
- Open graded friction course (OGFC)
- Continuously reinforced tinned concrete
- Jointed tinned concrete
- Longitudinally ground concrete
- Longitudinally ground and grooved concrete

Experiment 2 – Verification Experiment

- To refine the data collection approaches and finalize the proposed macrotexture characterization parameter(s)
- MnROAD: 24 – 27 Sep 18

Surfaces:

- Asphalt Concrete, dense graded
- Open Graded Friction Course
- Gap Graded Asphalt Surface (NOVACHIP)
- PCC with Transverse Tining
- PCC with Longitudinal Tining
- PCC with Longitudinal Diamond Ground, conventional diamond ground
- PCC w/Longitudinal Grooves, (NGCS)
- Microsurfacing
- Chip Seal

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Experiment 3 – Validation Experiment

- **TEXAS A&M RELLIS Test Track**
- **November 25-28, 2018**

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Rapid City September 18-21

Tire Pavement Interaction Noise and Correlation with Pavement Texture Parameters

Presentation by

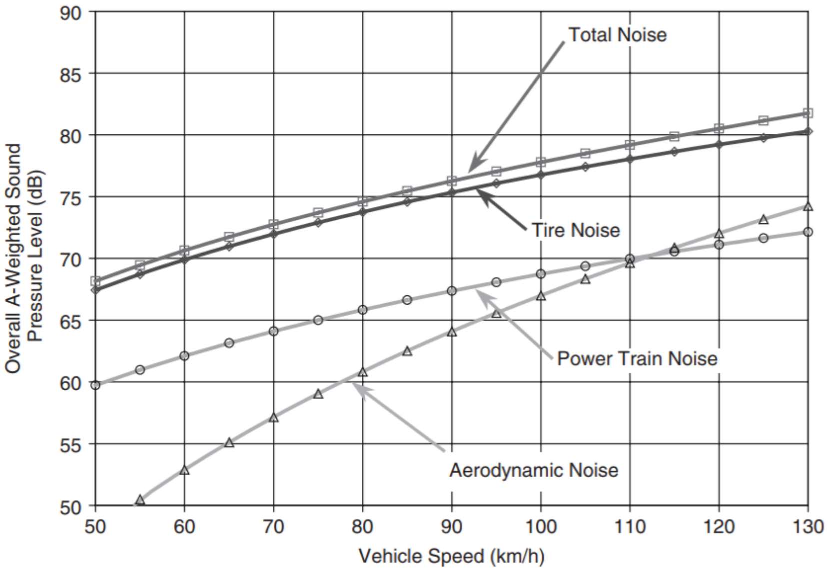
Dr. Ricardo Burdisso

Lucas Spies[1]; Sterling McBride[2]; Ricardo Burdisso[3]; Corina Sandu[4] and Vincent Bongioanni[5]

[1]lucass19@vt.edu; [2]msterl6@vt.edu; [3]rburdiss@vt.edu; [4] csandu@vt.edu; [5]VBongioanni@vtti.vt.edu

Introduction

- Tire noise is the main contributor to vehicle noise at highway speeds.
- Typical mitigation is to implement acoustic barriers for main highways and roads.
- The main noise sources for tire-pavement noise (TPIN) have not been accurately modeled.
- An experimental TPIN campaign was undertaken at Virginia Tech for:
  - Model development
    - Empirical and physically based predictions
  - Uncover physical insight into TPIN



Donavan, P. (2008) - Exterior Noise of Vehicles

Experiments: Pavements and Tires

- US460 Road

Dense graded hot mix asphalt (HMA)

- VT SMART road

26 pavement sections:

- 14 mixes asphalt
- 8 concrete
- 3 bridges
- 1 Open Graded Friction
- 1 concrete section with longitudinal grooves
- 7 concrete sections with transverse grooves

- 42 tires

- 5 tires

SRTT Tire was tested in all pavements

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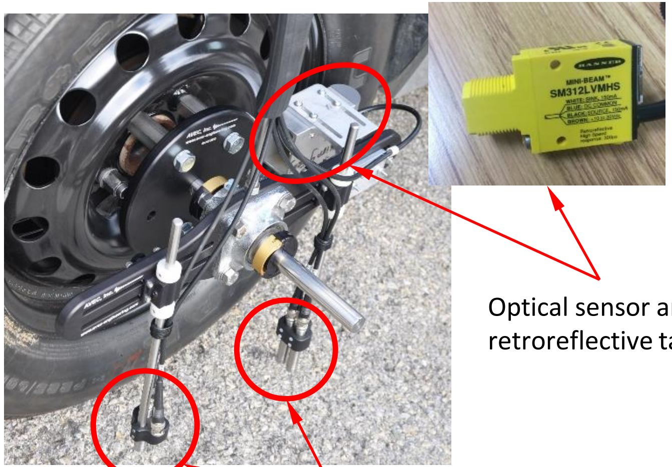
Experiments: Noise Measurements

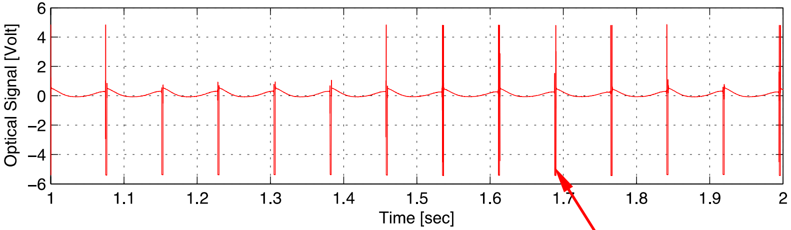
- Noise: OBSI with optical sensor



Optical sensor and retroreflective tape

Sound intensity probes

- Optical sensor produces a once per revolution signal. It is used to
  - obtain vehicle speed accurately.
  - perform order tracking analysis.

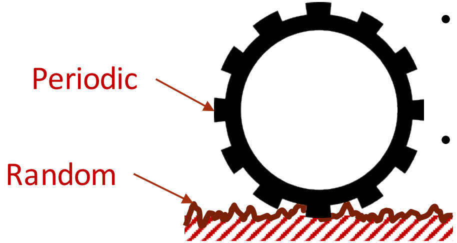


Each peak represents the retroreflective tape going in front of the optical sensor.

OBSI: On-Board Sound Intensity system

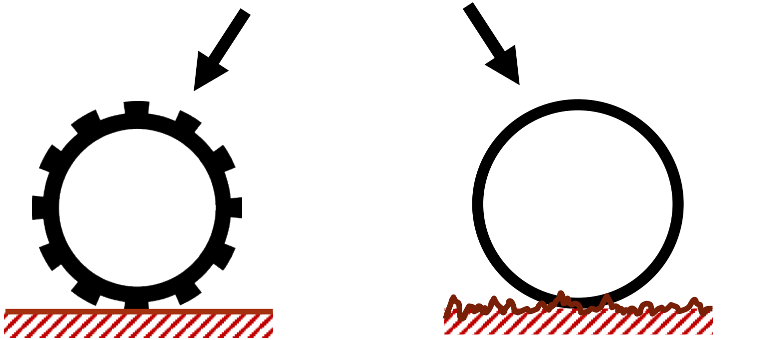
Experiments results: Tread and non-tread pattern Noise

- TPIN can be separated into two components: tread (TPN) and non-tread pattern (NTPN) noise



- **Two excitation sources:**
  - Tread pattern (periodic)
  - Pavement texture (random)
- **Two noise components can be separated:**
  - Tread pattern noise (due to tread pattern)
  - Non-tread pattern noise (mainly due to pavement)

Optical signal used to perform order tracking analysis.



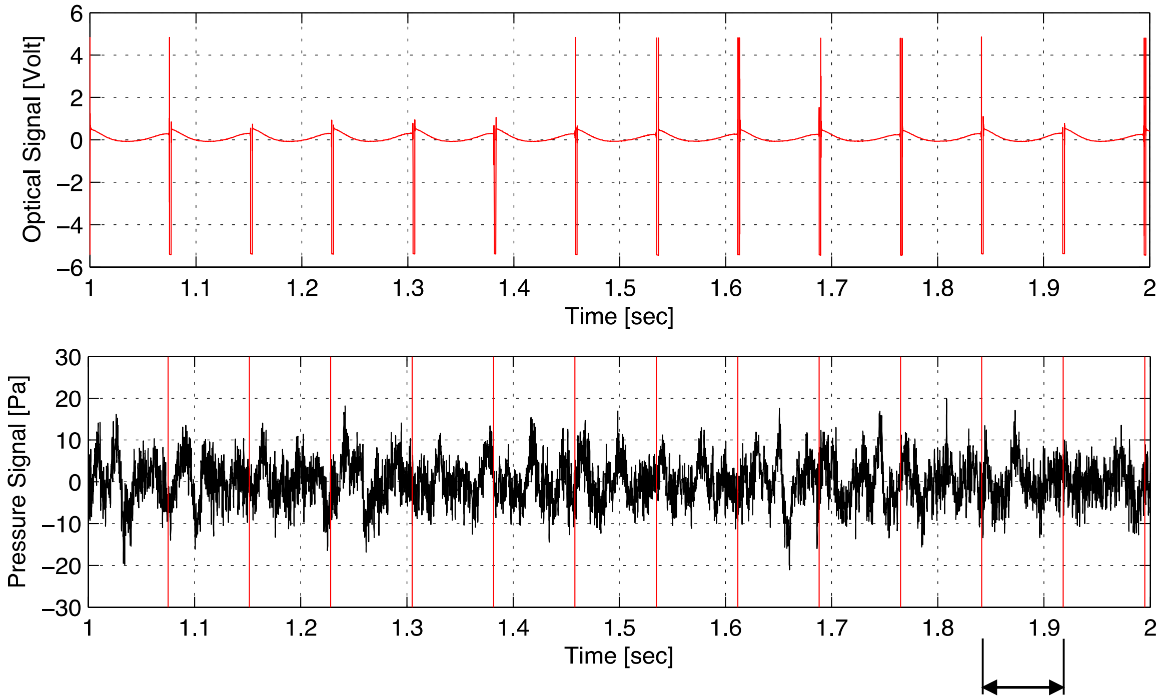
Tread pattern excitation: Tread pattern noise

Pavement texture excitation: Pavement texture noise

Order tracking analysis allows to extract the tread pattern noise from the total noise signal

Experiments results: Tread and non-tread pattern Noise

- Extraction of TPN noise:



1 revolution of the tire (window).

Order tracking analysis:
For each window

- Noise signal resampled
- Compute DFT
- Average DFTs (TPN in frequency domain)
- Take inverse DFT of average DFT (TPN in time domain)
- Subtract TPN signal from total signal (NTPN in time domain)

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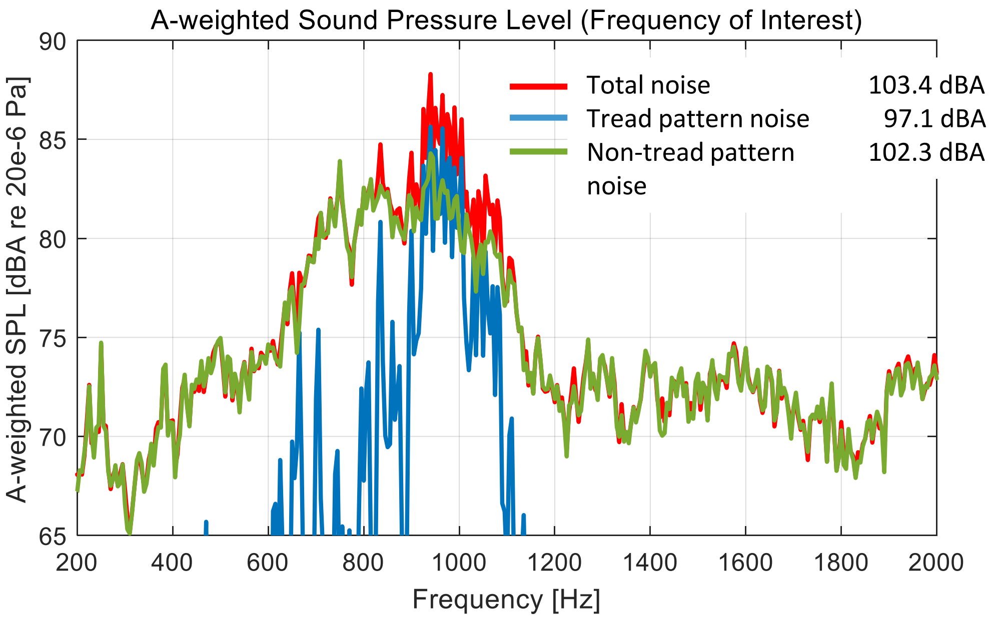
103.4	97.1	102.3

Experiments results: Tread and non-tread pattern Noise

- Tire noise separation results: winter tire – US460 – 60 mph

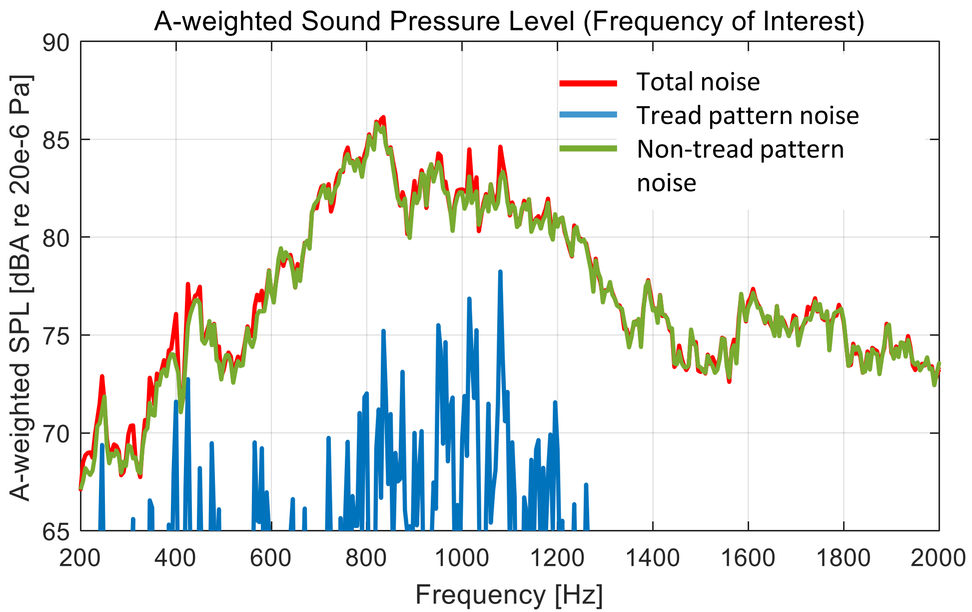


Michelin X-ICE X13
(Winter tire)
215/60R16

TPN accounts for 23.4% of total acoustic energy.

Experiments results: Tread and non-tread pattern Noise

- Tire noise separation results: SRTT – US460 – 60 mph



SRTT - Standard Reference Test Tire

TPN accounts for 3.8% of total acoustic energy (for the pavement tested).

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Experiments results: Tread and non-tread pattern Noise

- TPN is produced only by the tread pattern.
- NTPN is mainly produced by the pavement (independent of tread pattern).
- These observations suggest that the characterization of pavement noise should be based only on the NTPN.
- The rest of the results will focus on NTPN component.

Discussions

- A large number of tire noise data was collected using an OBSI system with an optical sensor (for order tracking analysis) under multiple testing conditions.
- Pavement profile data was acquired using a scanning laser.
- Tire noise was separated into two main components: tread (TPN) and non-tread-pattern (NTPN) noise
  - TPN is due only the tread pattern
  - NTPN is mainly a function of pavement.
- The NTPN spectrum is correlated to the pavement profile spectrum only over a limited frequency range (~ 200 to 900 Hz).

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Sept.
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PAVEMENT EVALUATION 2019

VIRGINIA TECH

Roanoke, VA

September 17-21, 2019

ATSSA
SAFER ROADS SAVE LIVES

SaferRoads2020
6th International Conference

The 6th International SaferRoads Conference

is coming to Virginia (USA)

May of 2020

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To learn more contact
Donna Clark, VP of Member Services
American Traffic Safety Services Association
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