CONTACTLESS ENERGY-BASED TIRE-PAVEMENT FRICTION MODELS

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RPUG
Road Profile Users' Group

OUTLINE

PROJECT BACKGROUND

TEXTURE AND FRICTION MEASUREMENTS

FRICTION-TEXTURE MODELS

CONCLUDING REMARKS AND FUTURE WORK

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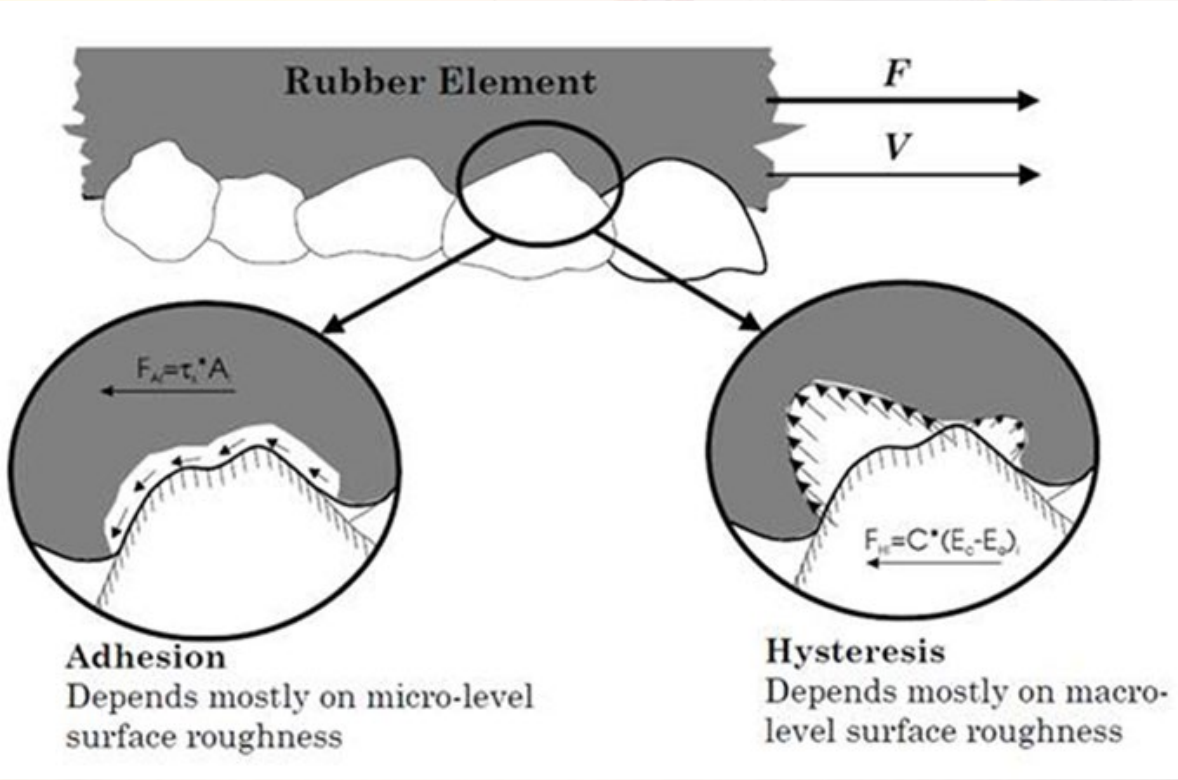
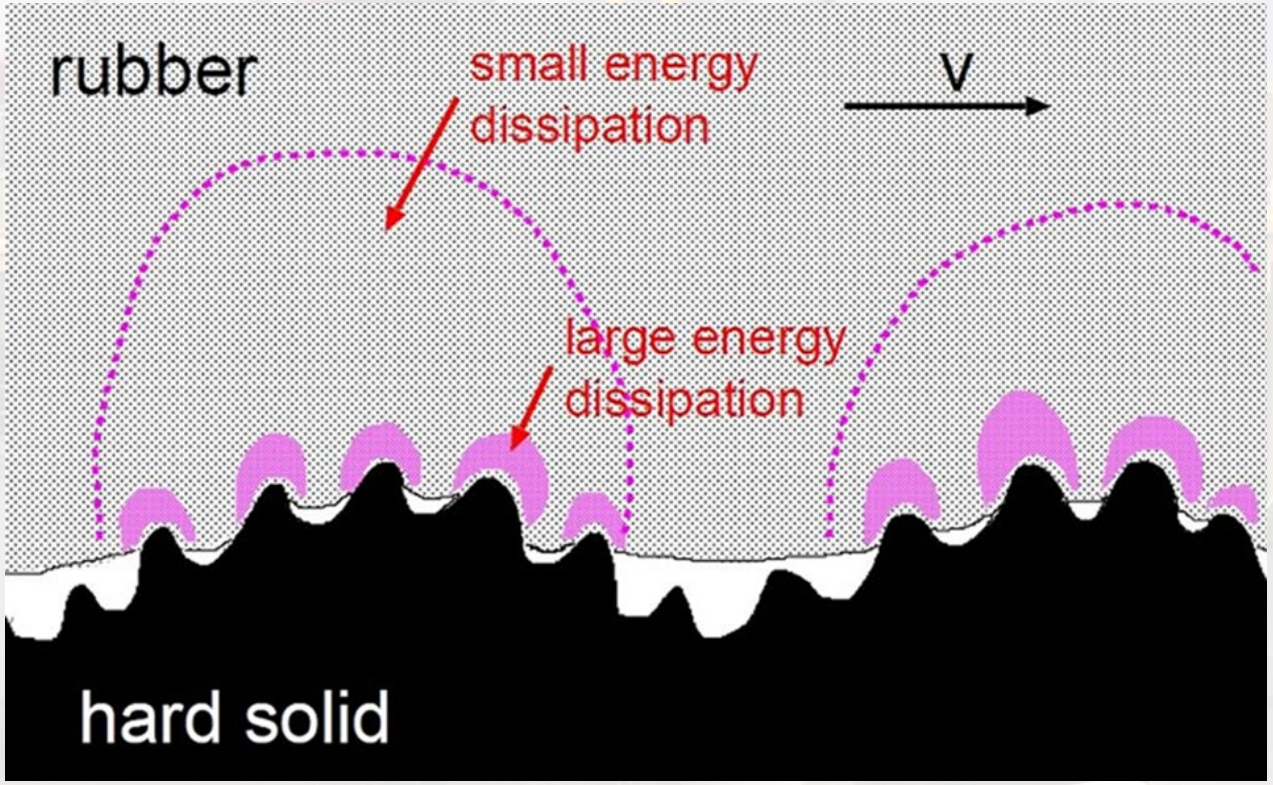
BACKGROUND (1/4)

Back in 2017 and 2018 a study was published on the use of Persson's friction model to predict the coefficient of friction (COF) measured using the British Pendulum from surface texture.





BACKGROUND (2/4)

Persson's friction model includes the hysteresis and adhesion components

$$\mu = \mu_{\text{hyst}} + \mu_{\text{adh}} = \mu_{\text{hyst}} + \frac{\tau_f A_1}{\sigma_0 A_0}$$

The model is in essence a contact model that accounts for surface texture

$$A_1 = A(q_1) = P(q_1)A_0$$

where

$$P(q) = \frac{2}{\pi}\int_0^{\infty} \frac{\sin x}{x} e^{-x^2 G(q)} dx = erf\left(\frac{1}{2\sqrt{G(q)}}\right)$$

$$G(q) = \frac{1}{8}\int_{q_0}^{q} dq q^3 C(q) \int_0^{2\pi} d\phi \left|\frac{E(qv\cos\phi)}{(1-\upsilon^2)\sigma_0}\right|^2$$

BACKGROUND (3/4)

A new view on micro and macro texture.

This model can calculate the COF of a simple sliding rubber block in dry conditions.

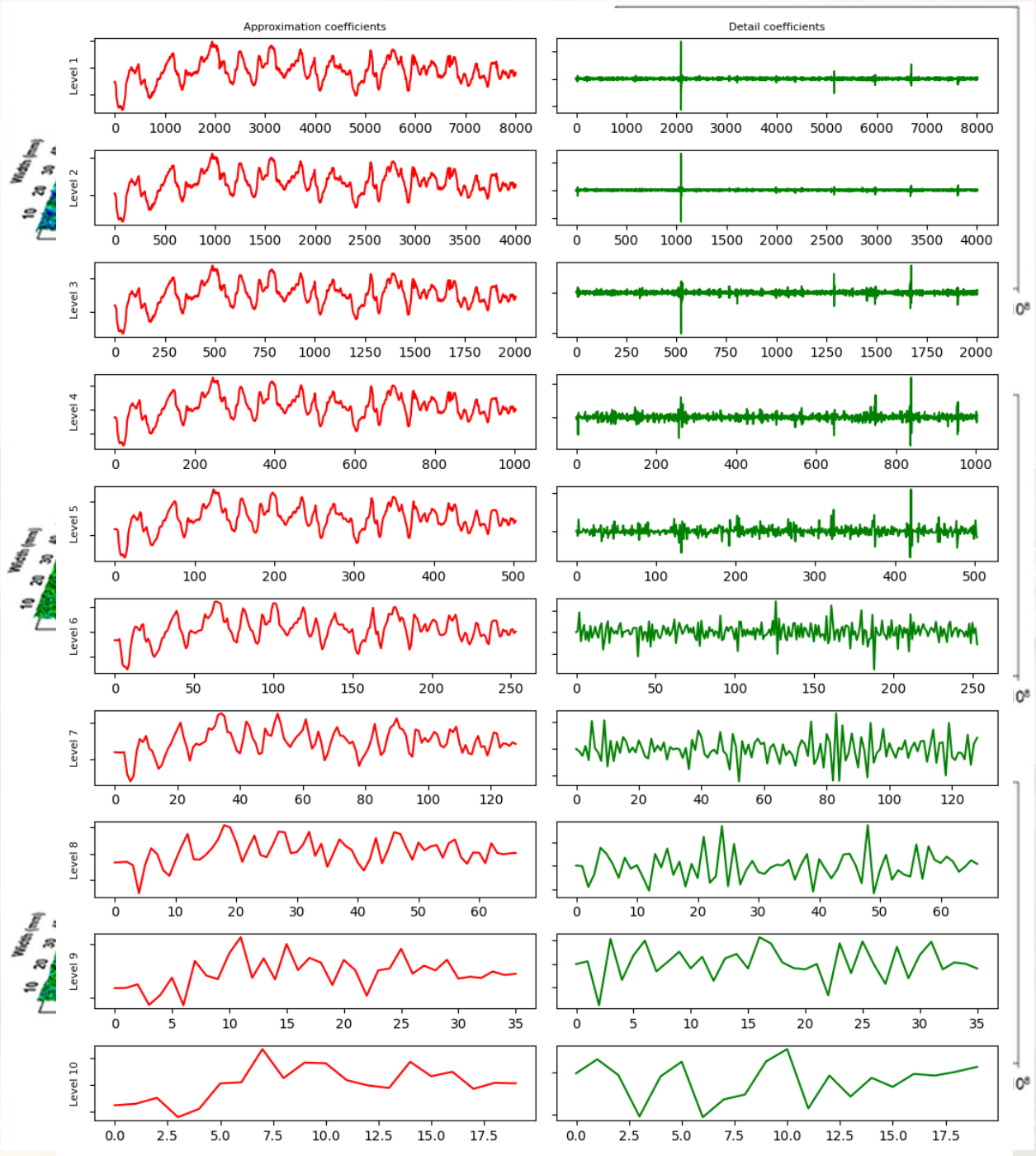
$$COF_{hyst} = \mu_{hyst} \approx \frac{1}{2}\int_{q_0}^{q_1} dq q^2 C(q) S(q) P(q)$$

$$COF_{hyst} \approx \sum_i q_i \int_{q_0}^{q_1} [C(q)] \int_0^{2\pi} d\phi \cos\phi \mathrm{Im} \frac{E(qv\cos\phi)}{(1-\upsilon^2)\sigma_0}$$

where

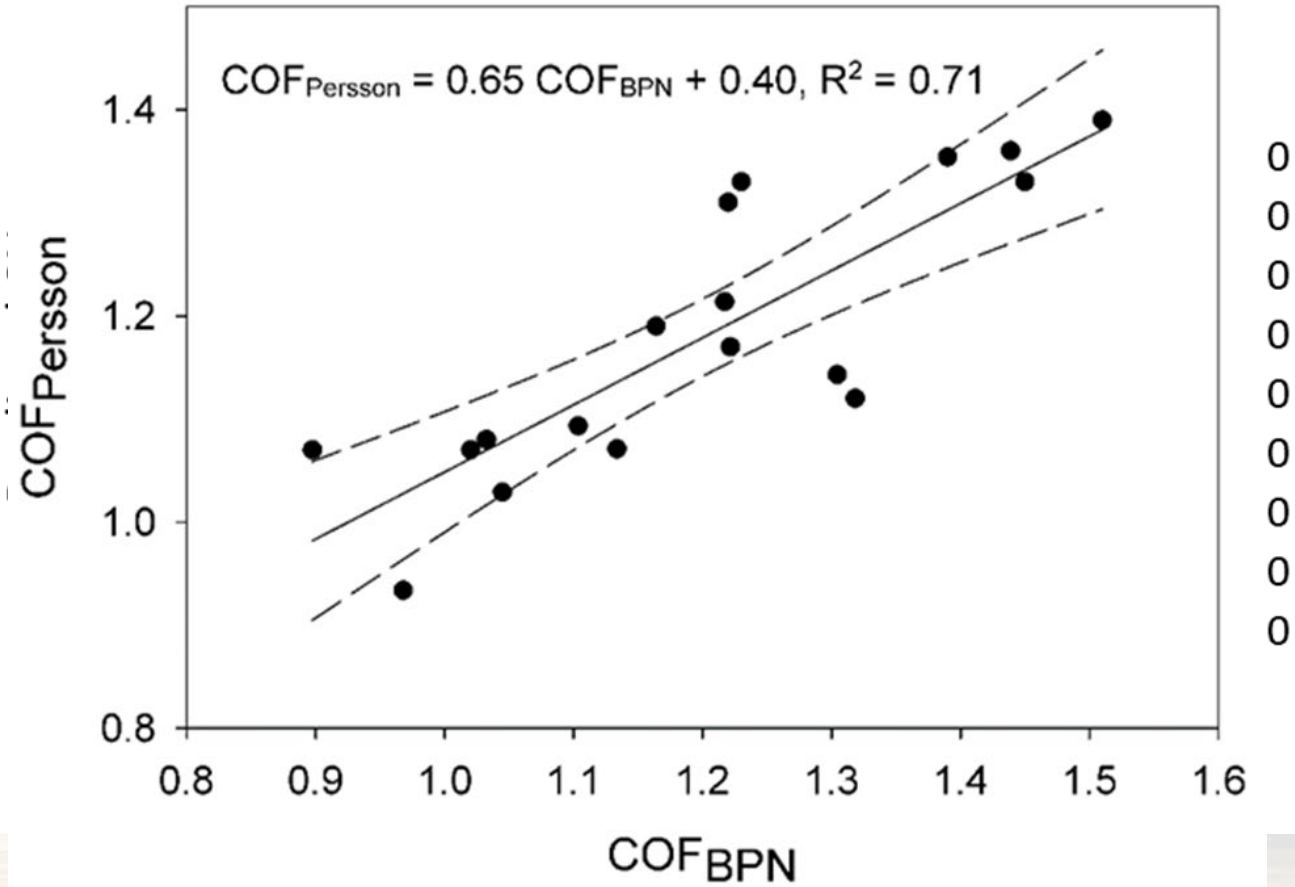
$$COF_{hyst} \approx \sum_i a_i W . E_i$$

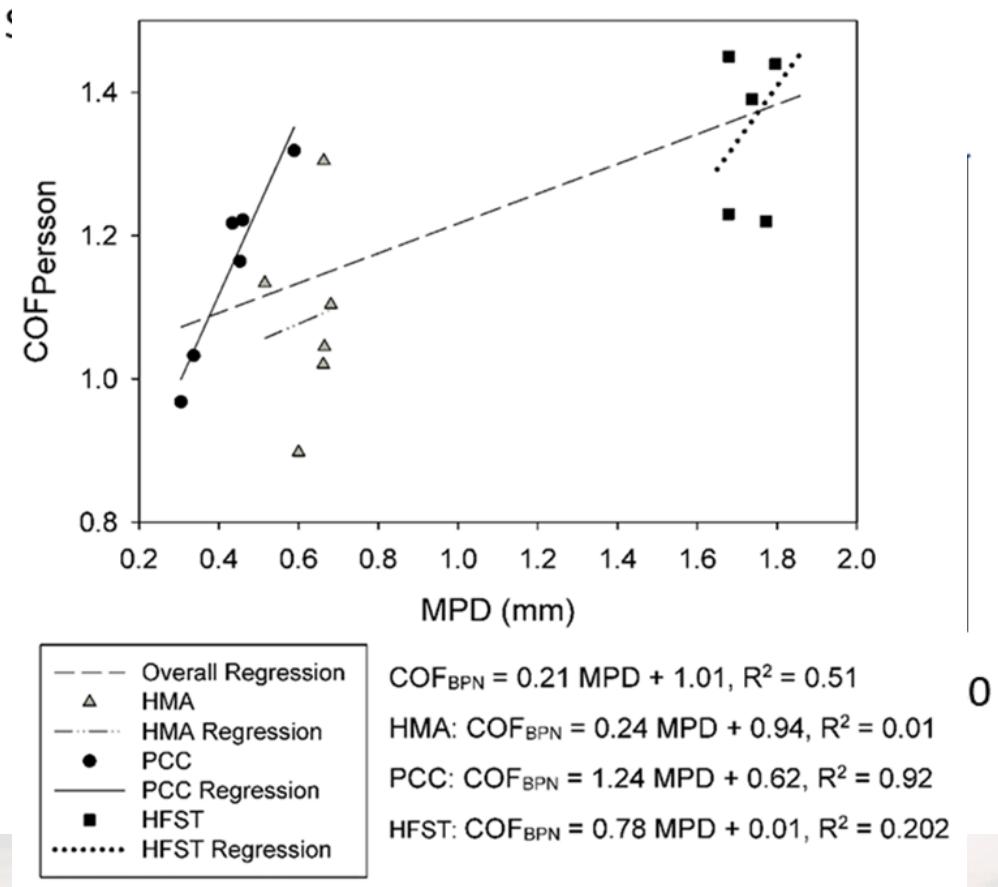
$$S(q) = \gamma + (1-\gamma)P(q)^2, \gamma \approx 1/2$$



BACKGROUND (4/4)

The findings were promising from multiple data sets.





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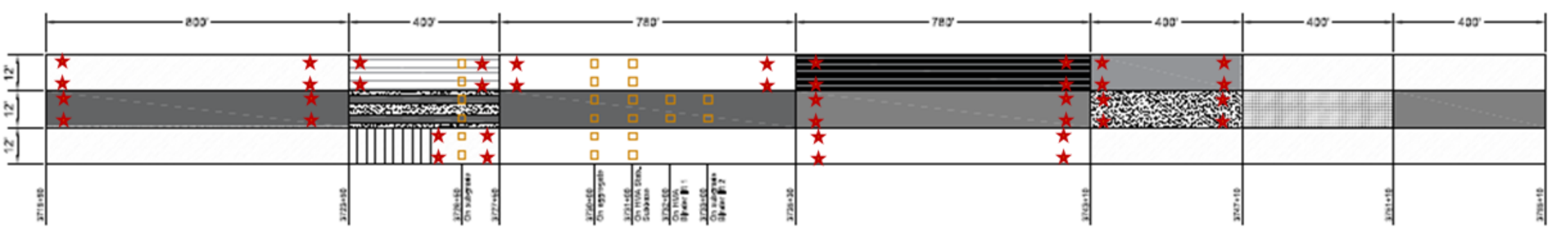
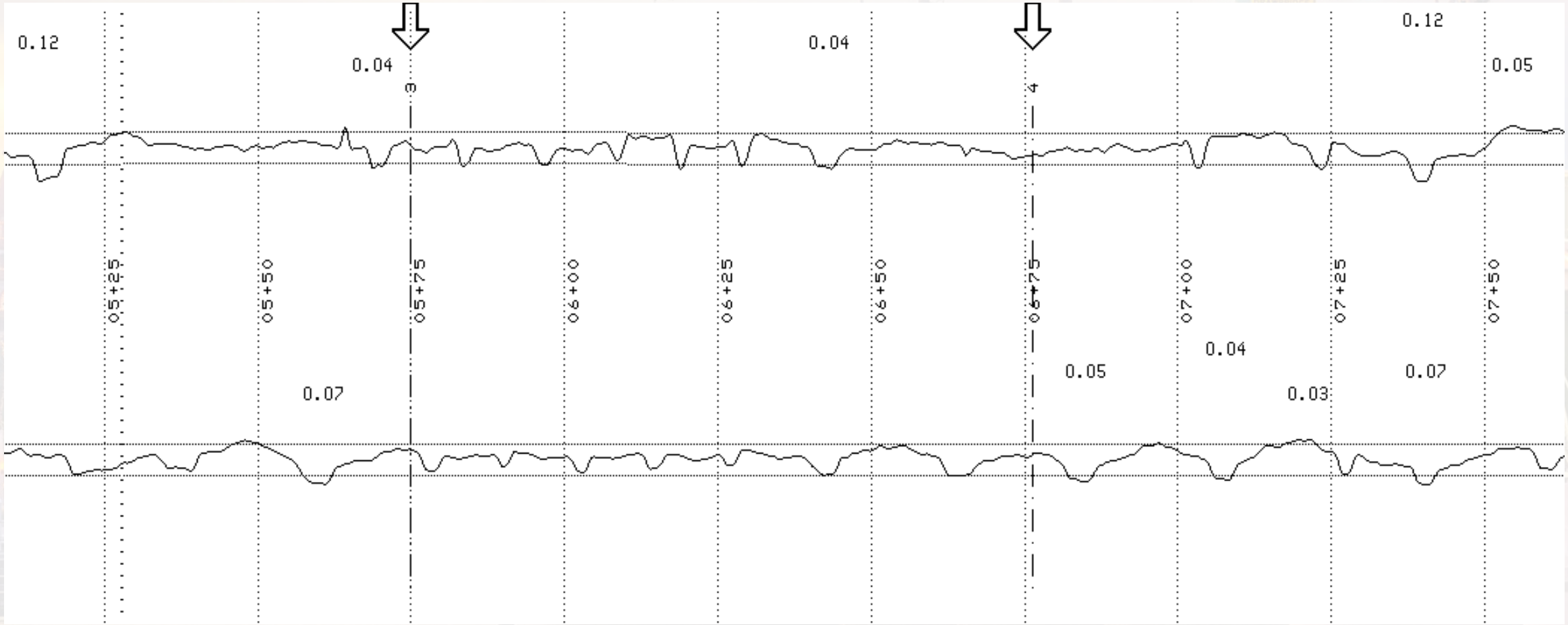
DATA COLLECTION AT ICART

Collected Texture, DFT, and LWST (Smooth and Ribbed)

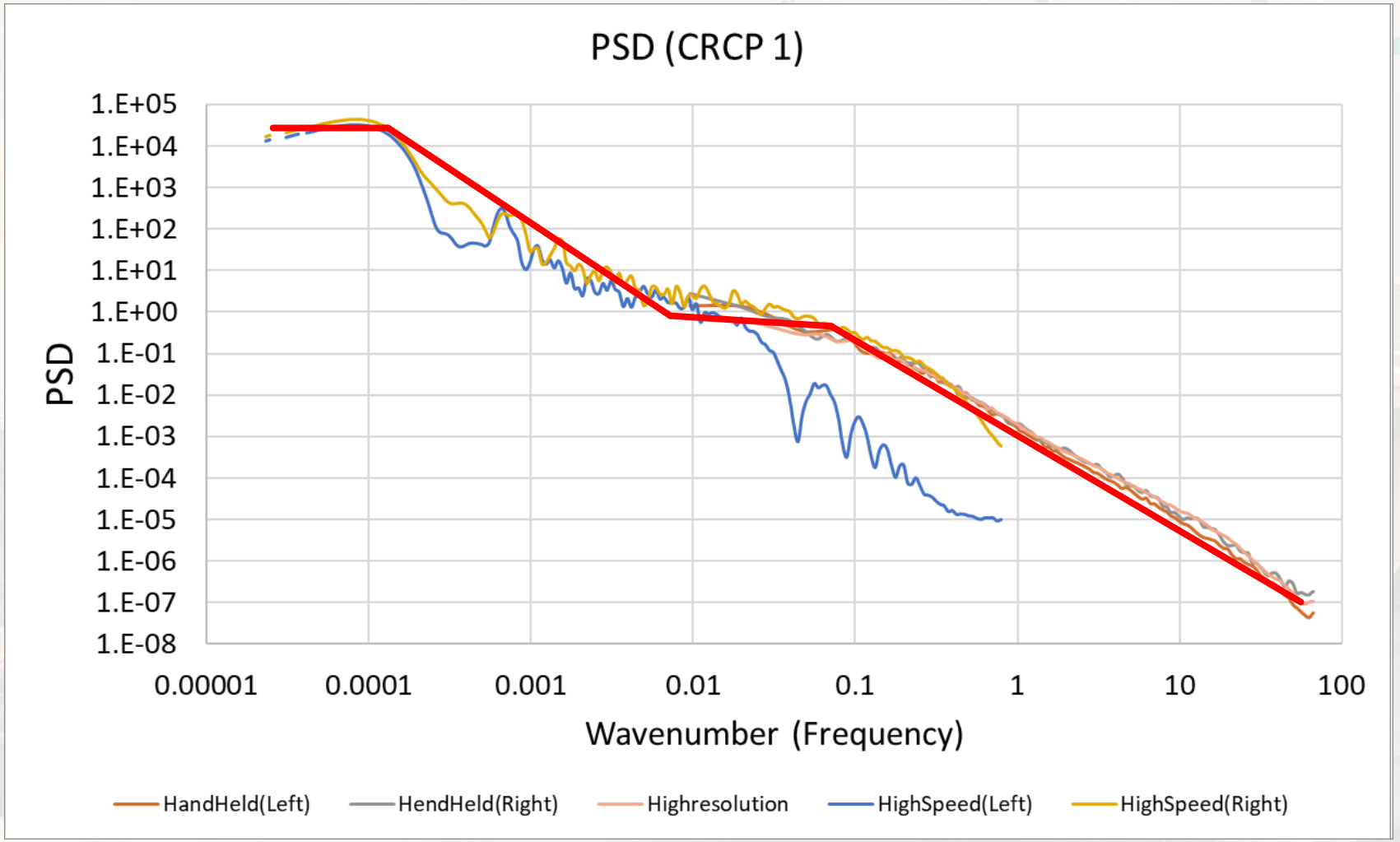


8.5" CRCP - Turf Drag Finish	Smooth Finish with Diamond Grooving	Turf Drag Finish w/ Diamond Grooving	Smooth Finish with Diamond Grinding	Smooth Finish	Turf Drag Finish	Turf Drag Finish
11.5" 12.5 mm SMA	Artificial Rutting	12.5 mm SMA	9.5 mm Dense Graded HMA	Mix surfacing with 30% Calcined Bauxite & 70% Slag	Single Chip Seal	9.5 mm Dense Graded HMA
8.5" JPCP - Turf Drag Finish	Artificial Faulting	Longitudinal Tining	Transverse Tining	Turf Drag Finish	Turf Drag Finish	Turf Drag Finish

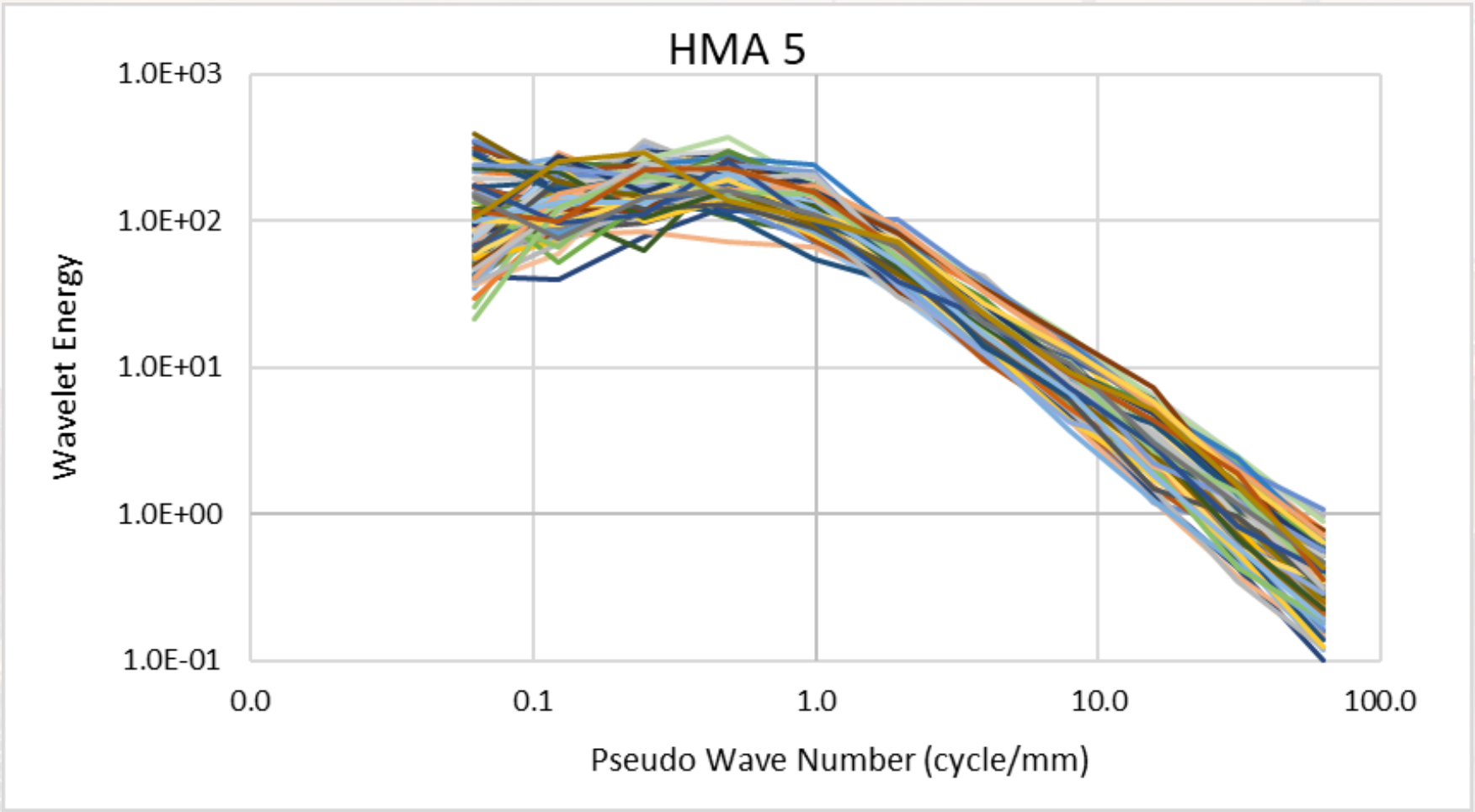
TEXTURE DATA



SPECTRAL CONTENT (PSD)



SPECTRAL CONTENT (W.E.)



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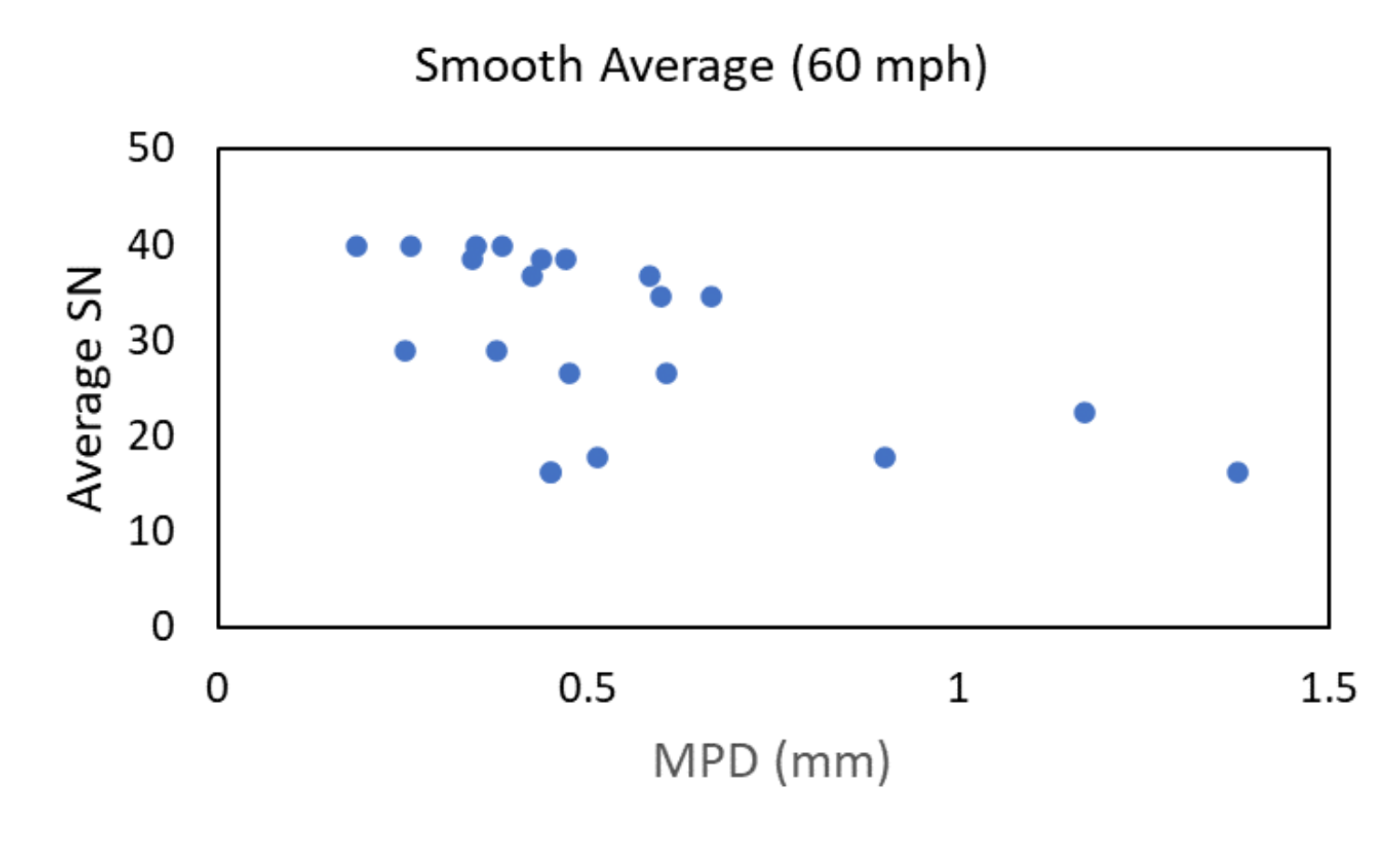
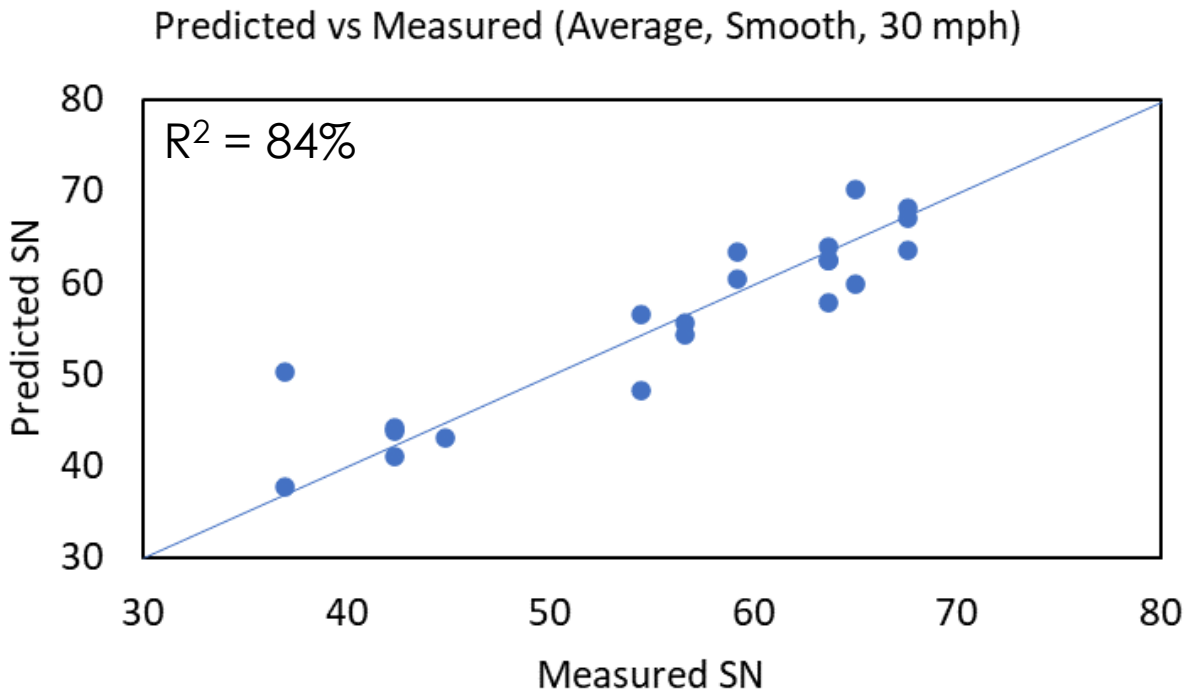
SMOOTH LWST MEASUREMENTS VS MPD

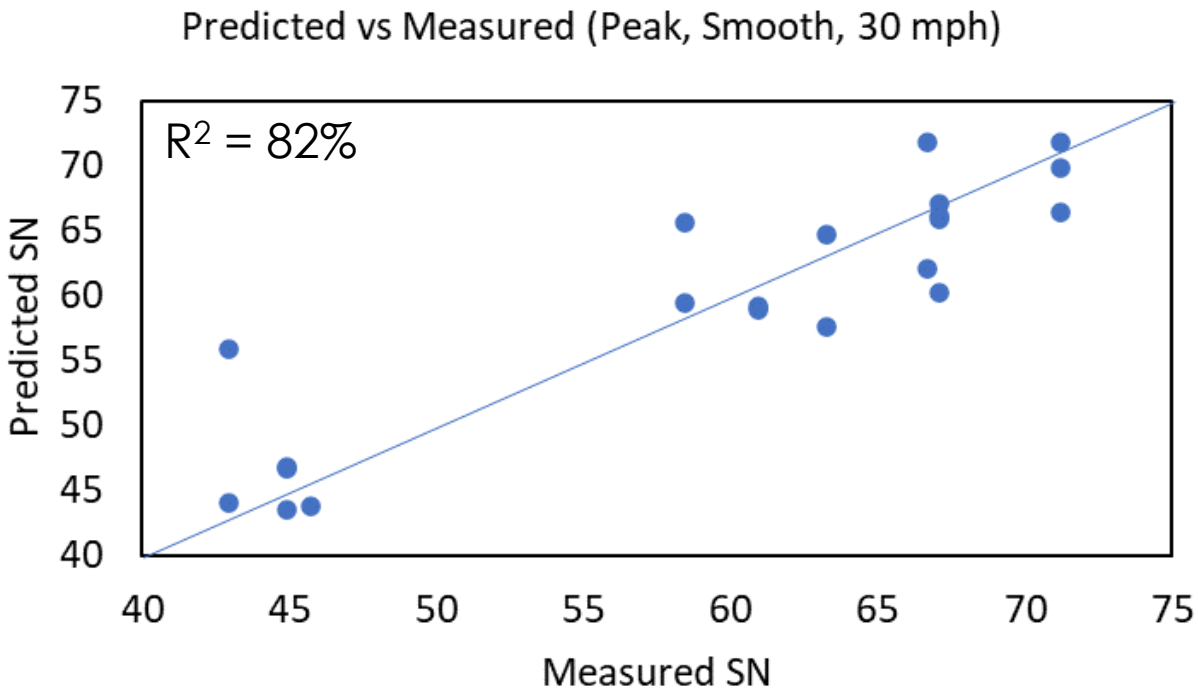
MPD did not show a clear trend with LWST measured using smooth tire.



SMOOTH LWST AND W.E. (30 MPH)

LWST measurements using smooth tire were modeled very well using wavelets energy.





SMOOTH LWST AND W.E. (40 MPH)

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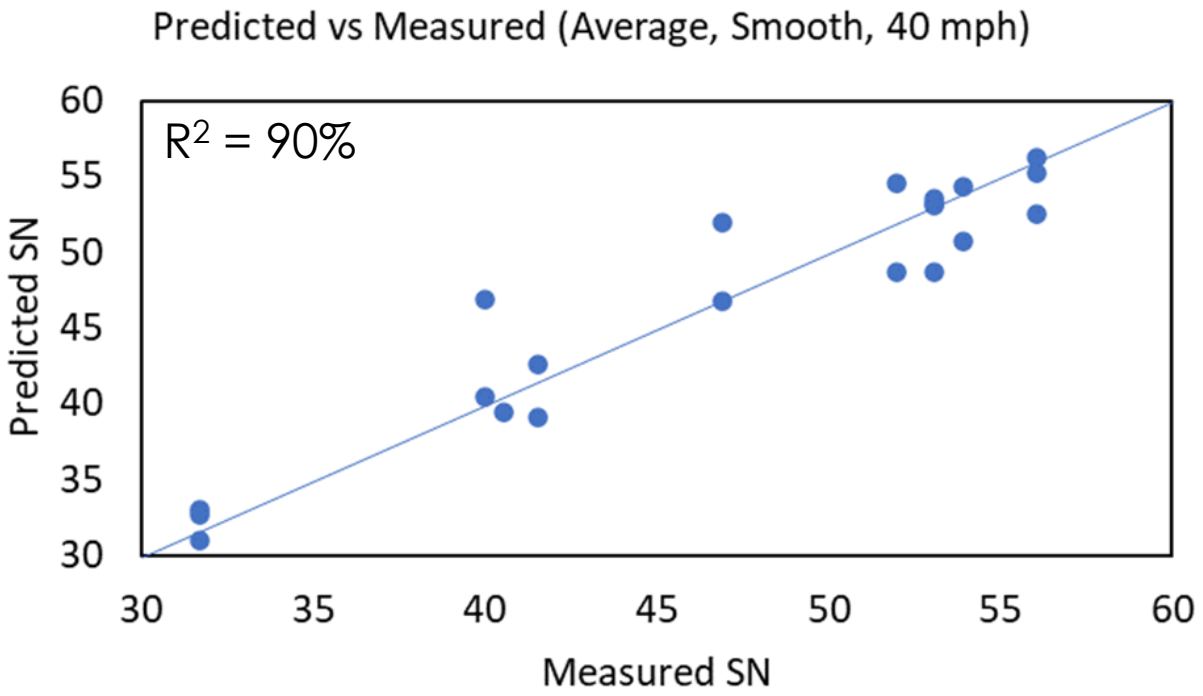
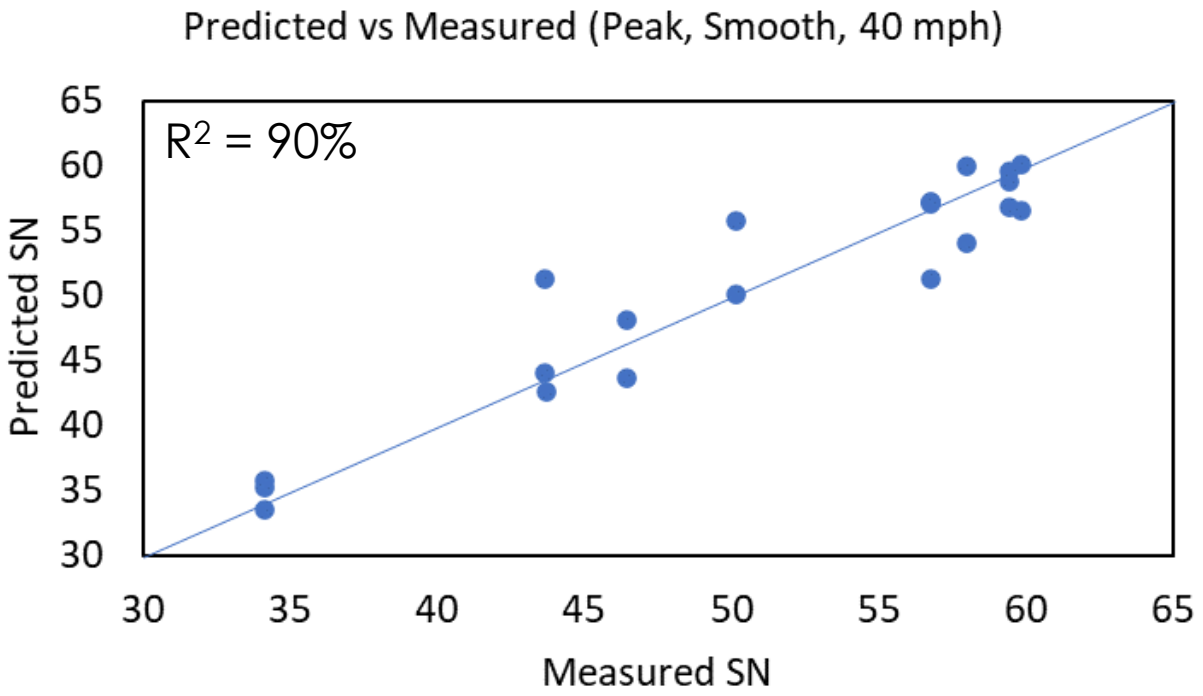
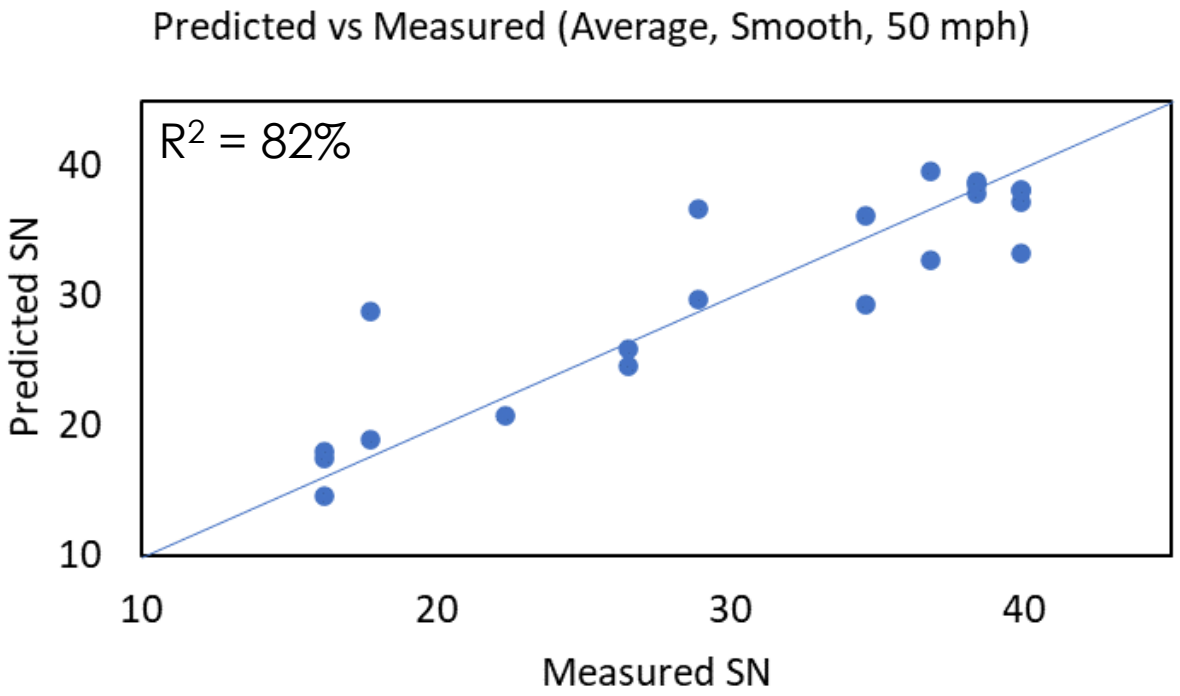
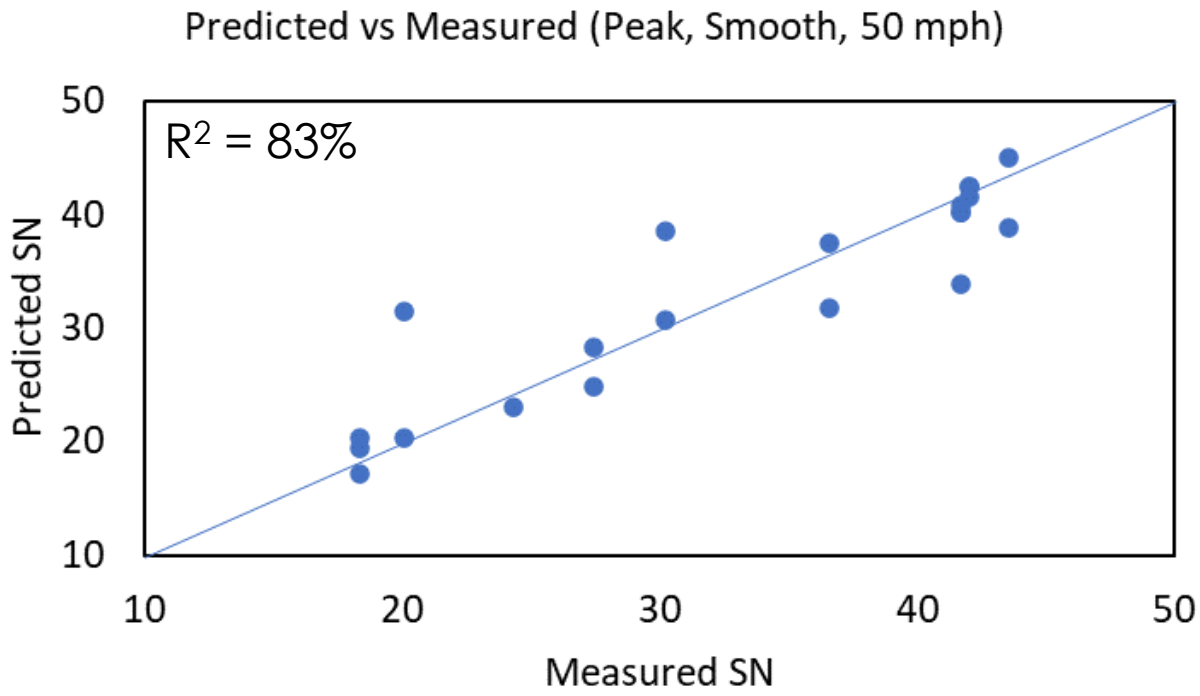




SMOOTH LWST AND W.E. (50 MPH)

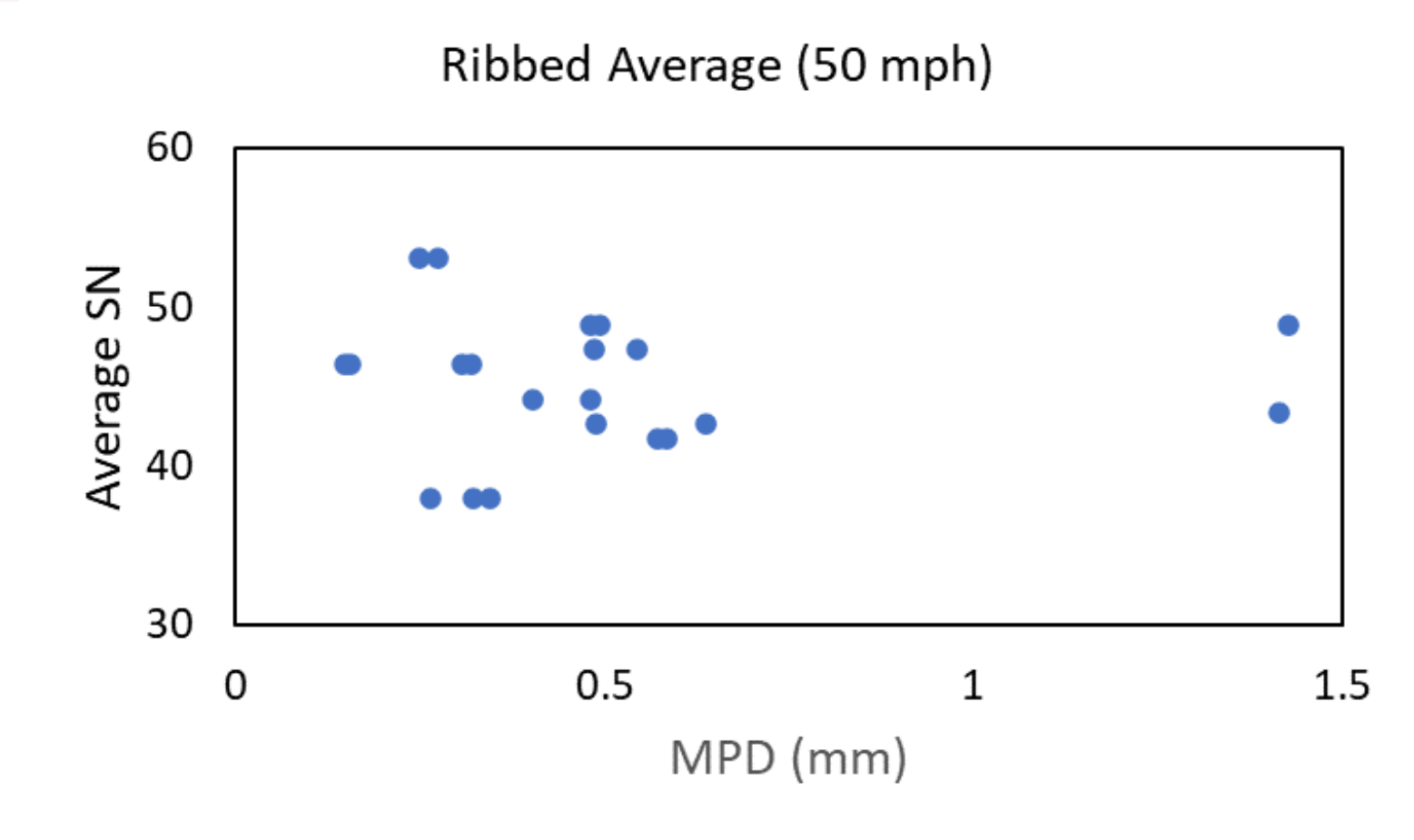
LWST measurements using smooth tire were modeled very well using wavelets energy.





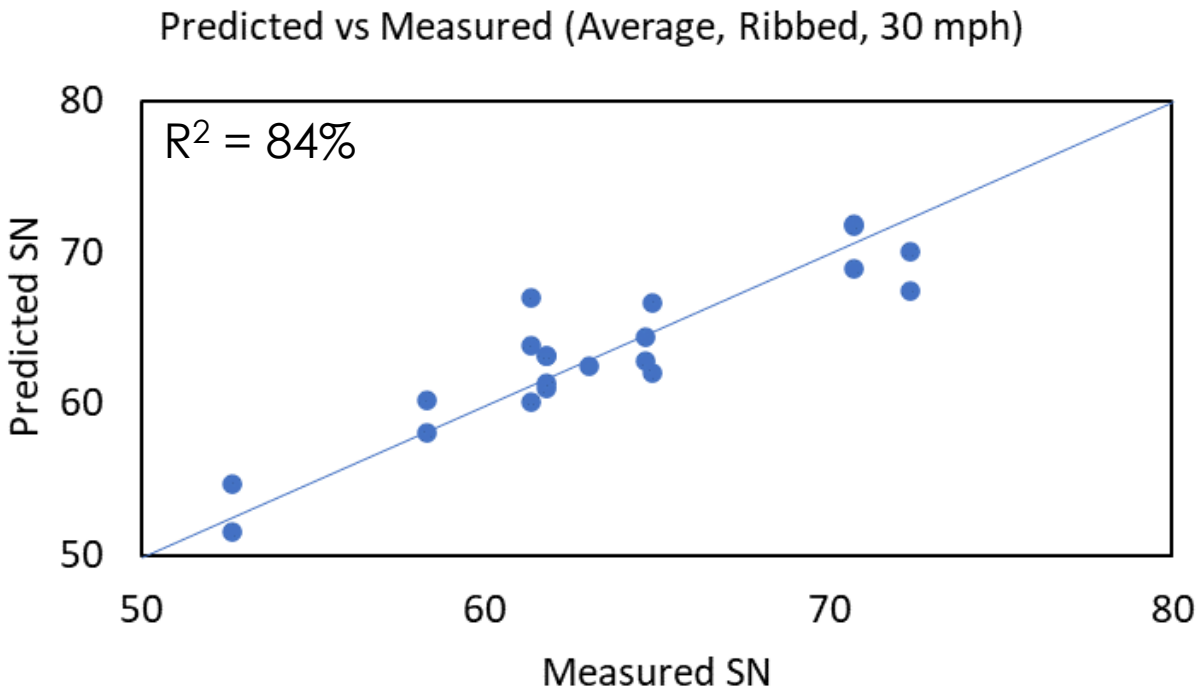
RIBBED LWST MEASUREMENTS VS MPD

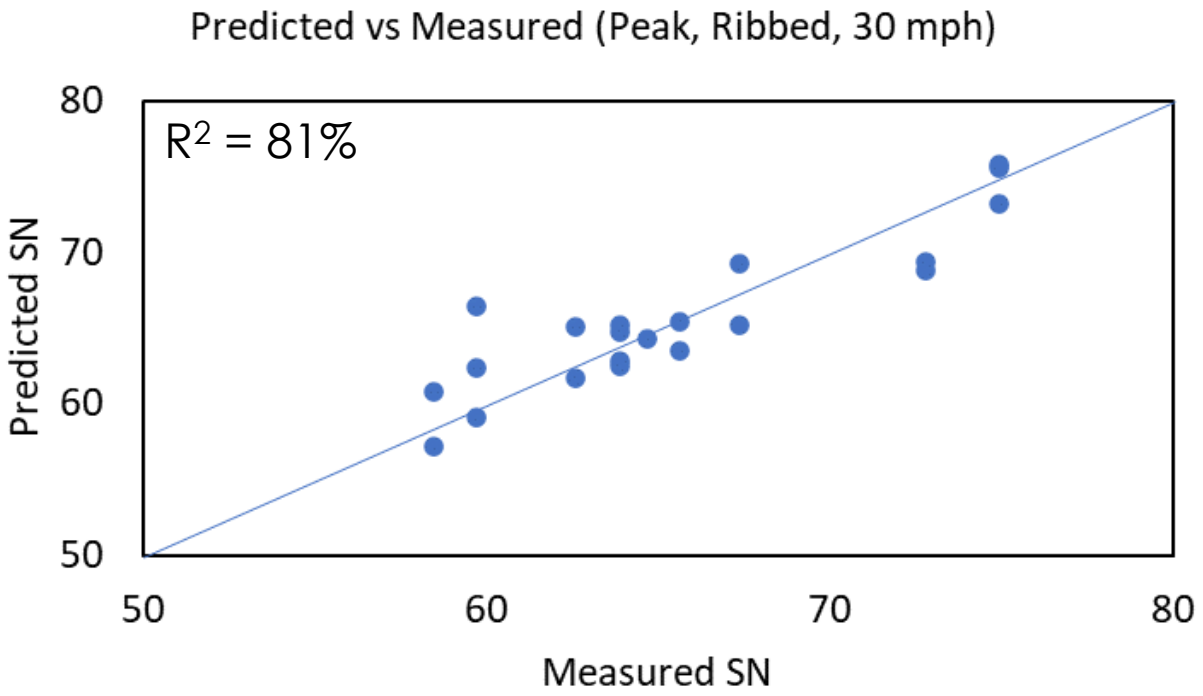
MPD did not show a clear trend with LWST measured using ribbed tire.



RIBBED LWST AND W.E. (30 MPH)

LWST measurements using ribbed tire were modeled very well using wavelets energy.





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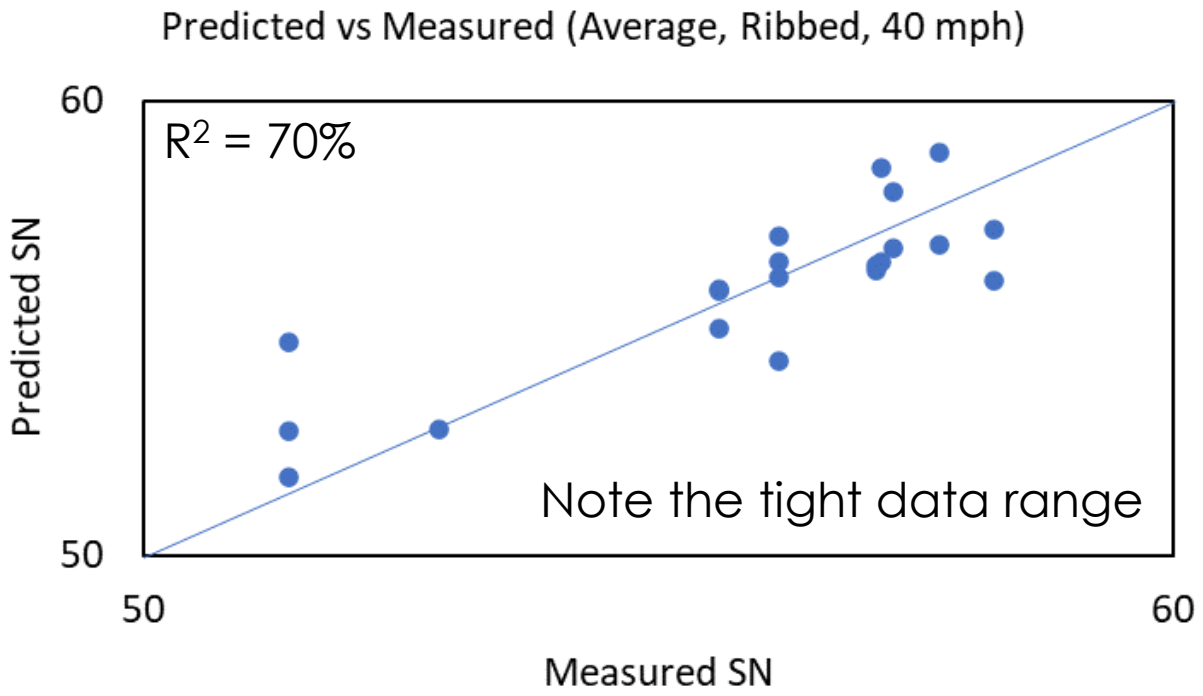

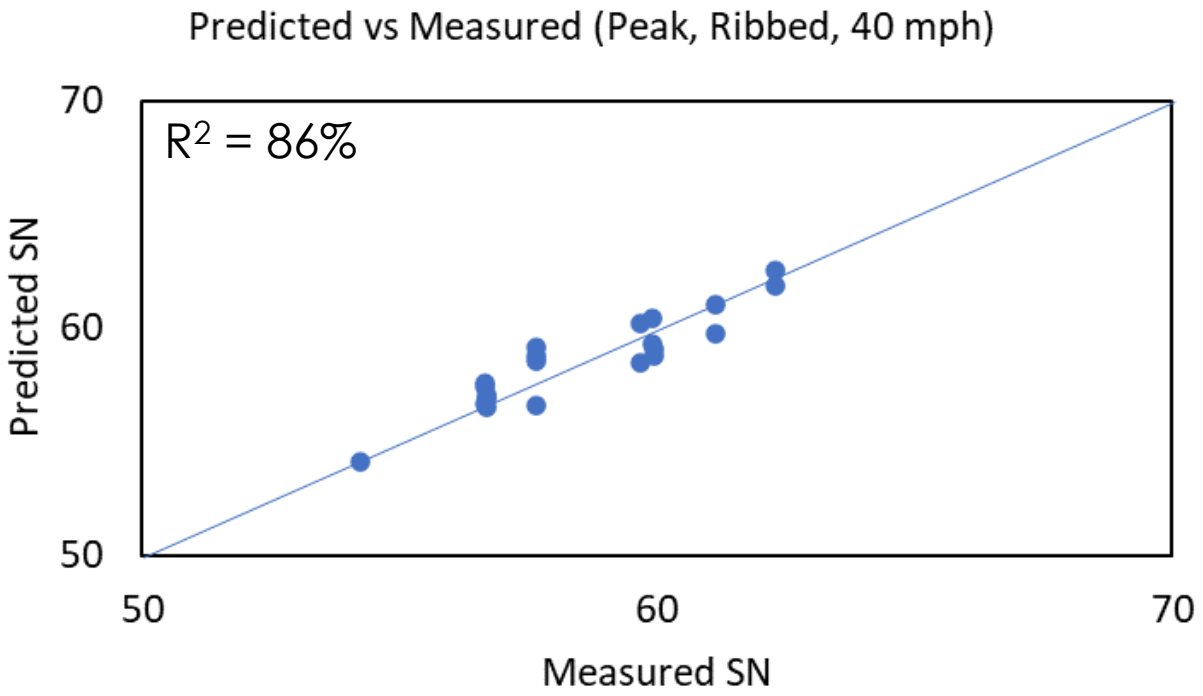

RIBBED LWST AND W.E. (50 MPH)

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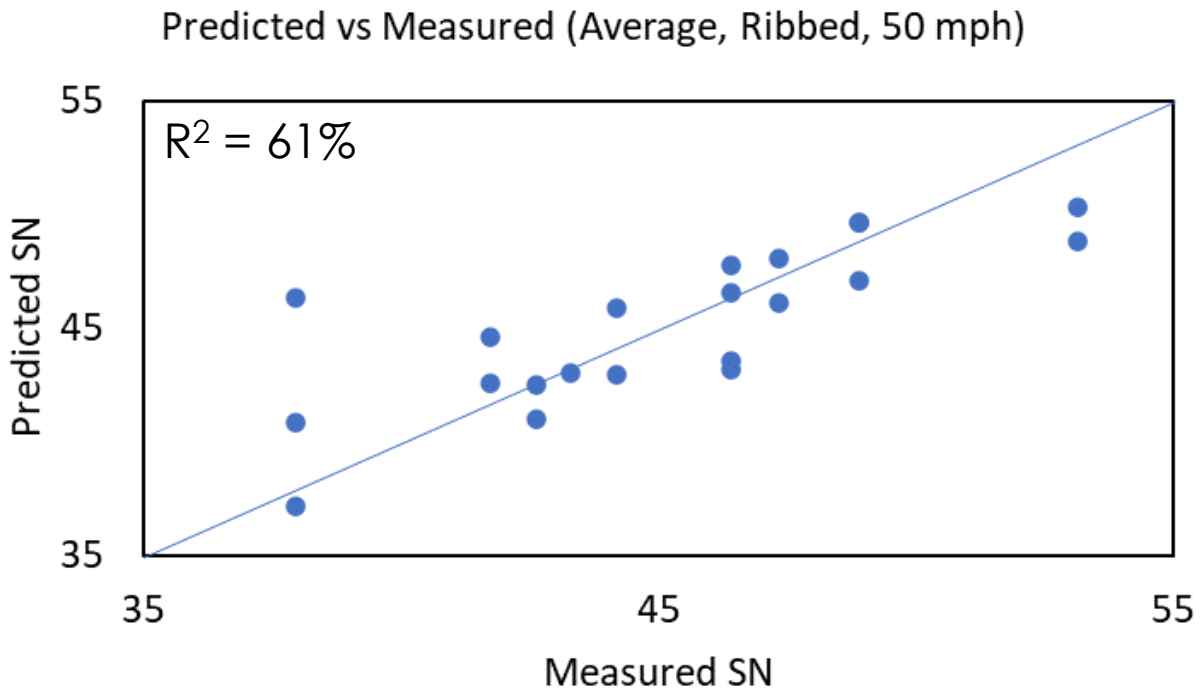

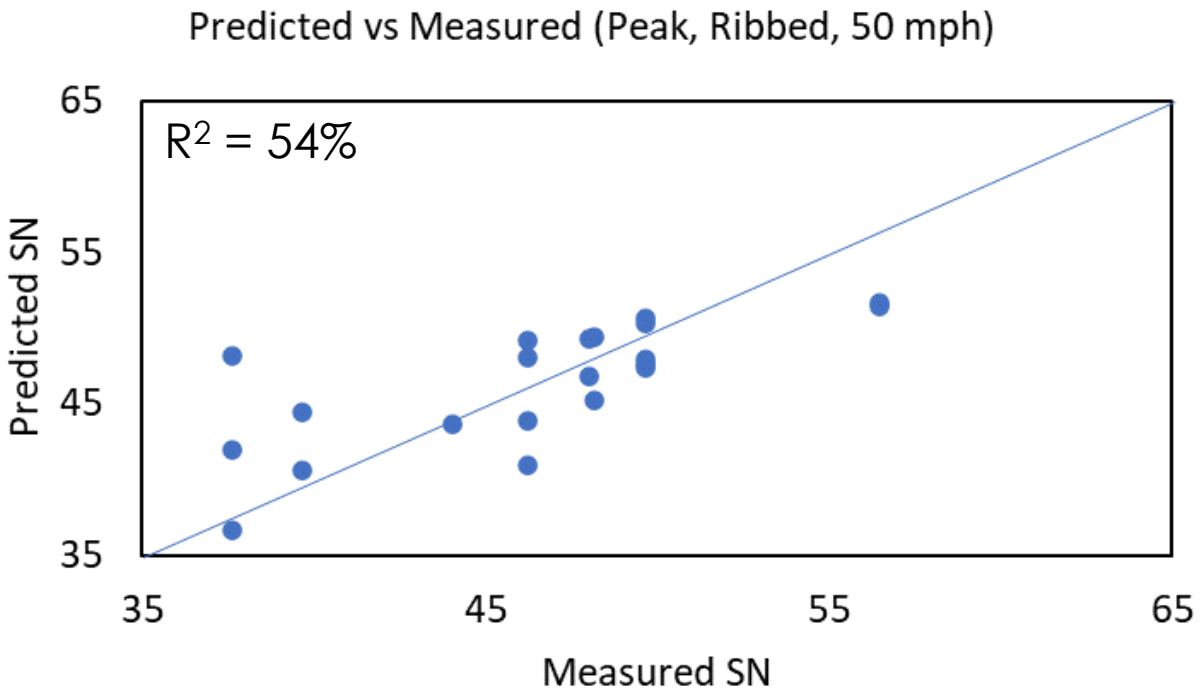

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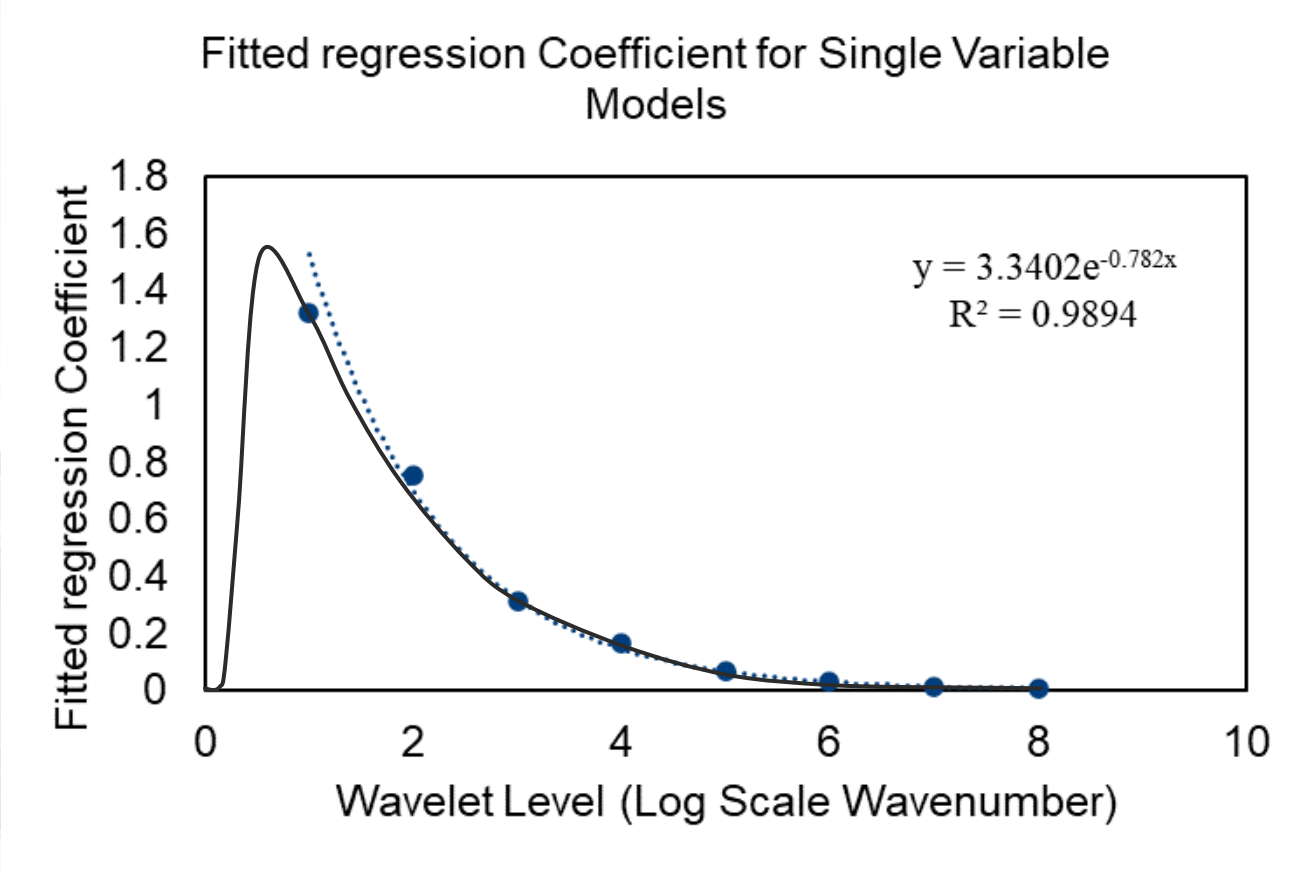
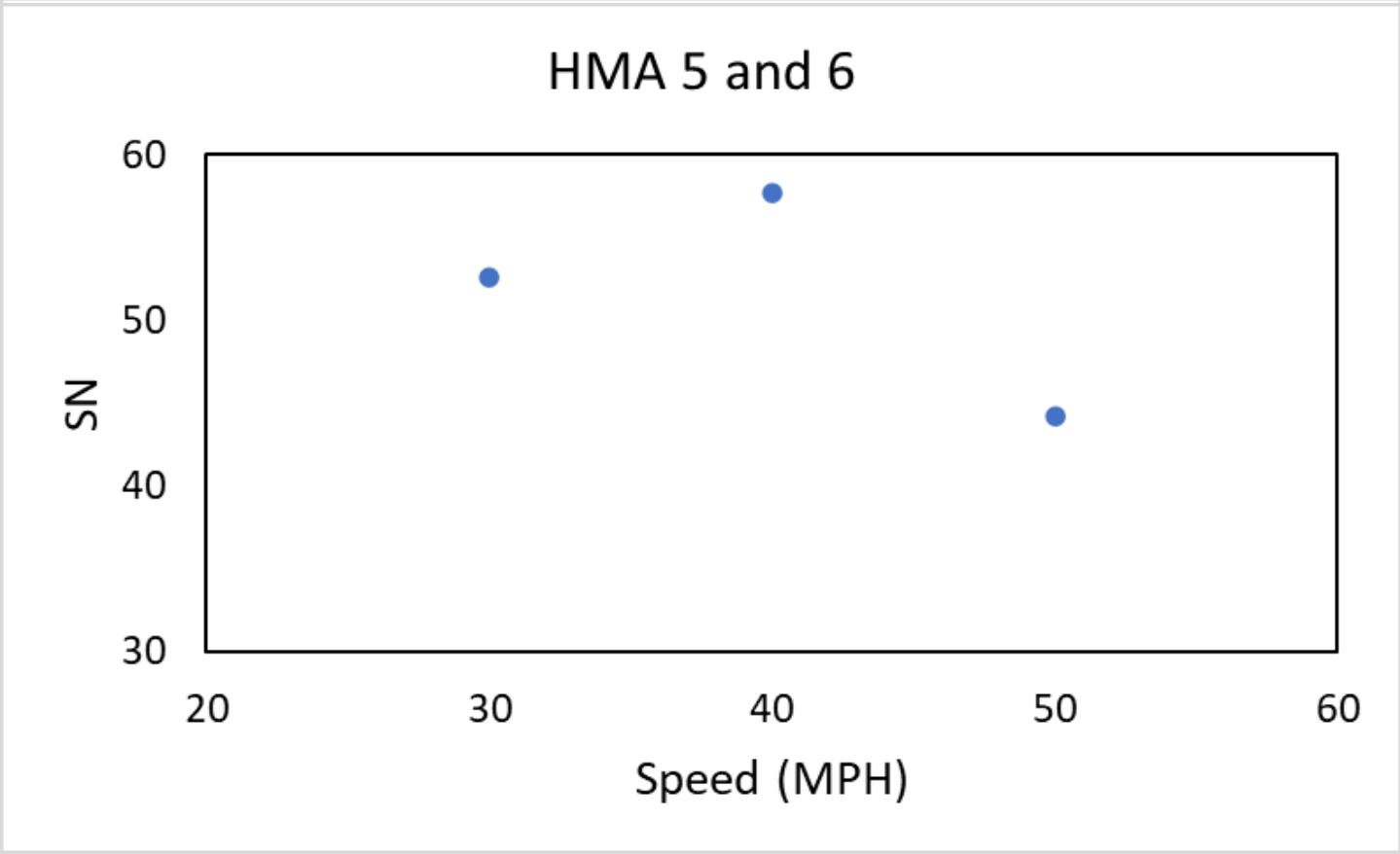
WAVEBANDS CONTRIBUTION

We are going back to the fundamentals to derive a Pareto-analytical solution.



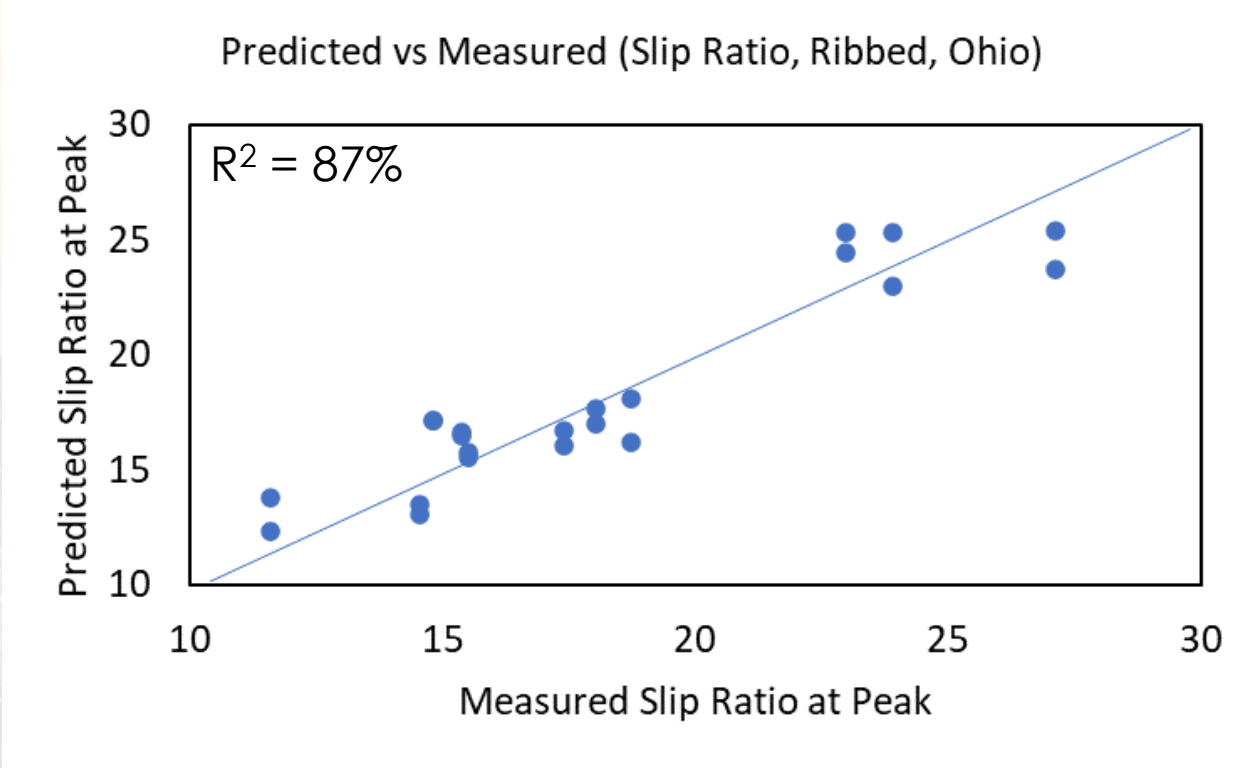
IMPACT OF SPEED

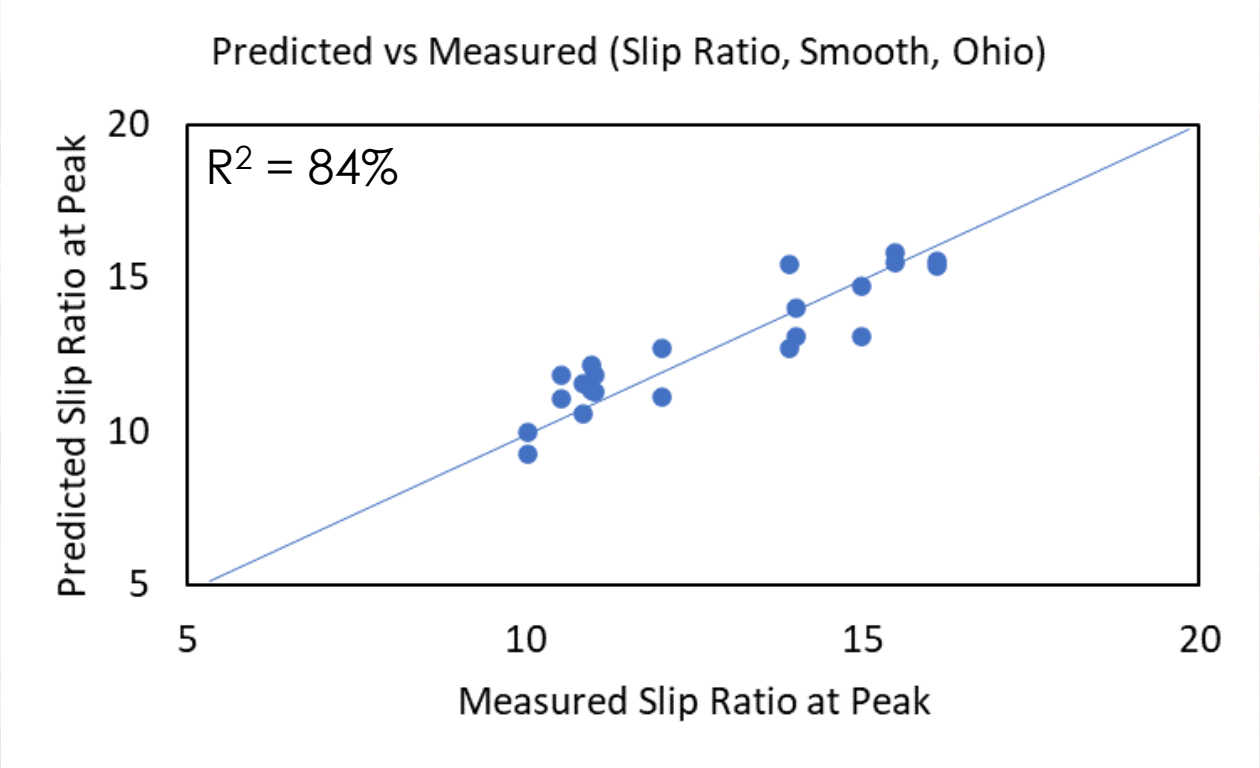
We are evaluating the impact of speed on SN values we have initial findings and waiting for the second season of testing.



WAVELETS AND SLIP RATIO

We are building a model to describe the SN at different slip ratios.





OUTLINE

- PSD and wavelets analysis provides more information about texture, and it is a representation of the full surface rather than capturing peak points only.
- The use of wavelets proved to be very effective in predicting different friction coefficients and skid number values for a wide range of devices and conditions.
- Different surfaces have different speed trends which is believed to be directly affected by texture.