RPUG
Road Profile Users' Group

TOWARDS STANDARDIZED PAVEMENT SURFACE TEXTURE SPECTRAL ANALYSIS AND EVALUATION

Ahmad Alhasan[1], Ph.D., P.E. and David White[2], Ph.D., P.E.

[1] Vice President of Engineering Services

[2] Founder and CEO

Ingios Geotechnics

CELEBRATING 250 YEARS OF PROGRESS

HONORING THE PAST. PAVING THE FUTURE.

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

OUTLINE

- Background
  - Texture Measurements, Smart Wave, and Spectral Analysis
  - Concluding Remarks and Future Work

Pavement Friction Management

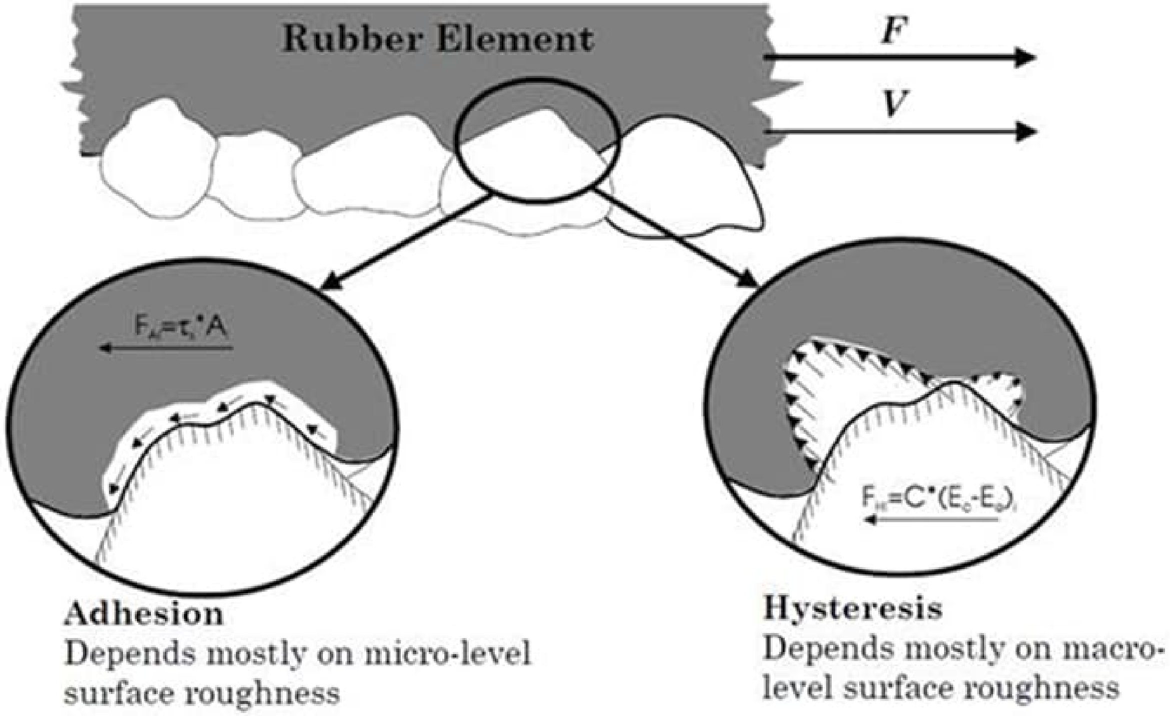
- Great progress has been achieved in standardizing continues friction measurements and their use in safety assessment.
- Still challenged with the physical systems need for water and tires, and the inconsistency between different systems.

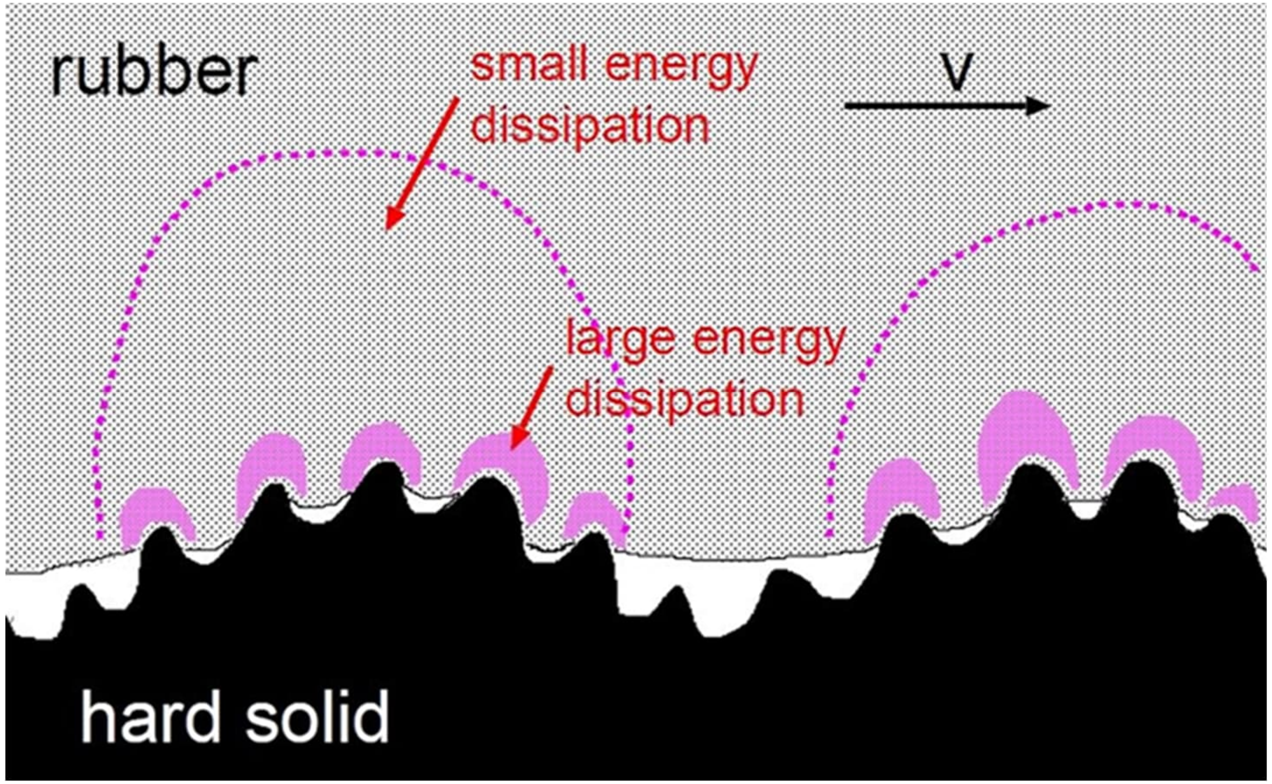
SCRIM, WDM USA

LWST, Iowa DOT

Pavement Texture Scanning

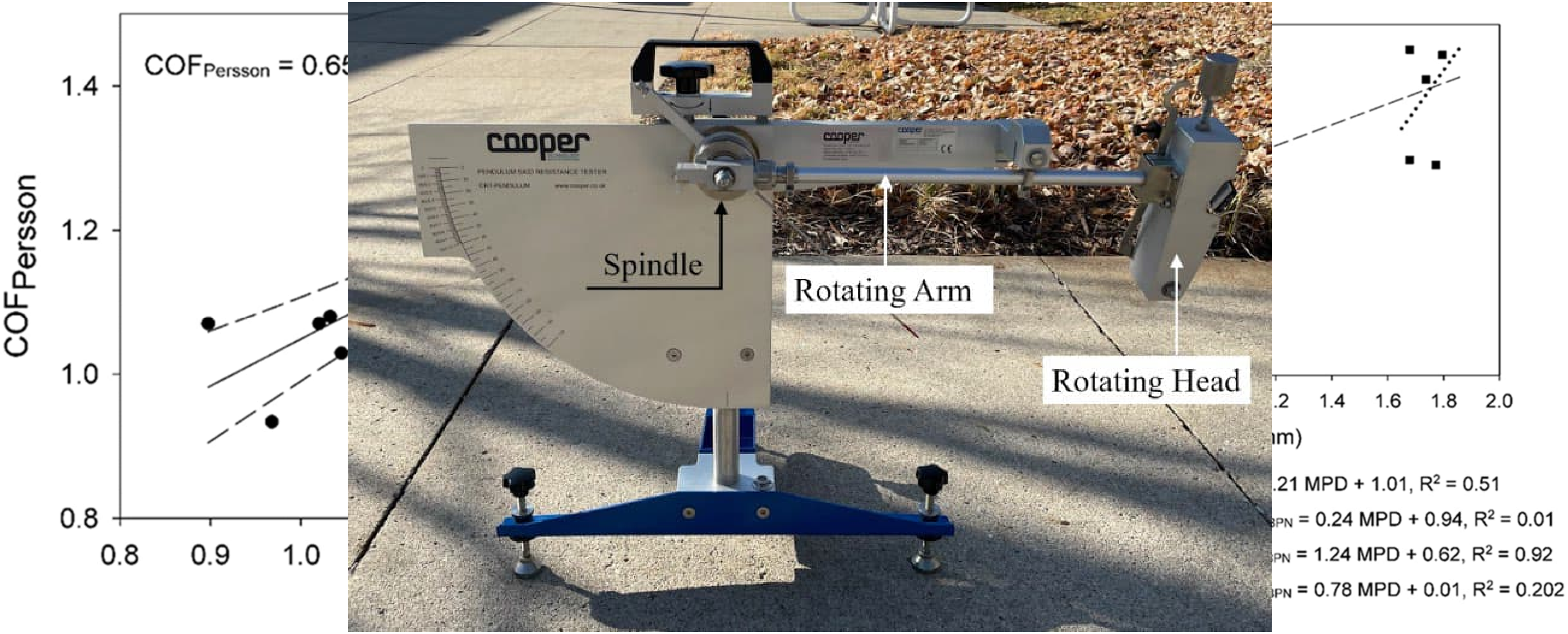
- Persson’s friction model provided a robust physical and analytical solutions for a simple rubber block.



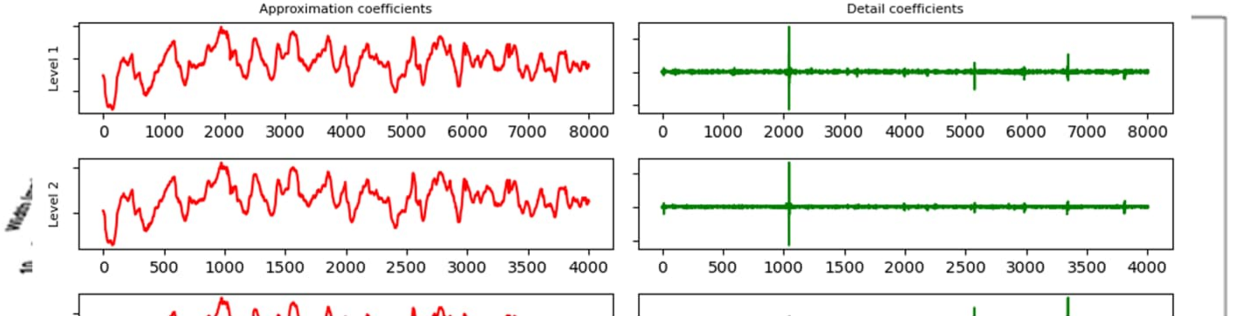


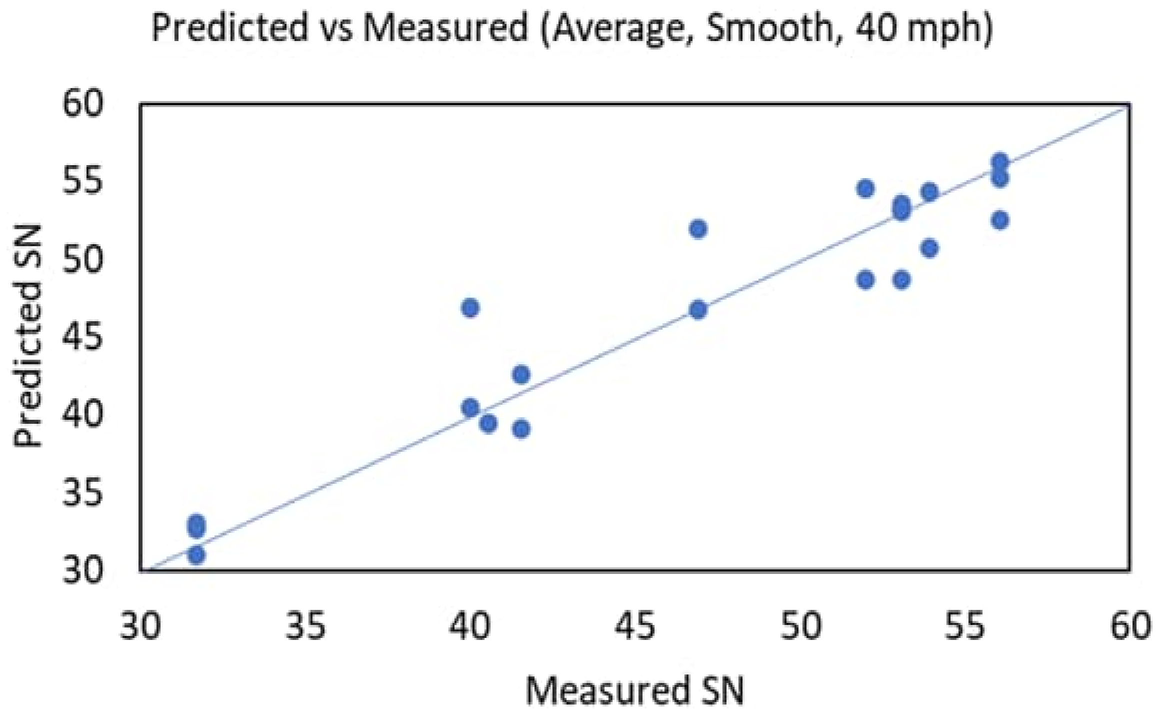
Testing the Theory

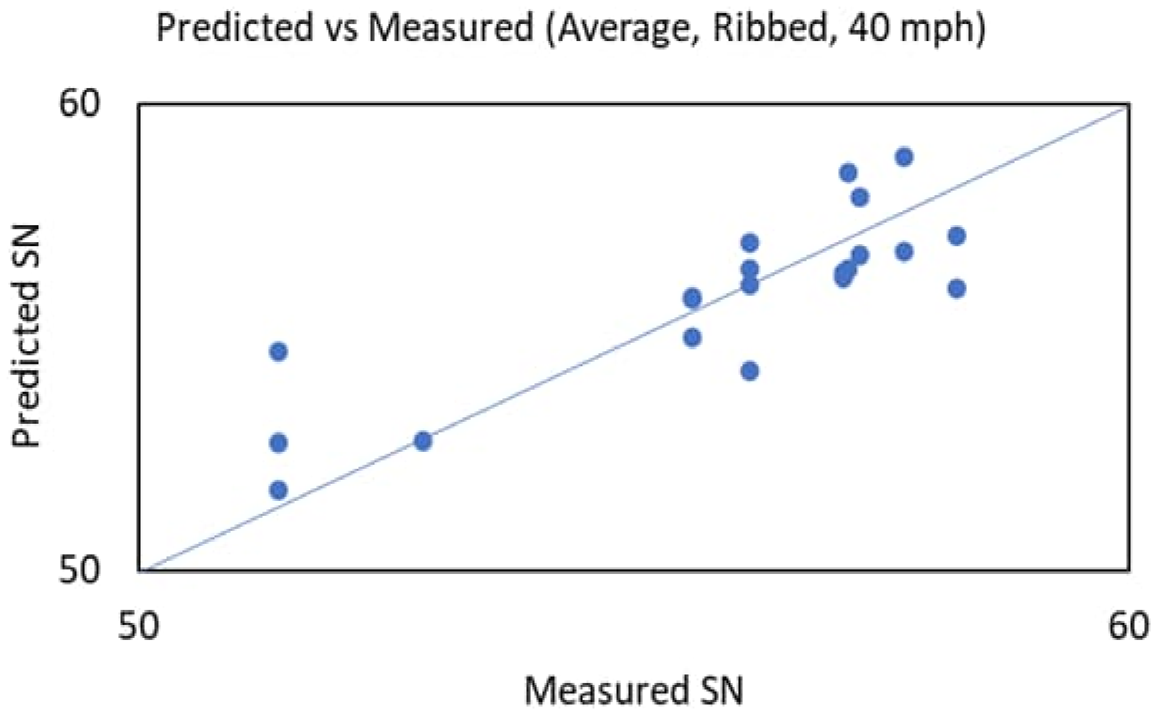
- Persson's friction model provided a robust physical and analytical solutions for a simple rubber block (British Pendulum).

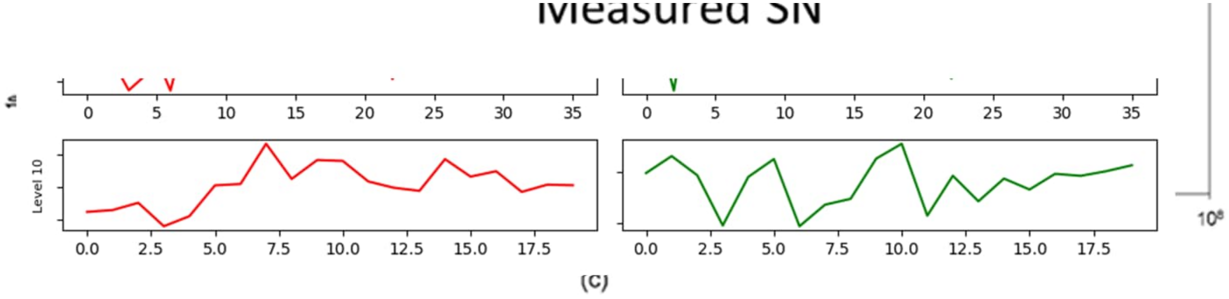


Implementing A Concept









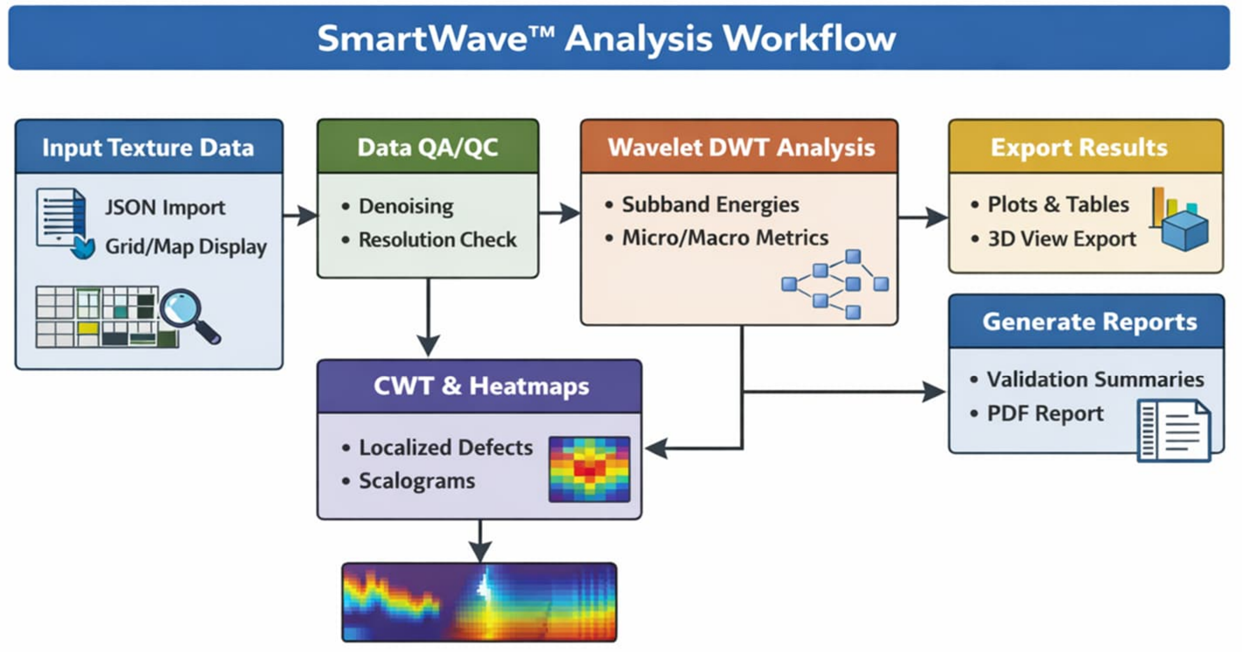
ingios GEOTECHNICS

OUTLINE

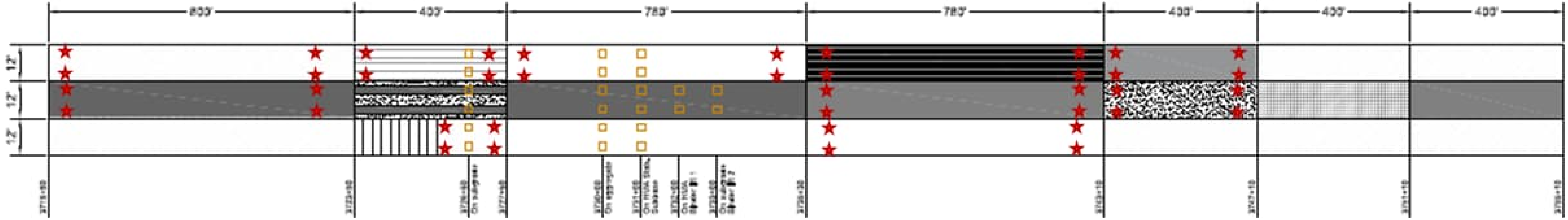
- Background
- Texture Measurements, Smart Wave, and Spectral Analysis
  - Concluding Remarks and Future Work

Pavement Texture Data Standardization

- To move towards contactless tire-pavement friction we need improved standards for texture data and analysis.
- Smart Wave™ is a proprietary platform capable of supporting analysis and friction of texture and friction data.

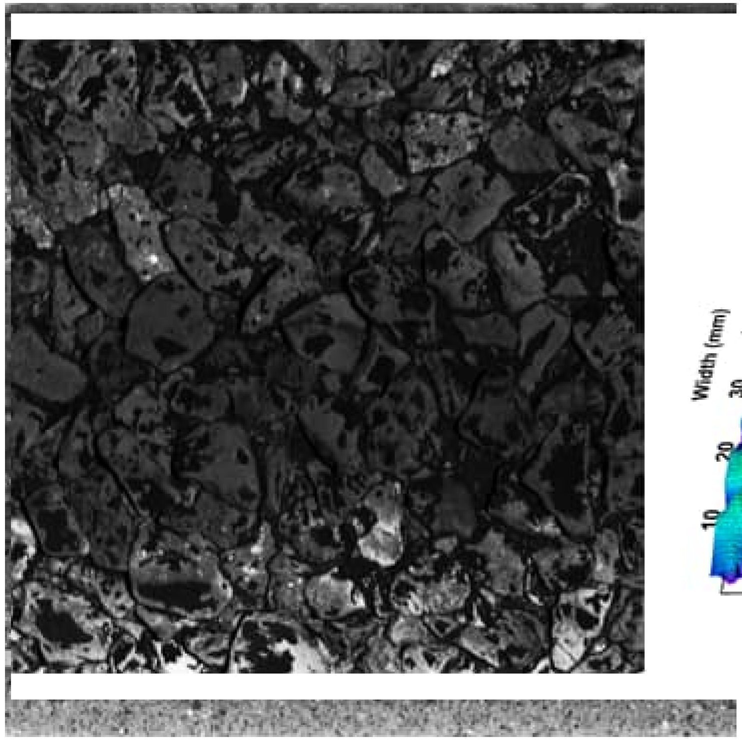


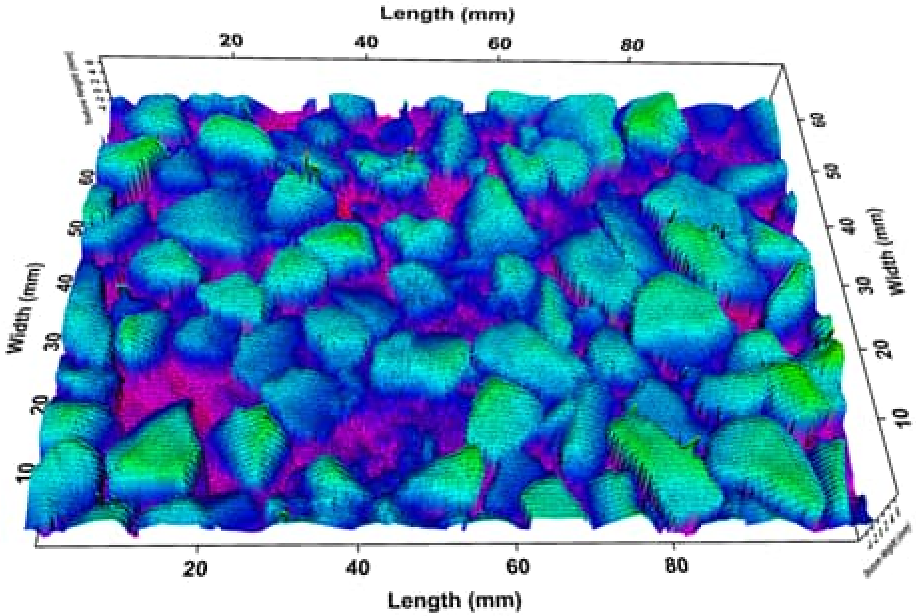
ICART Data Collection

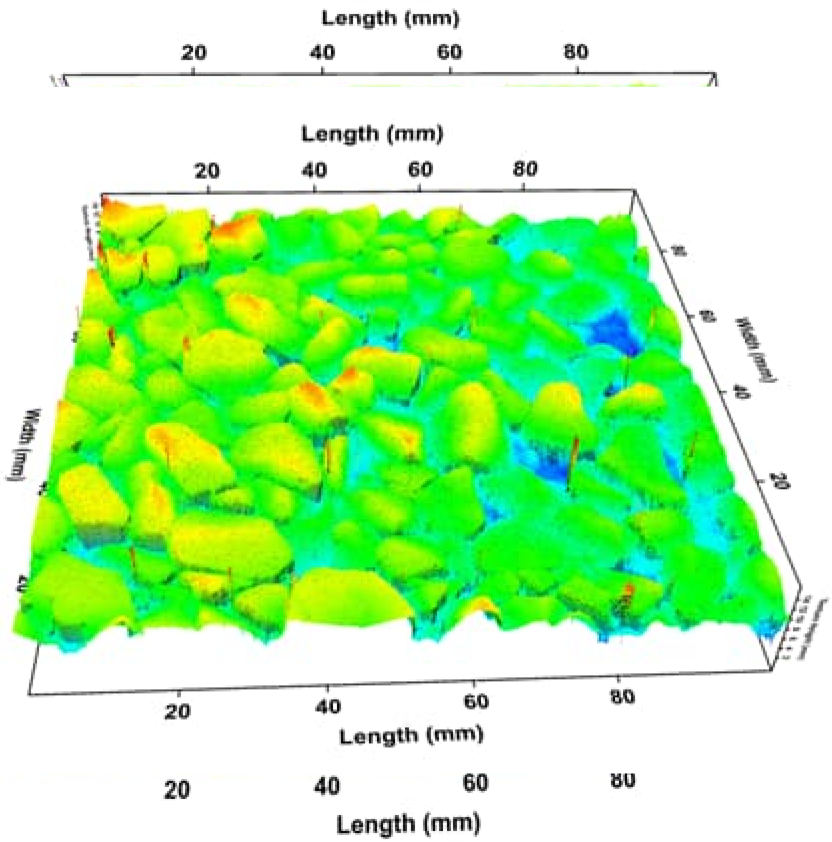



8.5" CRCP - Turf Drag Finish	[illegible]	Turf Drag Finish w/ Diamond Grooving	Smooth Finish with Diamond Grinding	Smooth Finish	Turf Drag Finish	Turf Drag Finish
11.5" 12.5 mm SMA	Artificial Rutting	12.5 mm SMA	9.5 mm Dense Graded HMA	[illegible]	Single Chip Seal	[illegible]
8.5" JPCP - Turf Drag Finish	Artificial Faulting	Longitudinal Tining	Transverse Tining	Turf Drag Finish	Turf Drag Finish	Turf Drag Finish

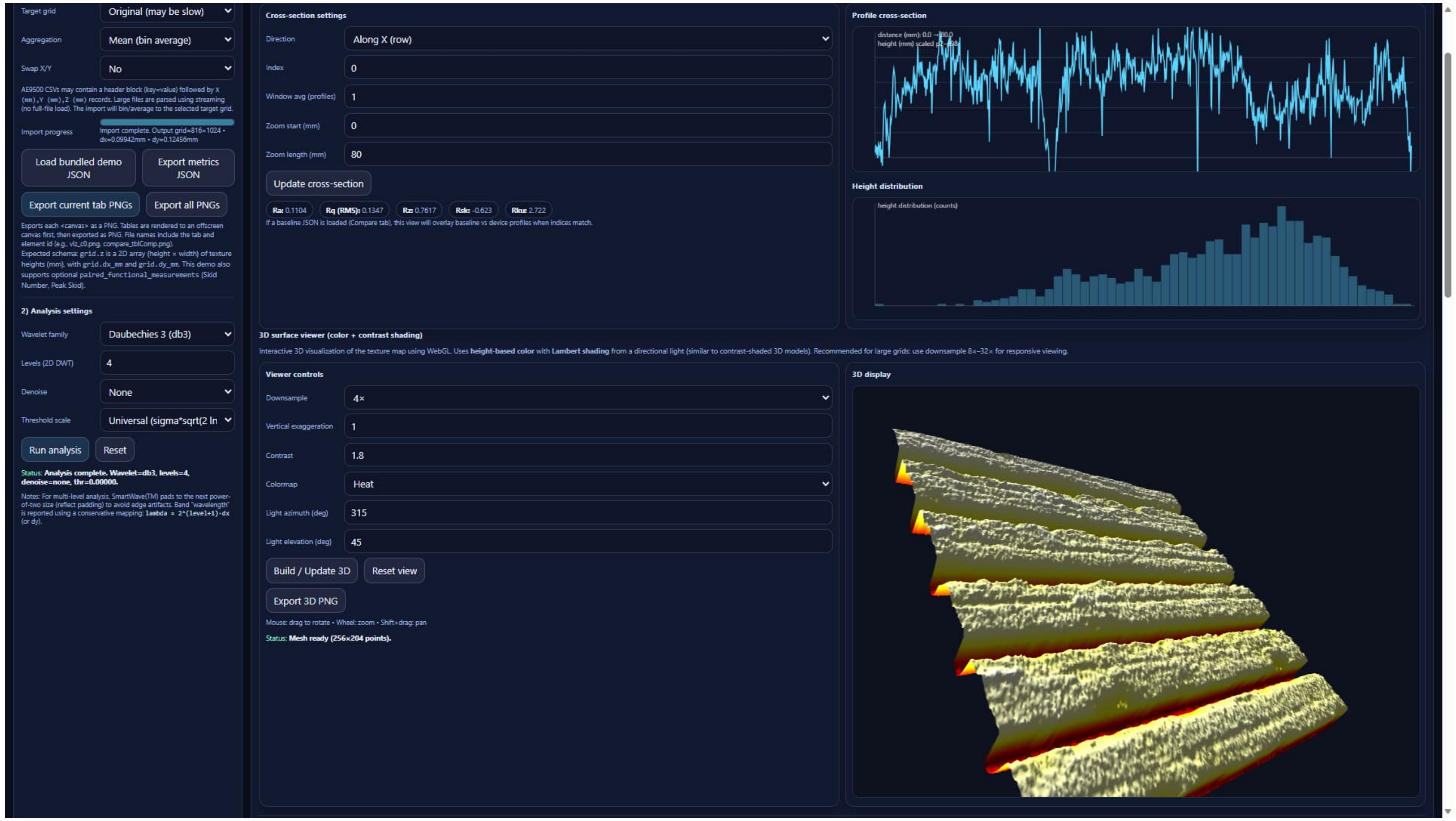

Included a Wide Range of Surfaces

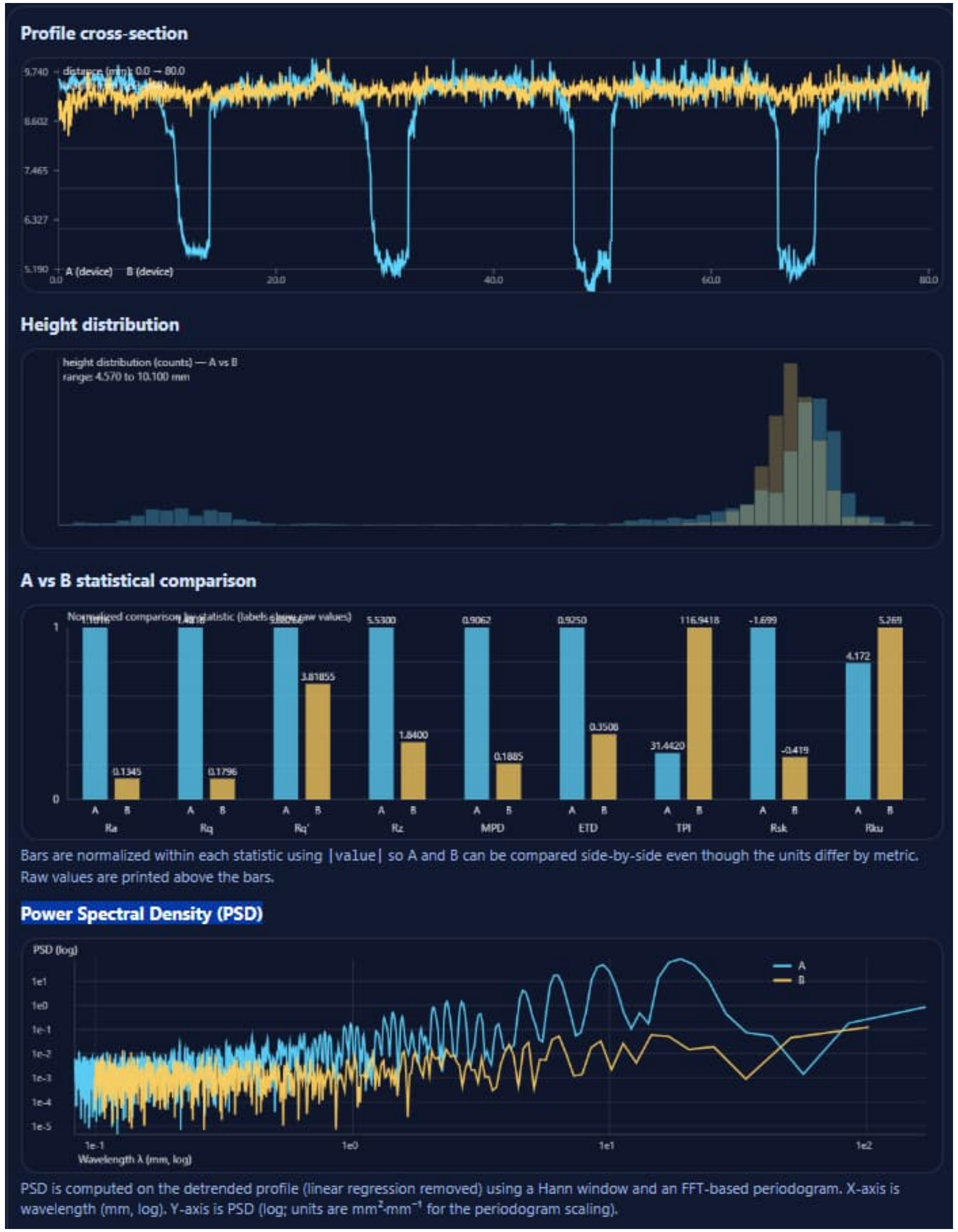




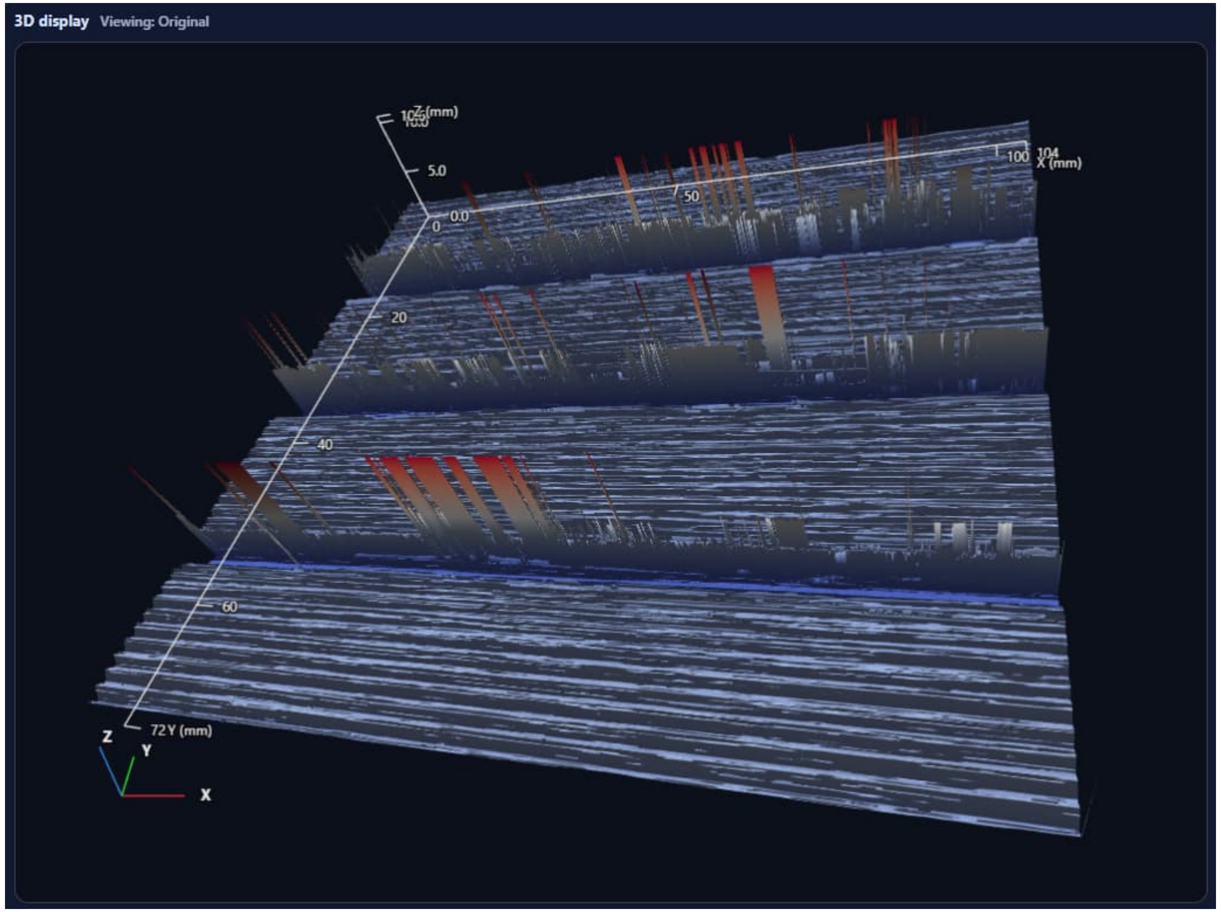


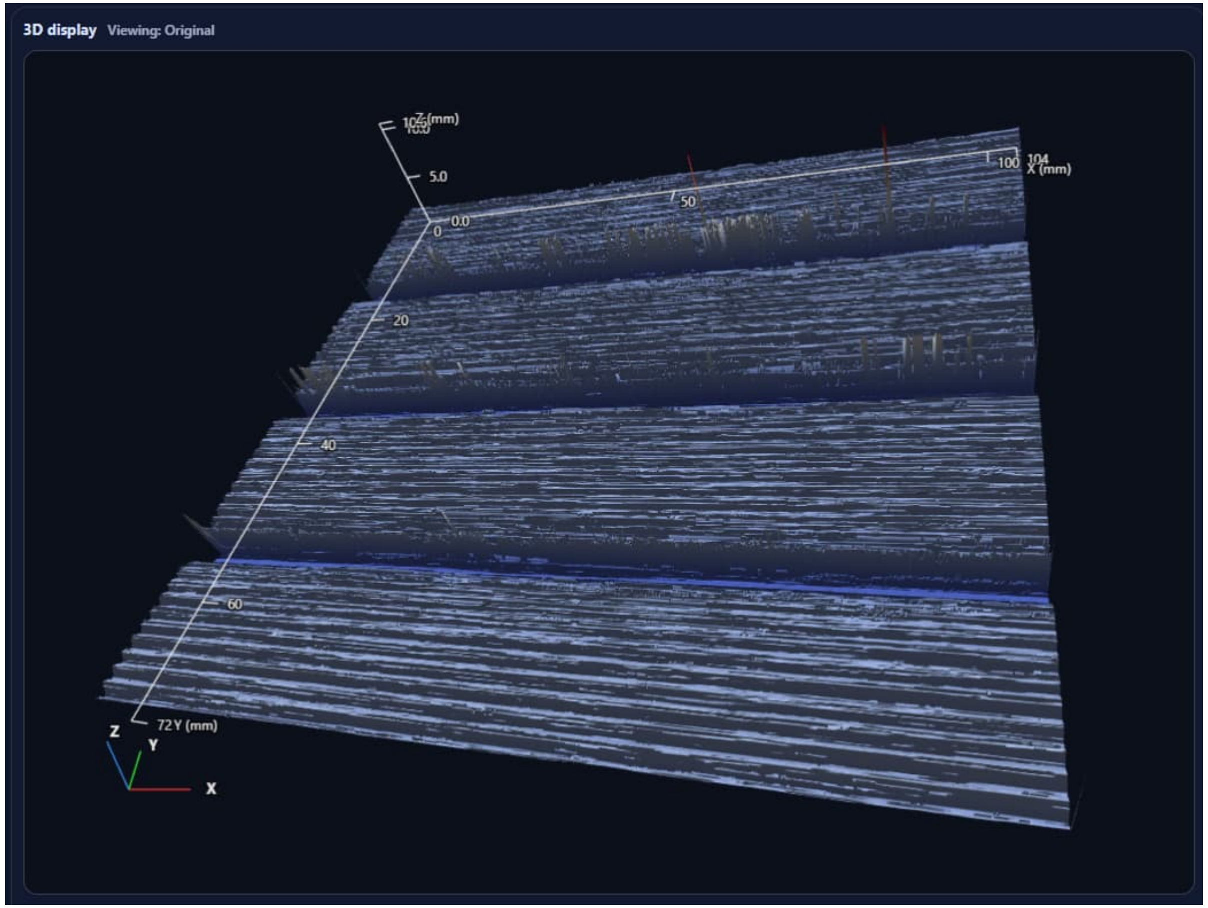
Smart Wave is a Comprehensive Platform



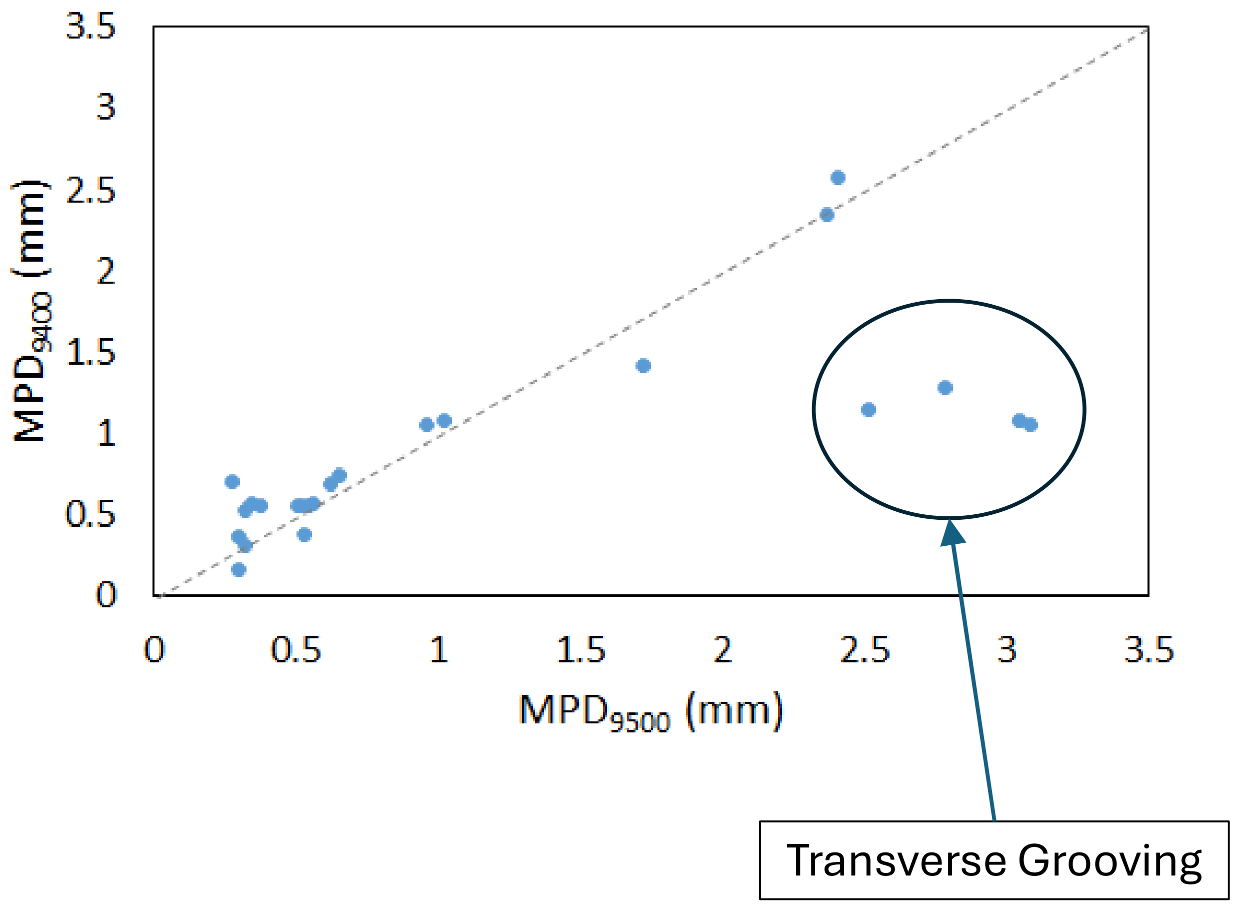


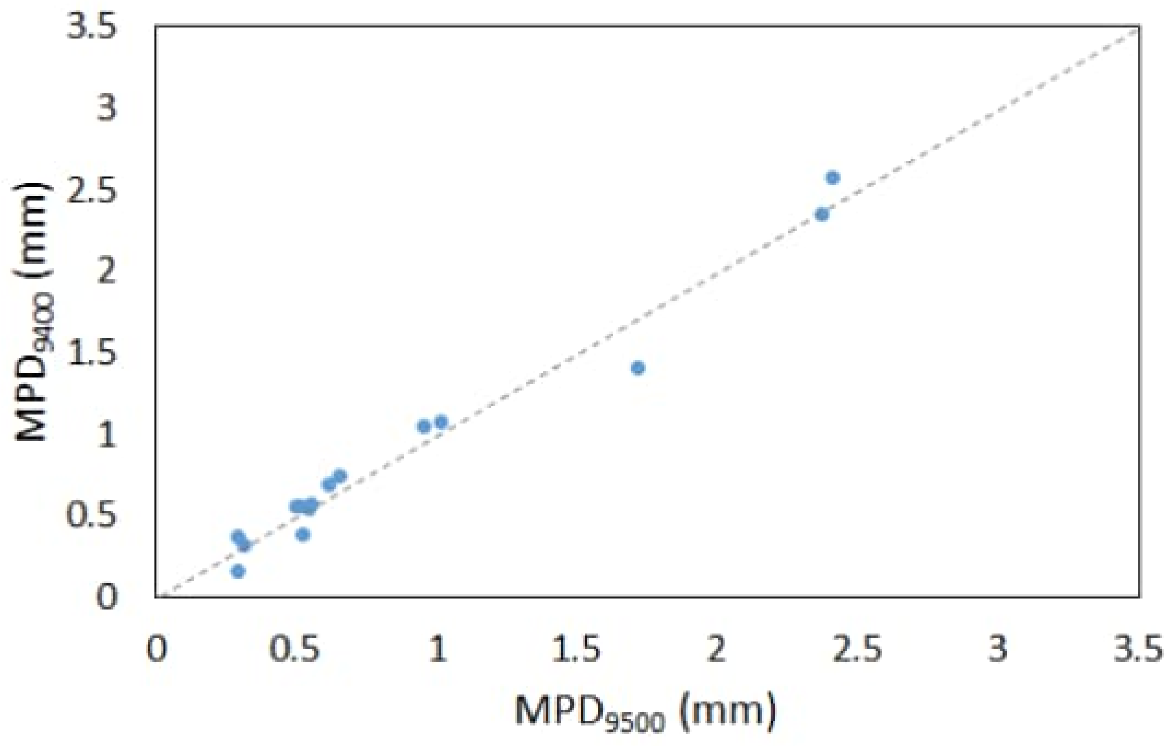
Filtering Varies Based on Laser Type and Surface Texture



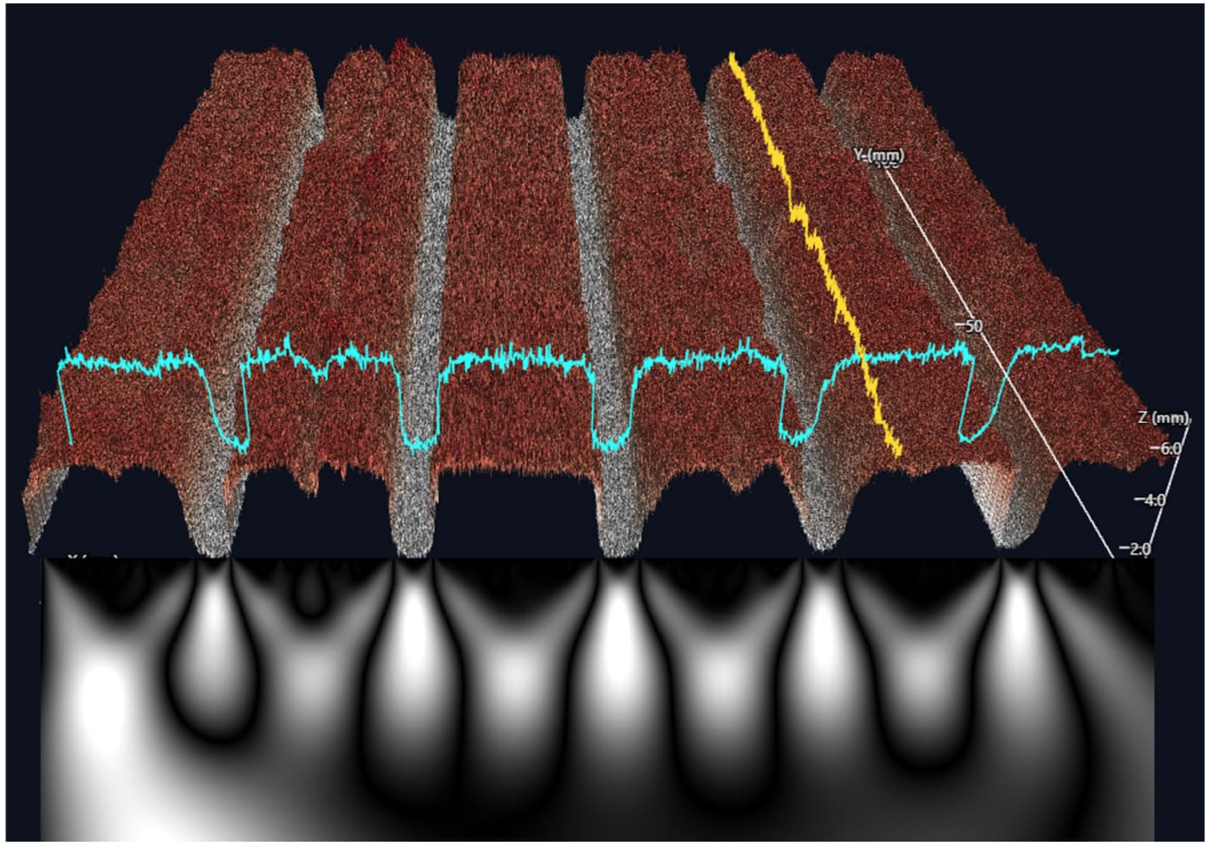


MPD is Highly Sensitive to Different Laser Measurements

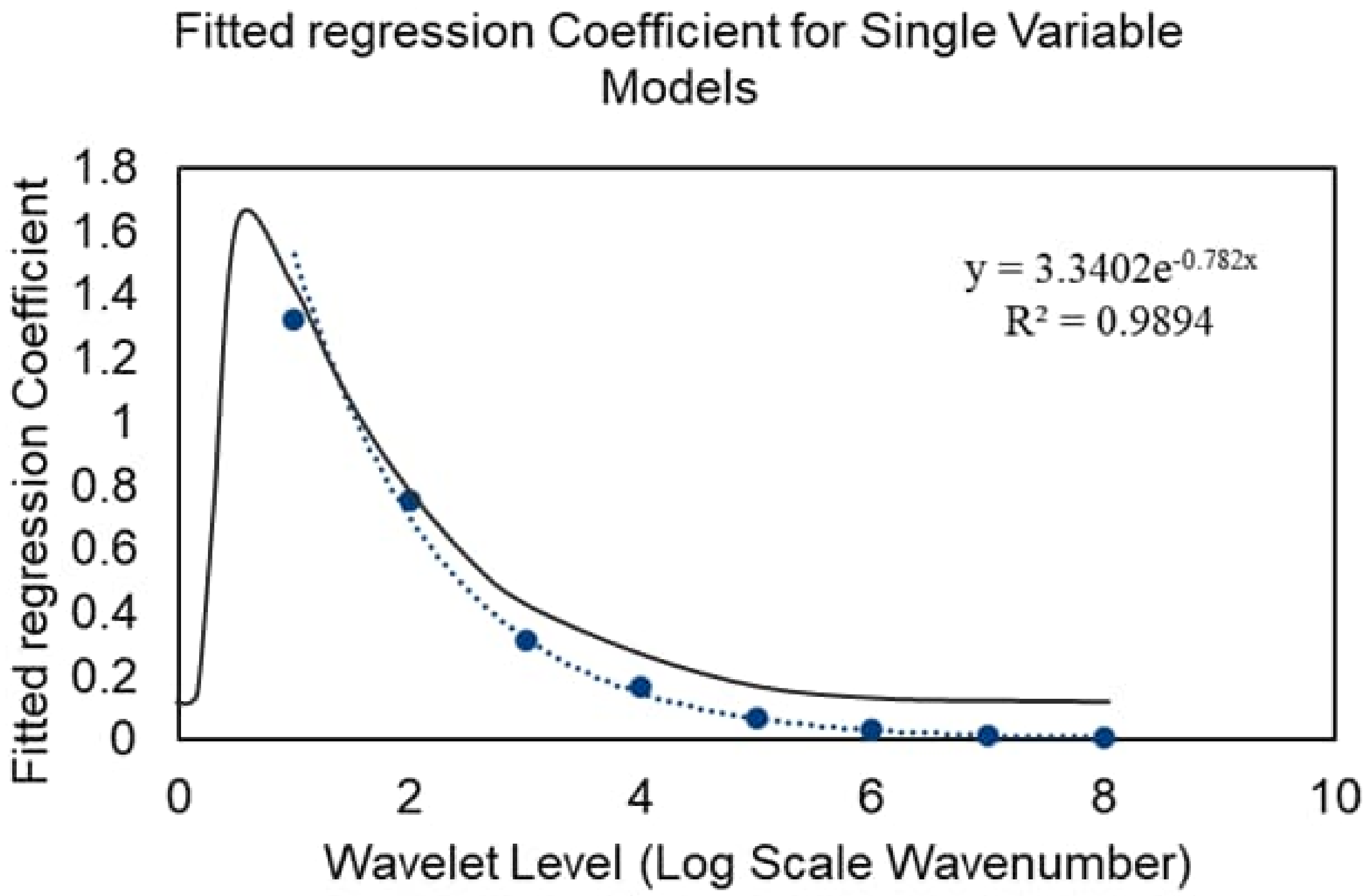




Wavelets Decompose Macro and Micro Texture



Wavelets Decomposition Can Estimate the Impact of Texturing



Towards a Global Friction Model

$$F = F[S, V, A, W, T, F_s]$$

F_s is the base friction measurement (used LWST at 40 MPH for now)

S tire slip ratio operator

V nominal vehicle speed impact ratio operator

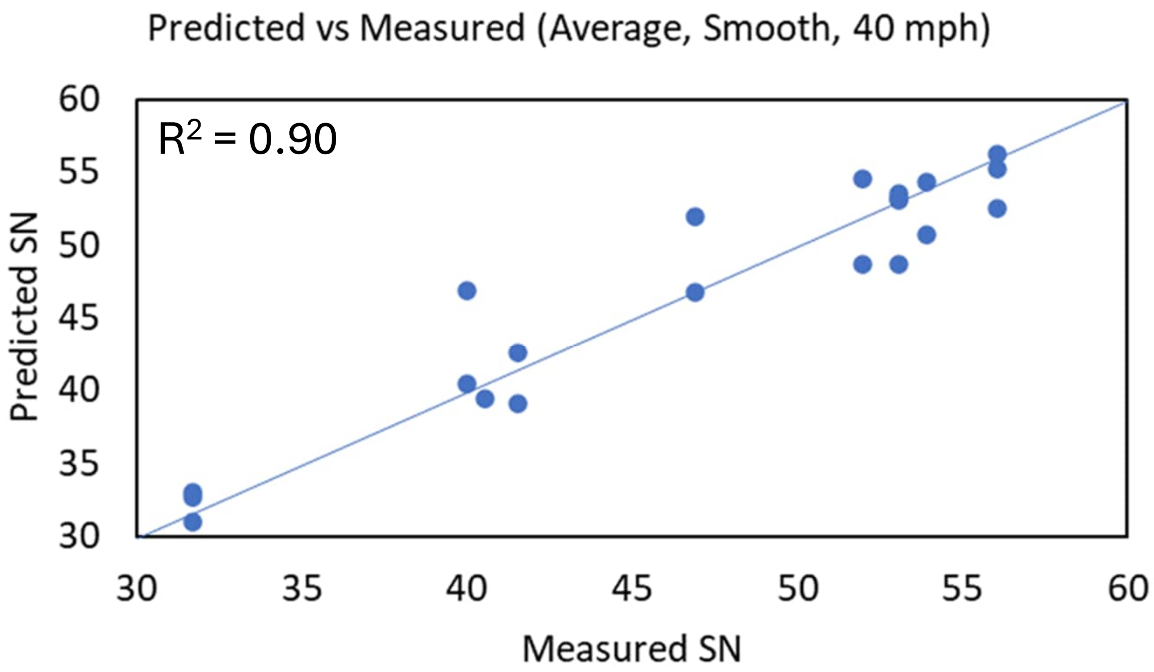
A tire angle impact

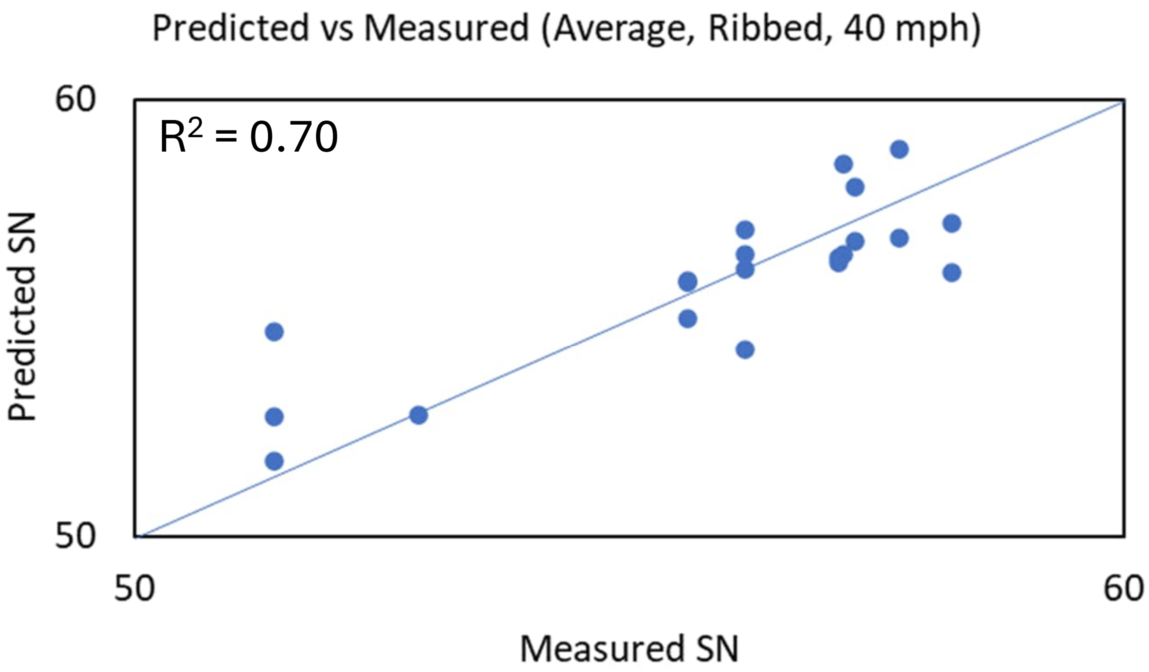
W wet conditions operator

T tire characteristics operator

Base Friction Measurements

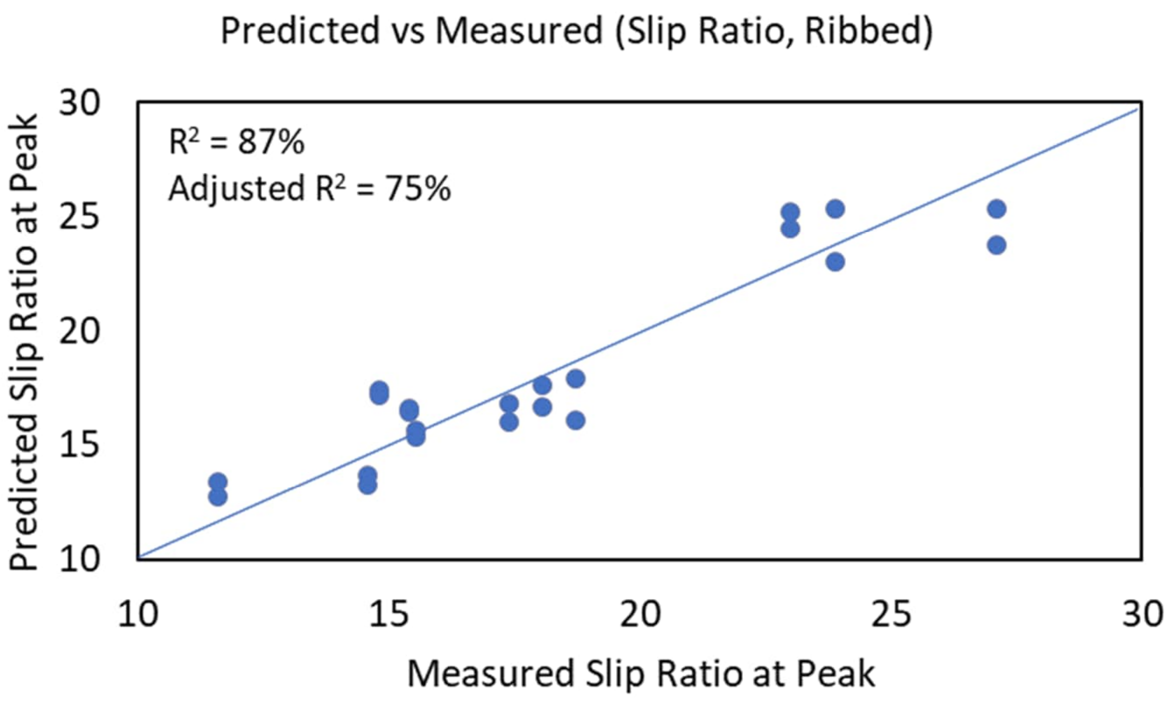
- Wavelets energy showed a strong to very strong correlations with LWST measurements.

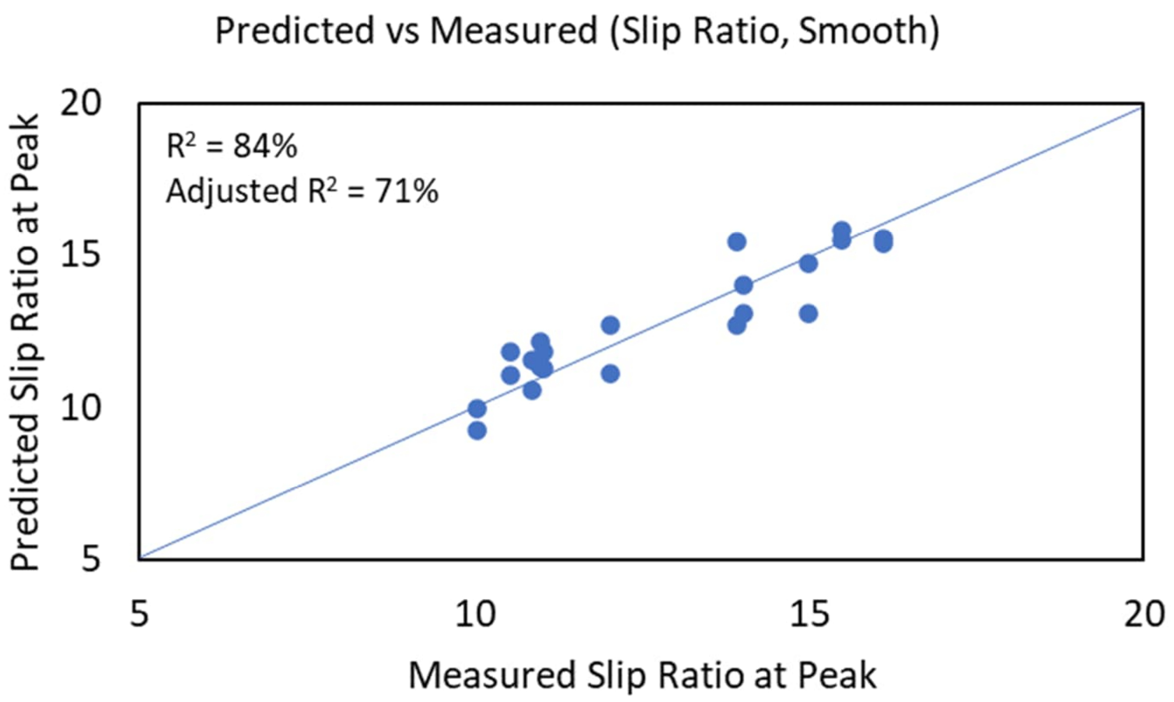




Slip Ratio Impact

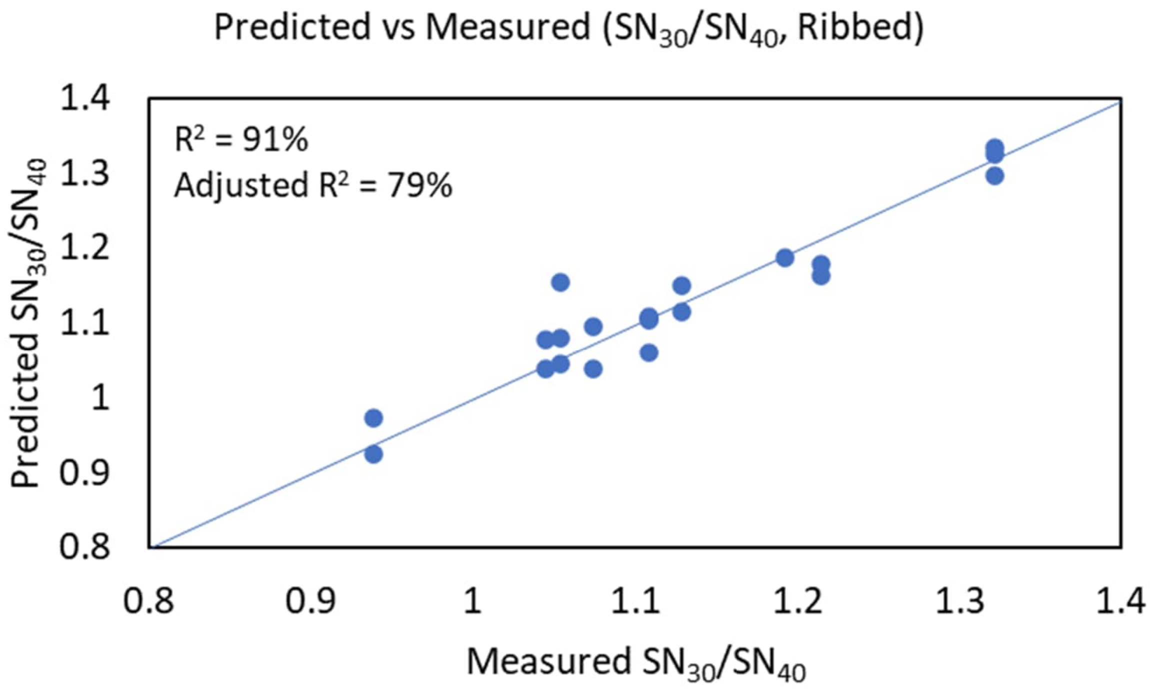
- $SR_{Peak} = \sum_{i=1}^{n} a_{SR,i} E_i$

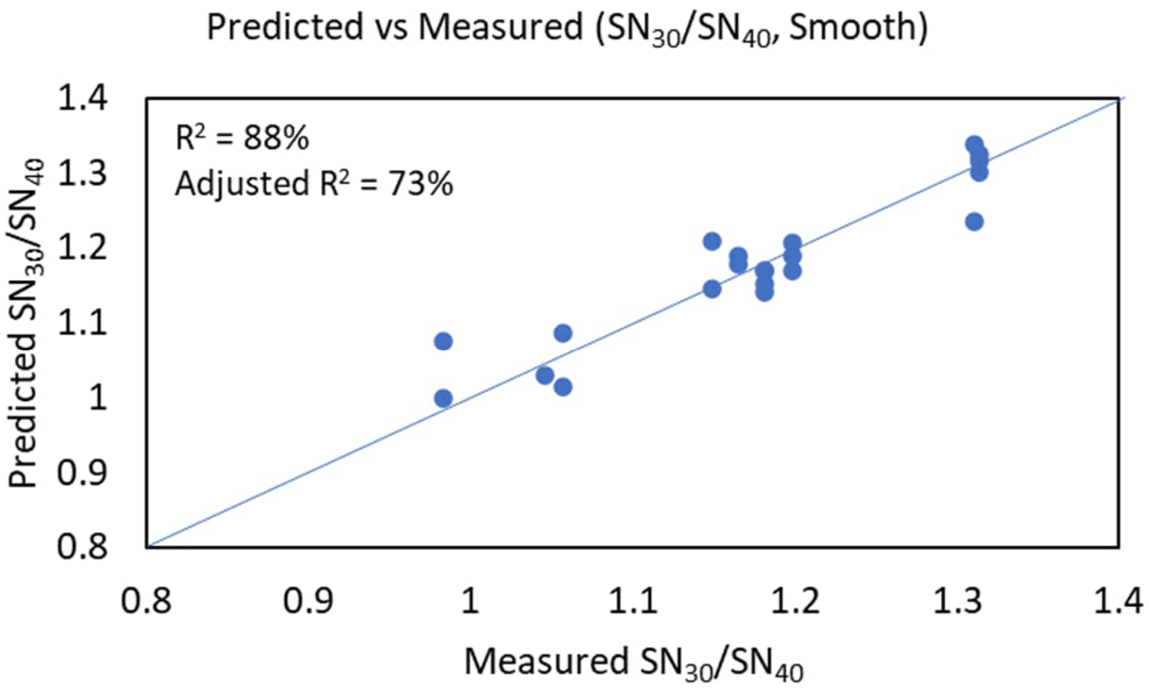




Speed Impact

- $SN_v = SN_v \sum_{i=1}^{n} a_{v,i} E_i$





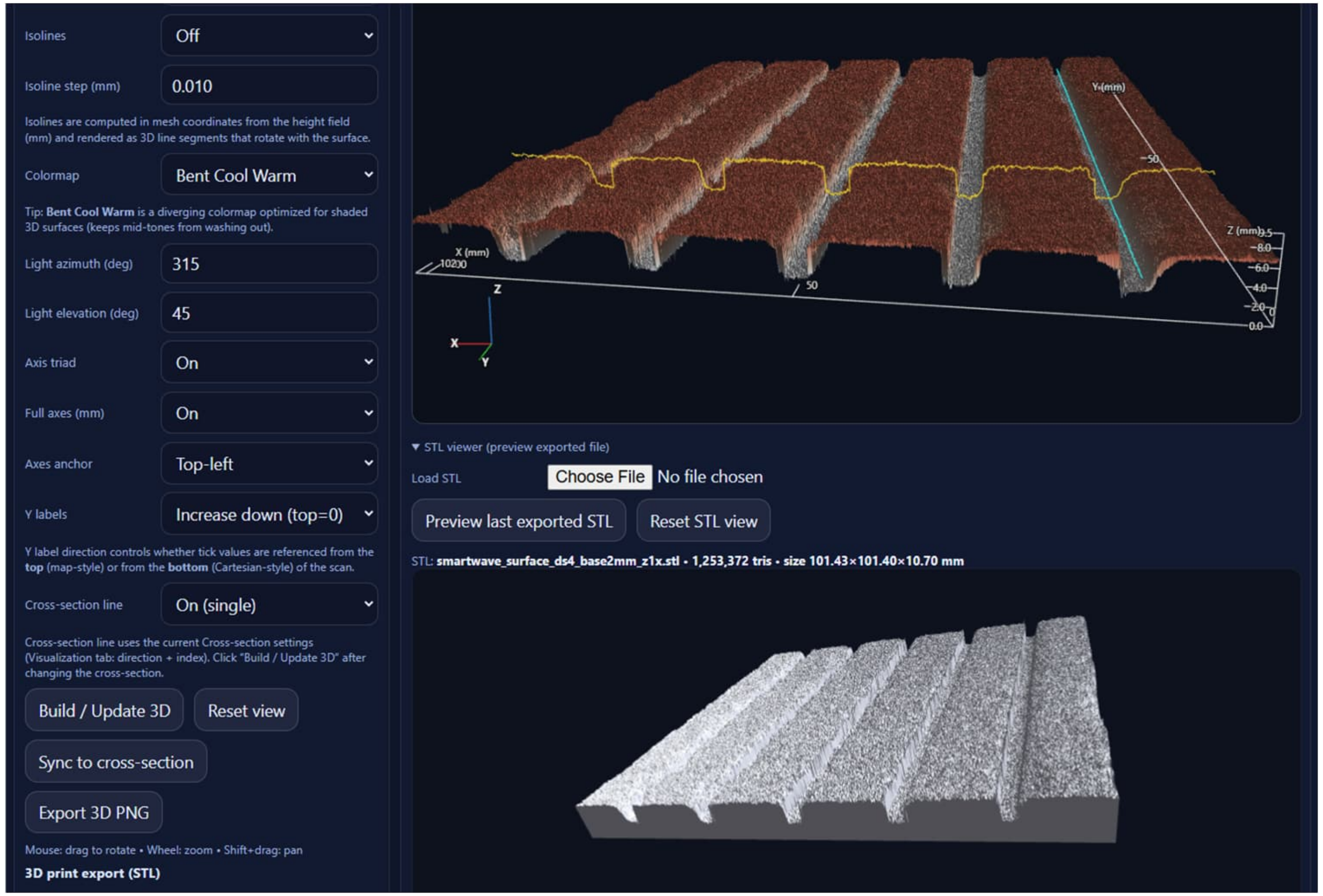
OUTLINE

- Background
- Texture Measurements, Smart Wave, and Spectral Analysis
- Concluding Remarks and Future Work

Concluding Remarks

- Spectral analysis is crucial for filtering, decomposition, and advanced contactless friction models.
- Wavelets analysis allows for more stable and less sensitive analysis to outliers compared to traditional texture parameters.
- Defining ground truth is based on a combination of stable spectral content, measurements from engineered surfaces, and performance in relation to friction predictions.

Engineered Surfaces Provide Stable Ground Truth



Future Work

- We are working on defining the tuning parameters for the various filters needed for different measuring systems.
- Need consistent definitions, yet flexible enough, to define the spectral and wavelets analysis parameters.
- Global models and procedures require a wider range of data from different texture and friction devices and collected from different locations.

QUESTIONS?

Ahmad Alhasan, Ph.D., P.E.

Vice President of Engineering Services

ahmad.Alhasan@Ingios.com

Ingios Geotechnics