THOUGHTS REGARDING TIRE-PAVEMENT NOISE

A Presentation to the TRB ADC40
Transportation-Related Noise & Vibration Committee
Summer Meeting—Santa Fe, New Mexico

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STAIANO ENGINEERING, INC.

PAVEMENT DESIGN

- OBSI quantifies noise generation
  - Database Ranks Performance
  - Qualitative design guidance
  - Empirical selection
- Quantitative prediction
  - Europe
  - Rasmussen

PAVEMENT PARAMETERS

- Texture
- Porosity
- Stiffness

NOISE EMISSIONS

- Generation Mechanisms
  - Tread impact (“The Hammer”)
  - Air pumping (“The Clapper”)
  - Stick-slip (“The Sneaker”)
  - Stick-snap (“The Suction Cup”)
- Amplifying Mechanisms
  - Acoustical Horn (“The Horn”)
  - Helmholtz Resonance (“The Pop Bottle”)
  - Pipe Resonance (“The Organ Pipe”)
  - Sidewall Vibrations (“The Pie Plate”)
  - Cavity Resonance (“The Balloon”)
- Multi-Coincidence Peak, f(pavement, tire)

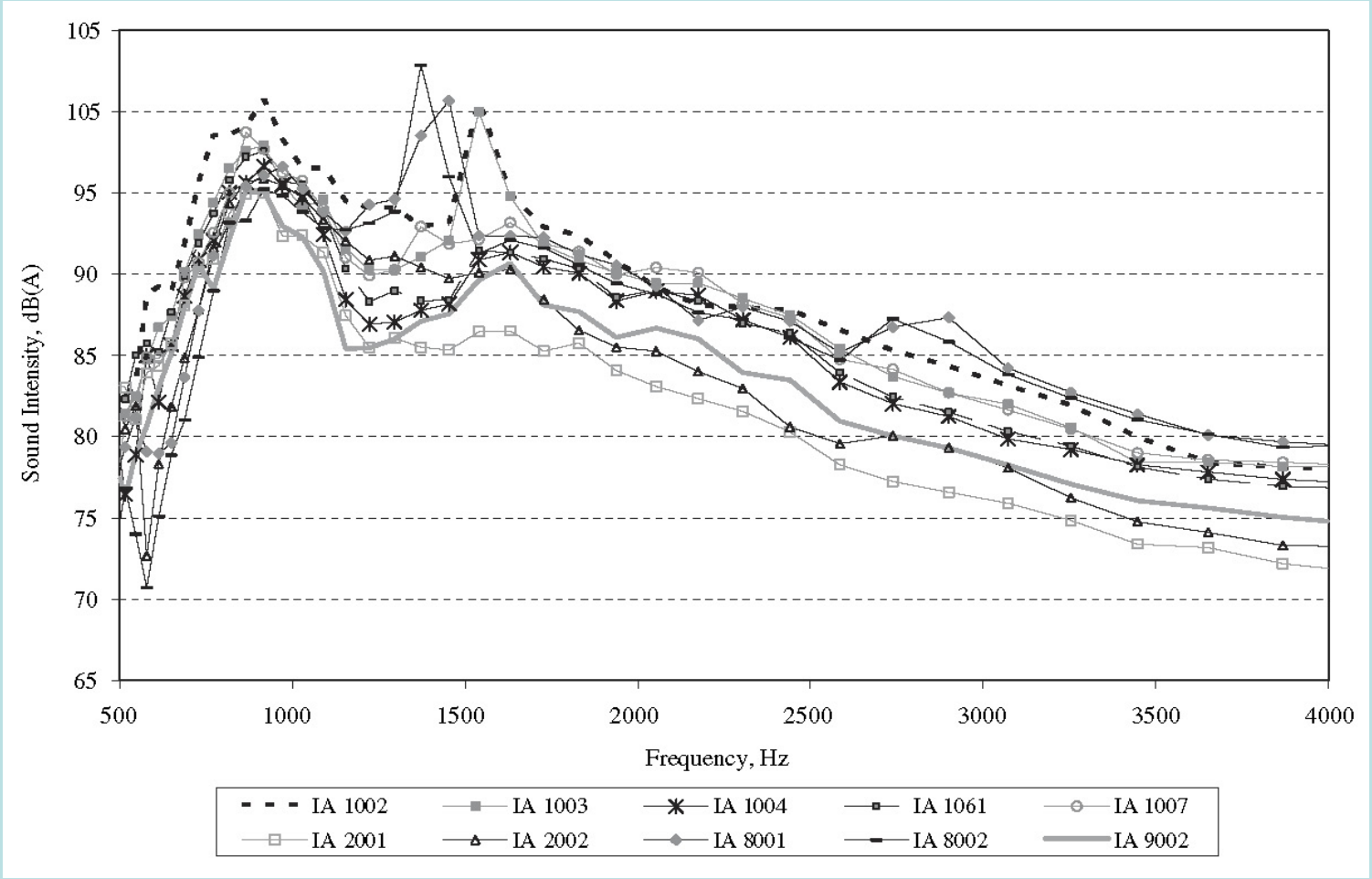
FREQUENCY CONTENT

- NCHRP 634 Iowa Measurements

SECTION	DESCRIPTION
1002	Tran Tine (0.5-in. spacing, 0.075-in. depth), turf drag
1003	Long Tine (0.5-in. spacing, 0.075-in. depth), turf drag
1004	Long Tine (0.75-in. spacing, 0.15-in. depth), turf drag
1061	Tran Groove (1-in. spacing, 0.18- to 0.25-in. depth), turf drag
1007	Long Turf Drag
2001	Long Tine (0.75-in. spacing, 0.125-in. depth), turf drag
2002	Long Tine (0.75-in. spacing, 0.125-in. depth), burlap drag
8001	Tran Tine (0.75-in. spacing, 0.15-in. depth), turf drag
8002	Tran Tine (0.75-in. spacing, 0.15-in. depth), turf drag
9002	Dense-Graded AC (Superpave)

  - 1/12th octave band spectra
  - Goodyear Aquatred III test tire / all-wheel drive Honda CR-V

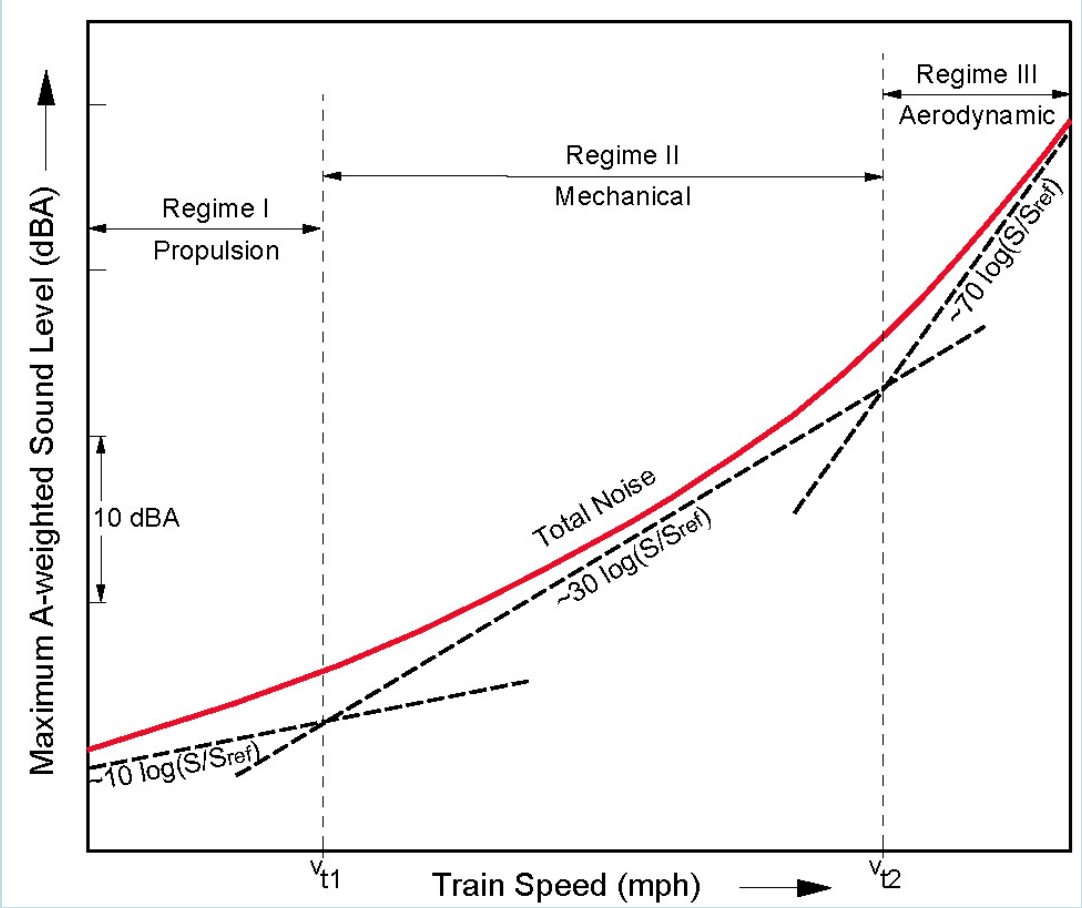
NARROWBAND SPECTRA



NCHRP 634

TOTAL NOISE

- Summation of sources
- $L_{Ai} \sim k_i \log(v)$



Noise source speed dependence for high-speed train

SPEED RELATIONS

SOURCE	SPEED RELATIONSHIP	FREQUENCY RANGE
Air Pumping	40→50	1→3 kHz
Tire Vibration (surface irregularities coupling to tire sidewalls)	20→30	500 Hz→3 kHz
Stick-Slip & Snap-Stick	30→50	1→6 kHz
Resonances (leading/trailing edge contact zone channels—Helmholtz resonances)	0	500 Hz→3 kHz
Resonances (tire cavity)	0	1→2 kHz

Goubert

SPEED INFLUENCE

- Tire/pavement contribution
  - –“almost all” for Cruise ≥35 MPH
- Noise Intensity Testing in Europe (NITE)
  - – 66 pavements via OBSI

Donavan

NITE 35 & 60 MPH DATA

Comparative Europe and the United States Measurements

30

Goodyear Aquatred III pavements

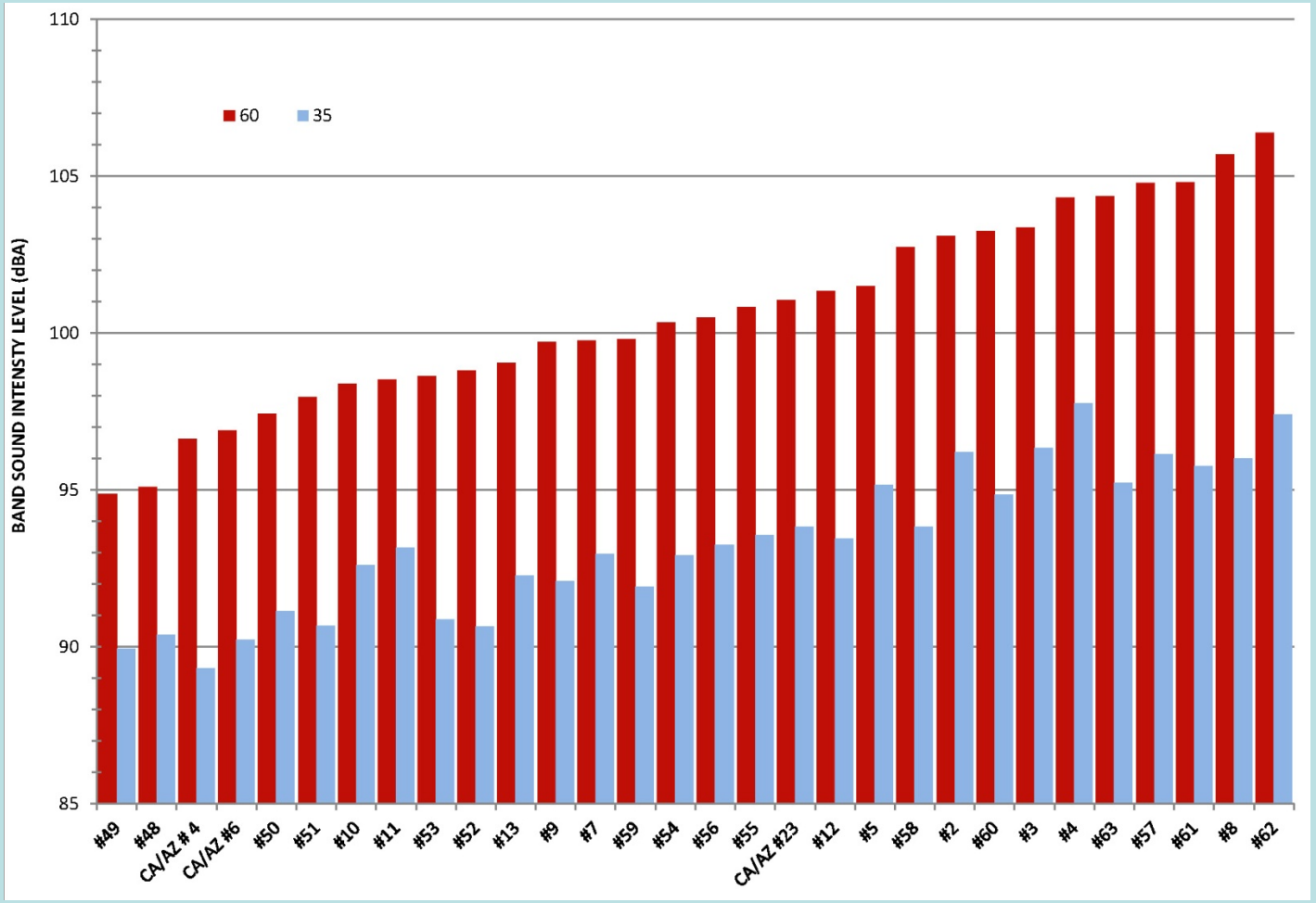
PAVEMENT:	RANK Quietest	DESCRIPTION:
#49	1	Double Layer Porous Asphalt 4/8 mm
#48	2	Porous Asphalt 4/8 mm
CA/AZ # 4	3	DGAC - Fine Aggregrate
CA/AZ #6	4	OGAC (non-porous) 75mm thick on DGA
#50	5	Novachip 0/8 mm
#51	6	ISO 10844
#10	7	Fine Dense Graded Asphalt
#11	8	Porous Asphalt 0/10 mm
#53	9	Stone Mastic Asphalt, 0/5 mm
#52	10	Stone Mastic Asphalt, 0/3 mm
#13	11	Thin Layer Asphalt 0/6 mm
#9	12	Fine Surface Dressing 0.8/1.5 mm
#7	13	Porous Cement Concrete
#59	14	DSK 0/3 mm
#54	15	Stone Mastic Asphalt, 0/8 mm
#56	16	Stone Mastic Asphalt, 0/8 mm
#55	17	Stone Mastic Asphalt, 0/11 mm
CA/AZ #23	18	DGAC (Type B) 30mm thick on DGAC
#12	19	Dense Graded Asphalt 0/10 mm
#5	20	Exposed Aggregate Cement Concrete 0/7 mm
#58	21	DSK 0/5 mm
#2	22	Stone Mastic Asphalt, 0/14 mm
#60	23	Surface Dressing OB 2/3 Round
#3	24	Porous Cement Concrete 0/7 mm
#4	25	Porous Asphalt 0/14 mm
#63	26	Surface Dressing OB 5/8 Sharp
#57	**27**	Smooth Surface (Stone Mastic 0/8 with Epoxy Coat)
#61	**28**	Surface Dressing OB 3/5 Round
#8	**29**	Surface Dressing 8/10 mm
#62	**30**	Surface Dressing OB 5/8 Round

Quietest 1st Four

Quieter 2nd Four

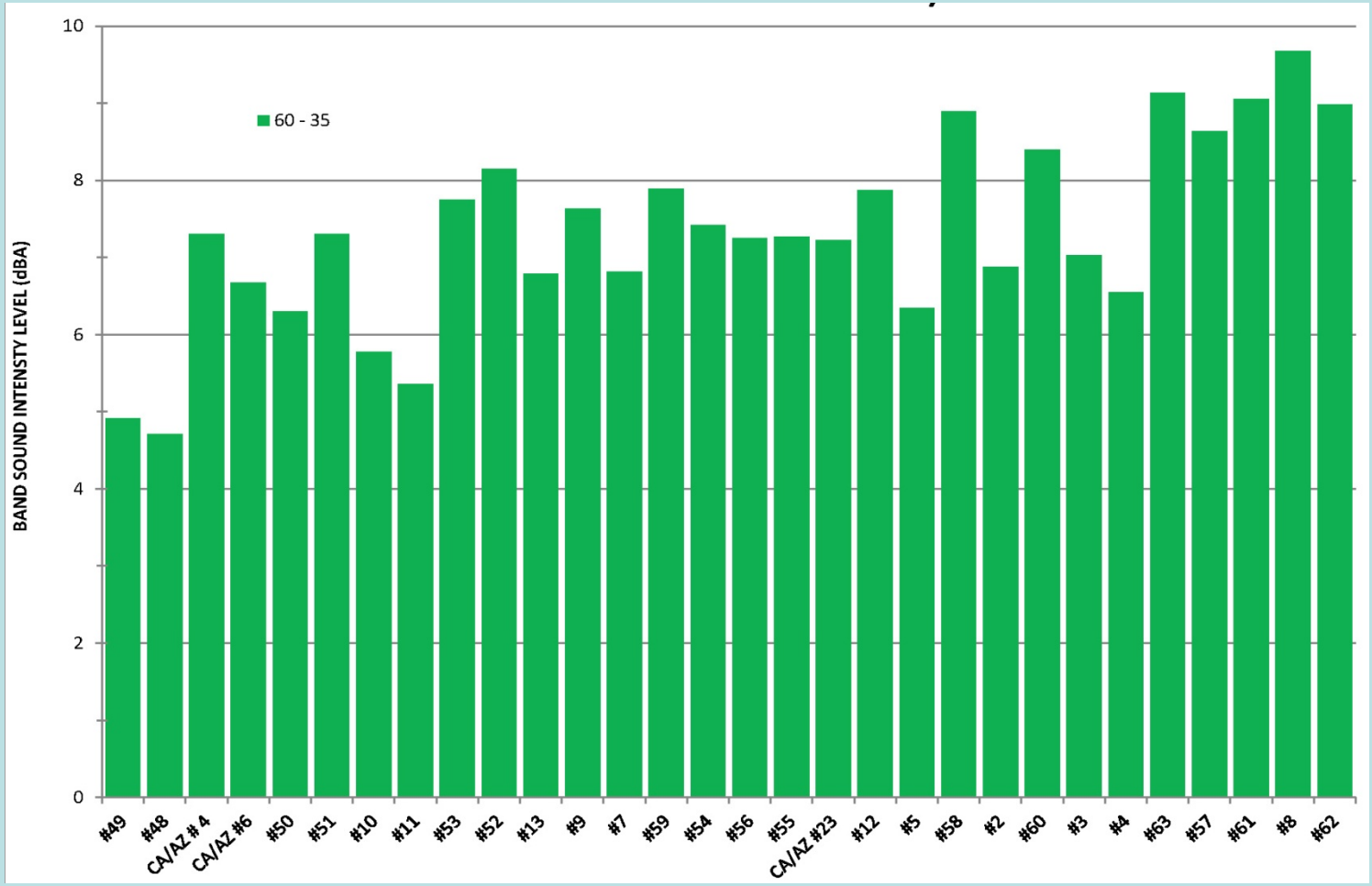
Noisiest Four

NITE Overall Levels



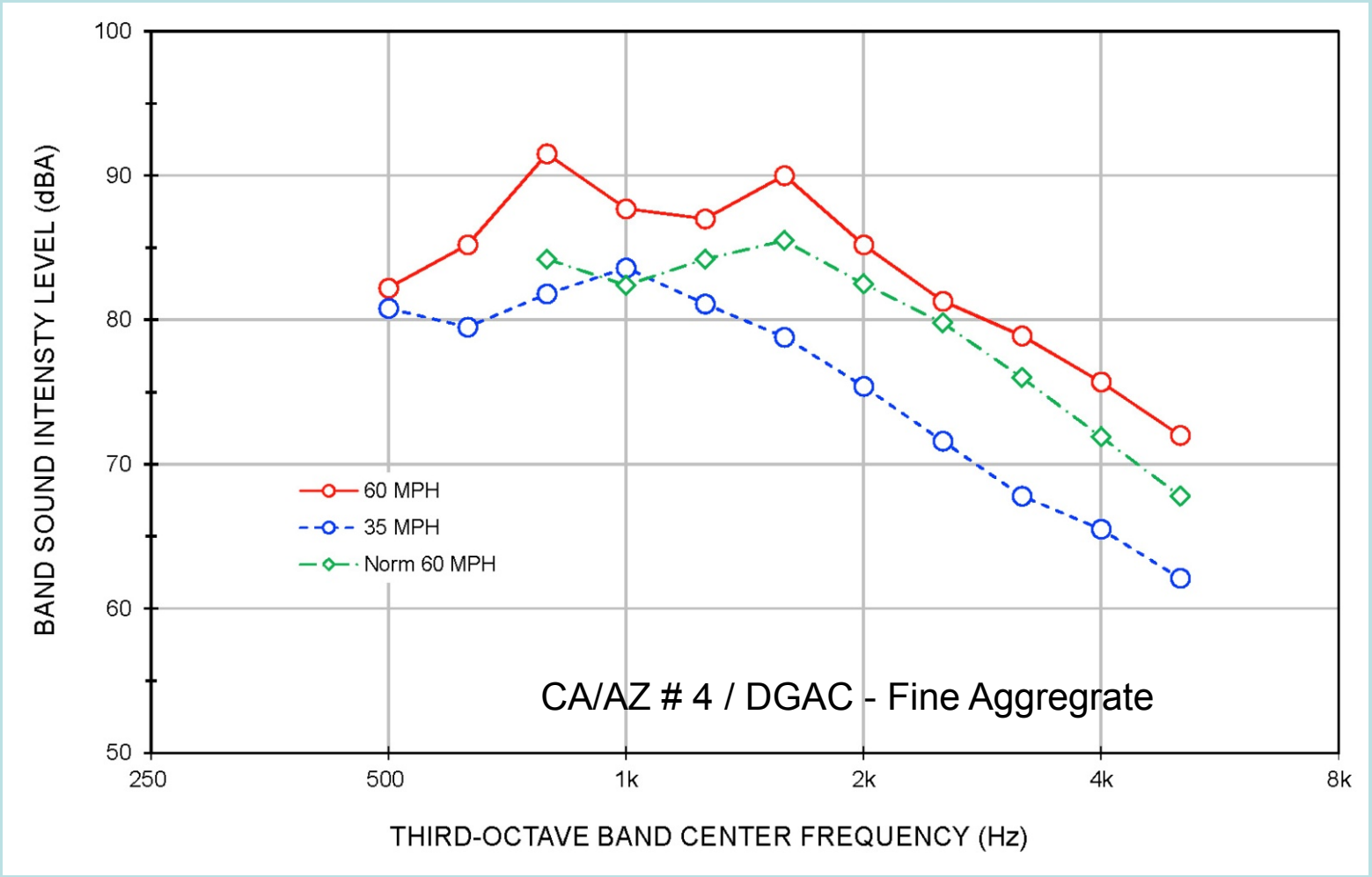
NITE Overall Levels

60-35 MPH Differences



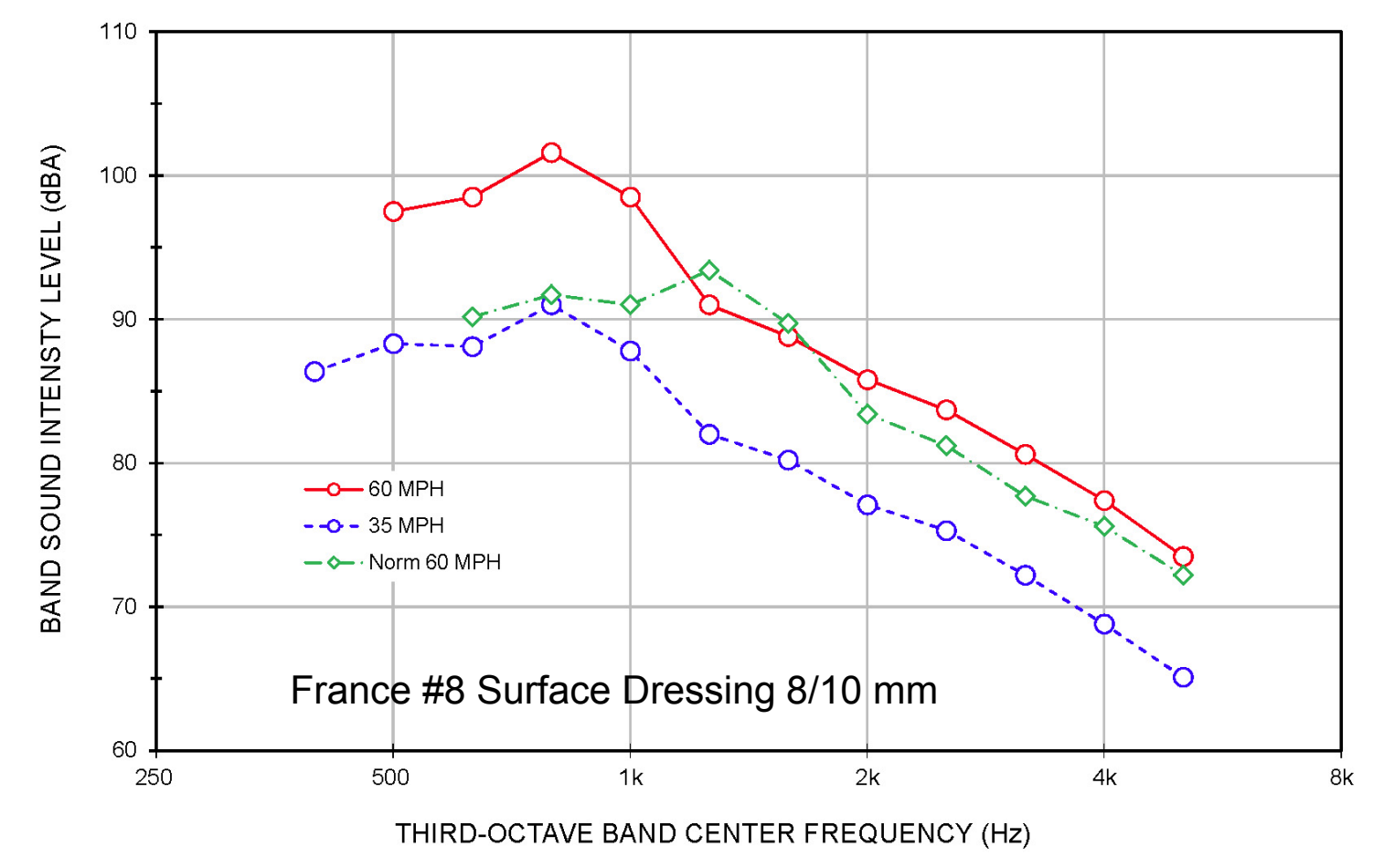
NITE SPECTUM

Relatively Quiet Pavement



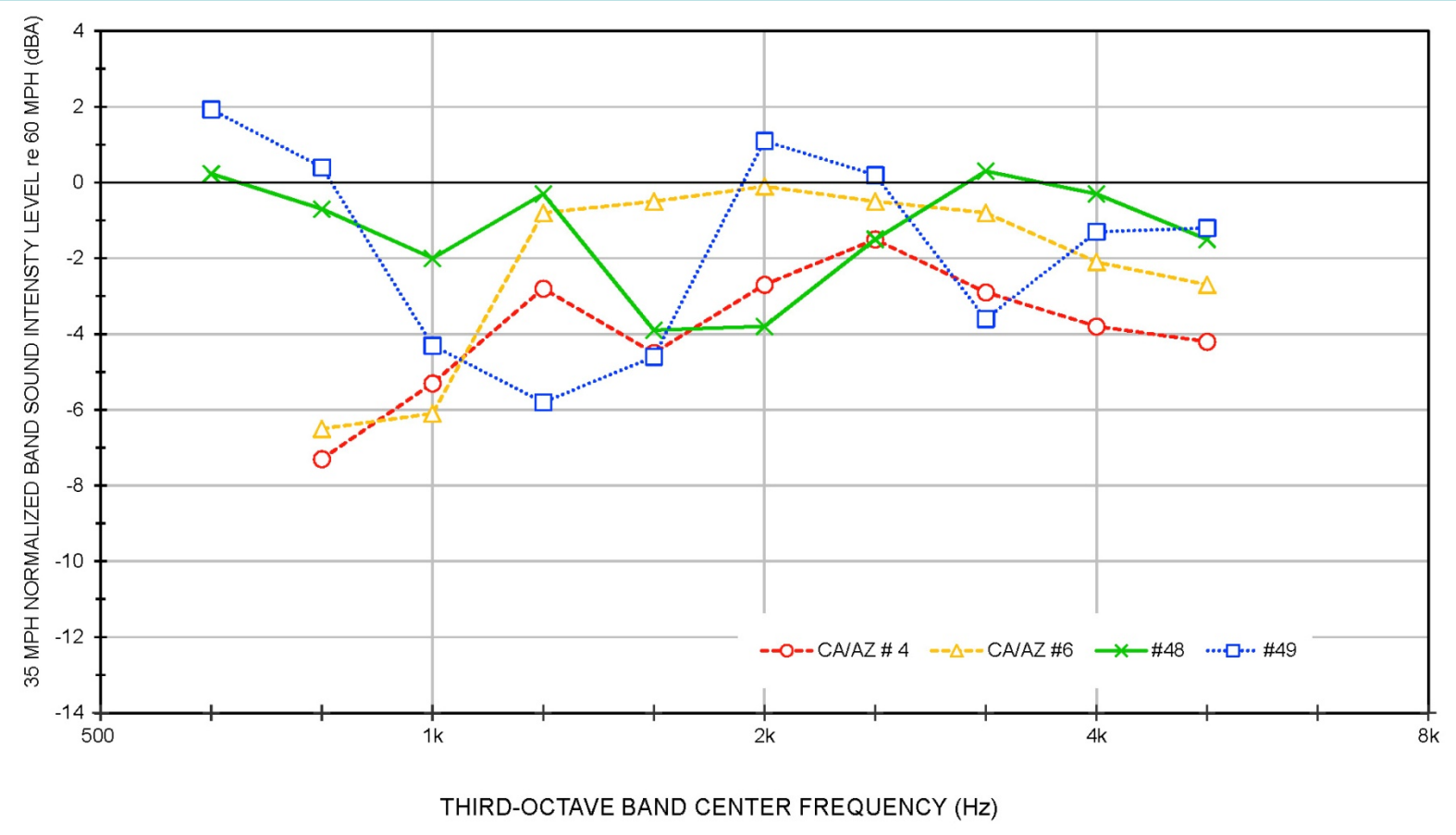
NITE SPECTRUM

Relatively Noisy Pavement



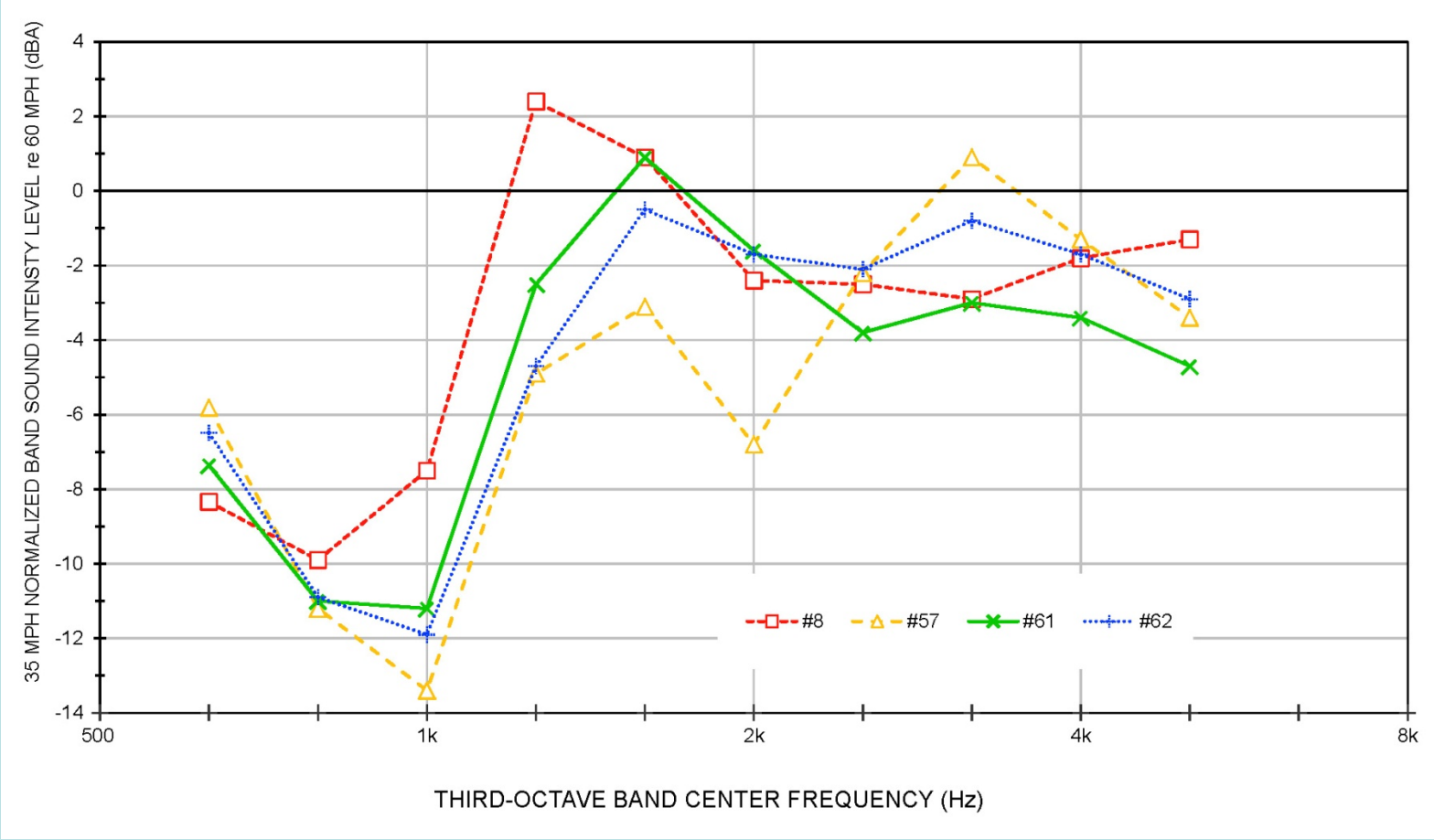
NITE SPECTRUM DIFFERENCES

Quietest

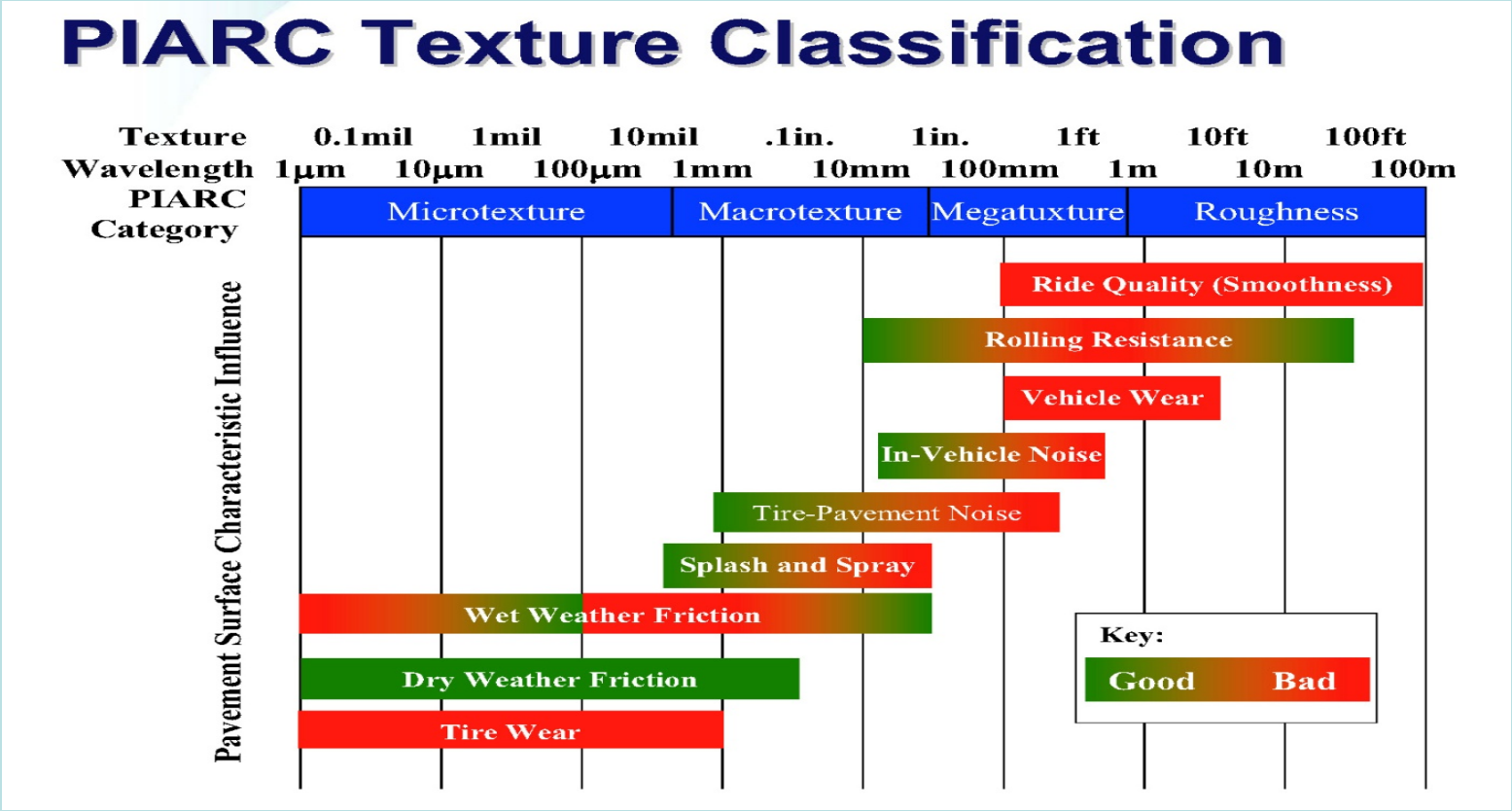


NITE SPECTRUM DIFFERENCES

Noisiest



FORCING FUNCTION—TEXTURE

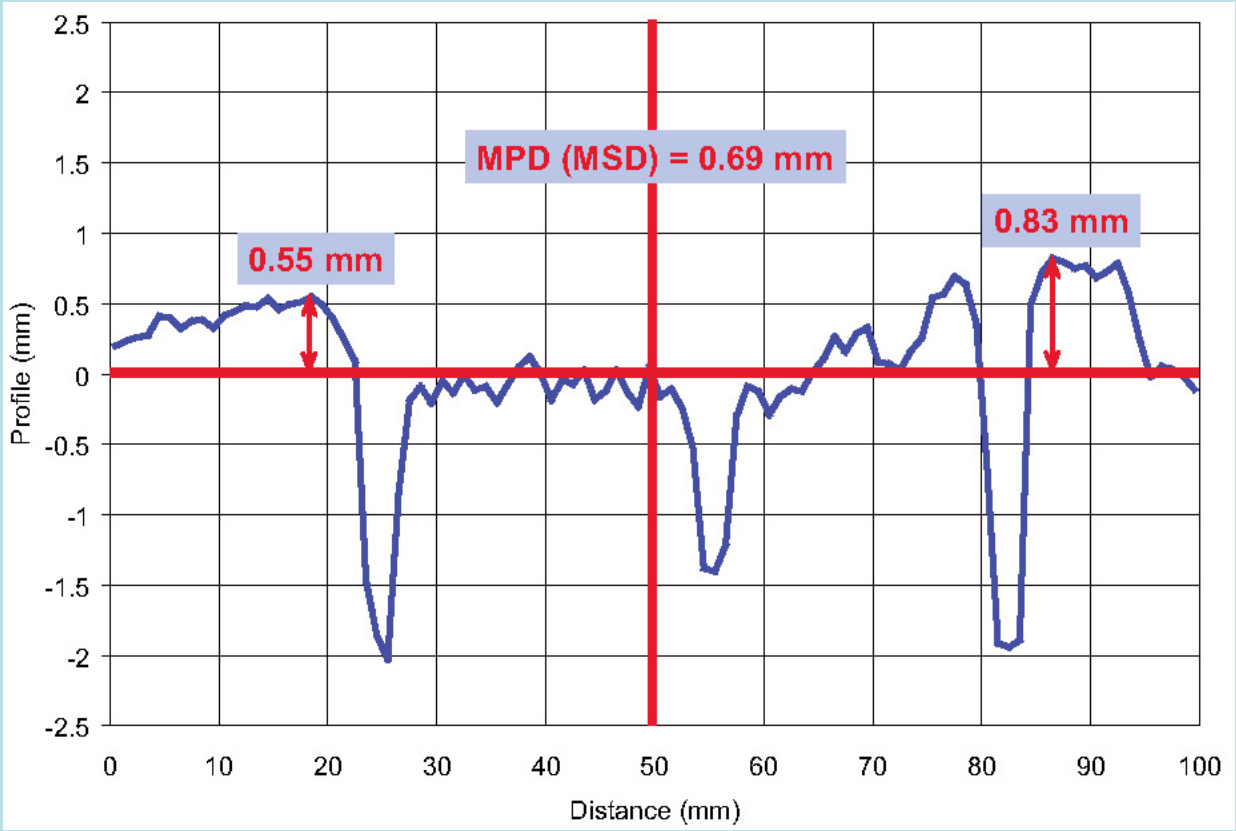


Permanent International Association of Road Congresses (PIARC)

TEXTURE PARAMETERS

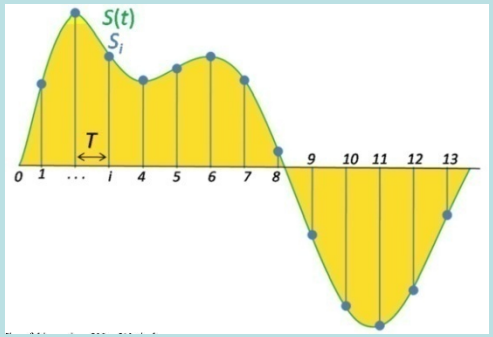
- Wavelength, λ
- Profile Depth
  - Mean Profile Depth, MPD
  - Texture Profile $L_{tx}(\lambda)$
- Skewness (profile asymmetry)

MEAN PROFILE DEPTH

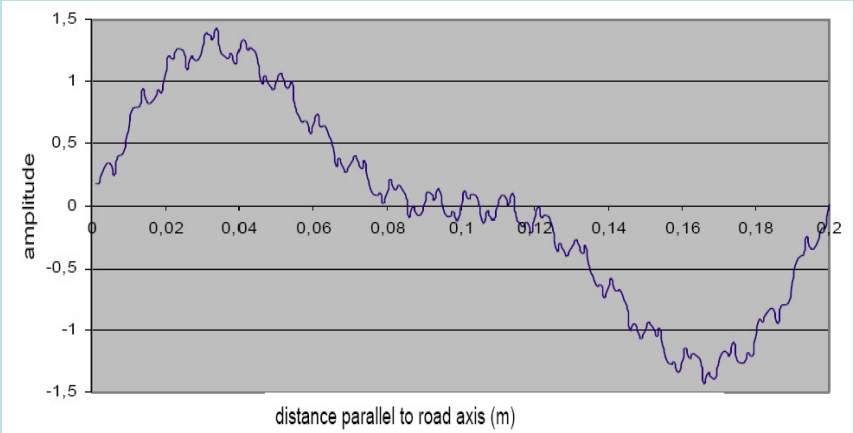


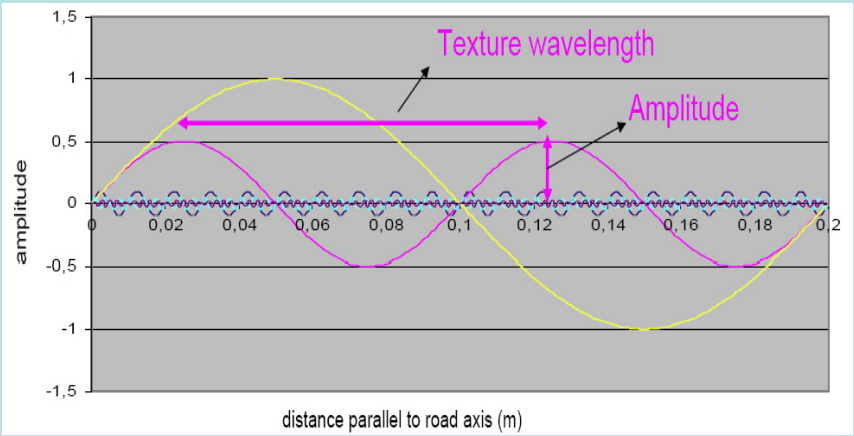
TEXTURE LEVEL

$L_{tx} \sim \log(a)$

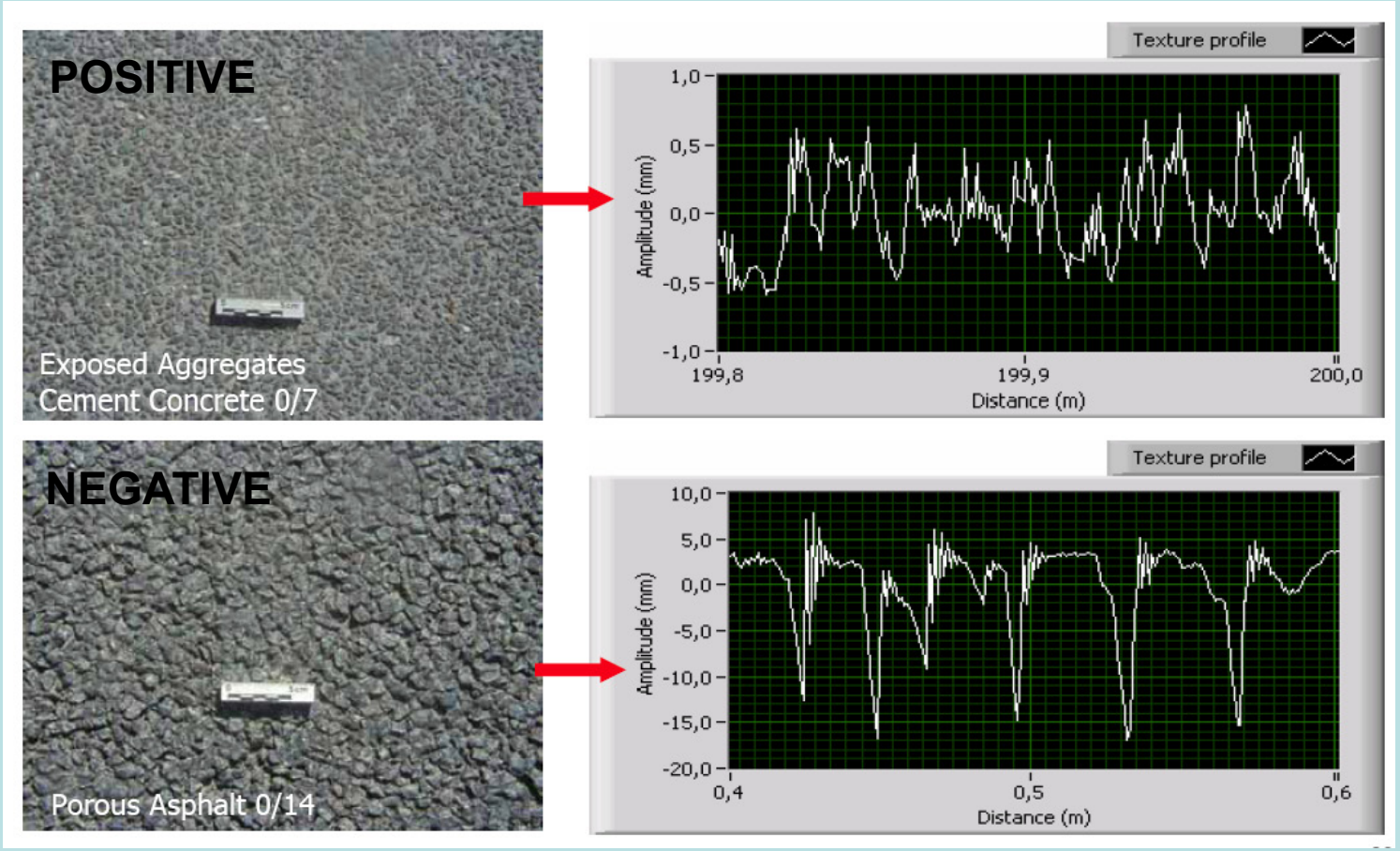


ISO TS 13473-4 Part 4
Characterization of pavement texture by use of surface profiles—Spectral analysis of surface profiles





SKEWNESS

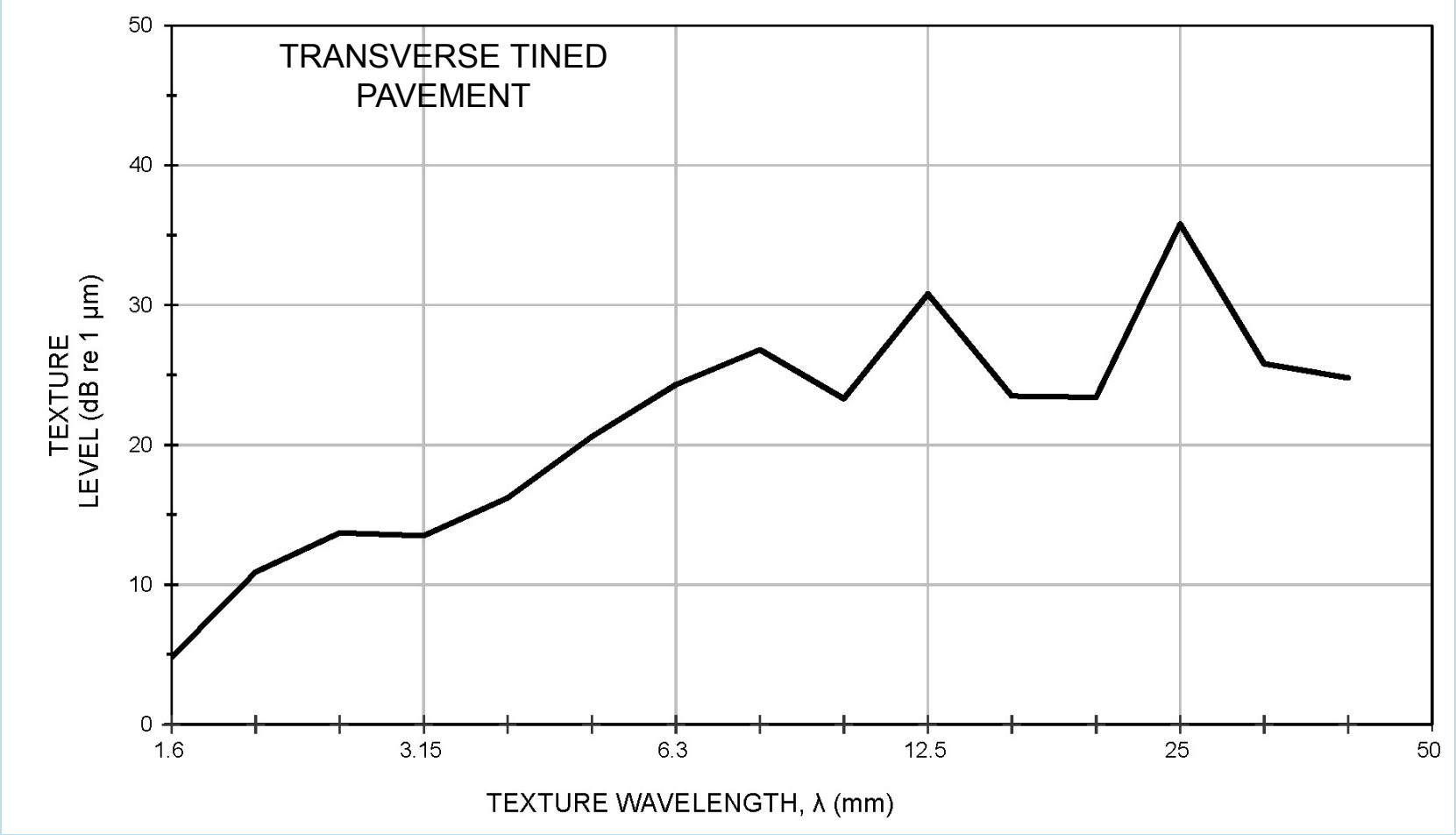


Goubert

LASER PROFILOMETER

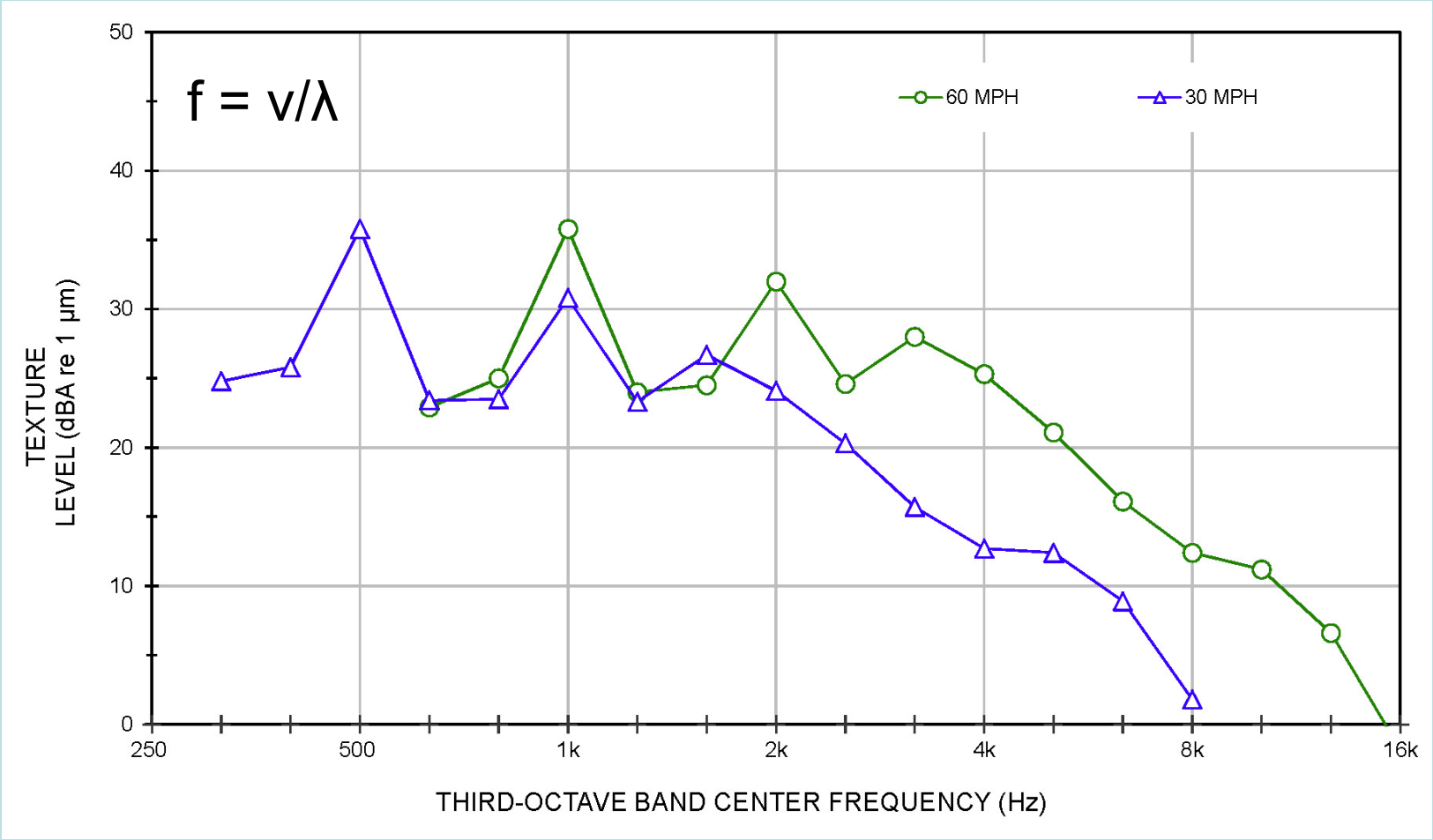
FHWA ROSAN$_V$

TEXTURE SPECTRA, $L_{tx}(\lambda)$



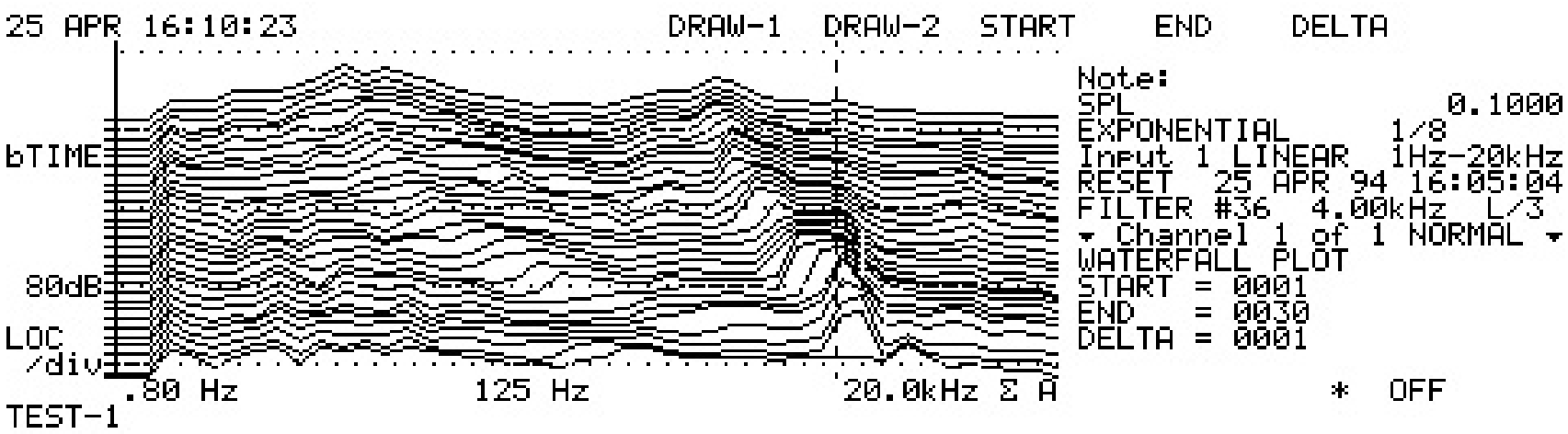
Rasmussen, et. al.

TEXTURE SPECTRA--$L_{Atx}(f)$



TEXTURE SPECTRA—$L_{Atx}(f,v)$

Waterfall Plot



MEASUREMENT CAPABILITY

RECOMMENDATIONS

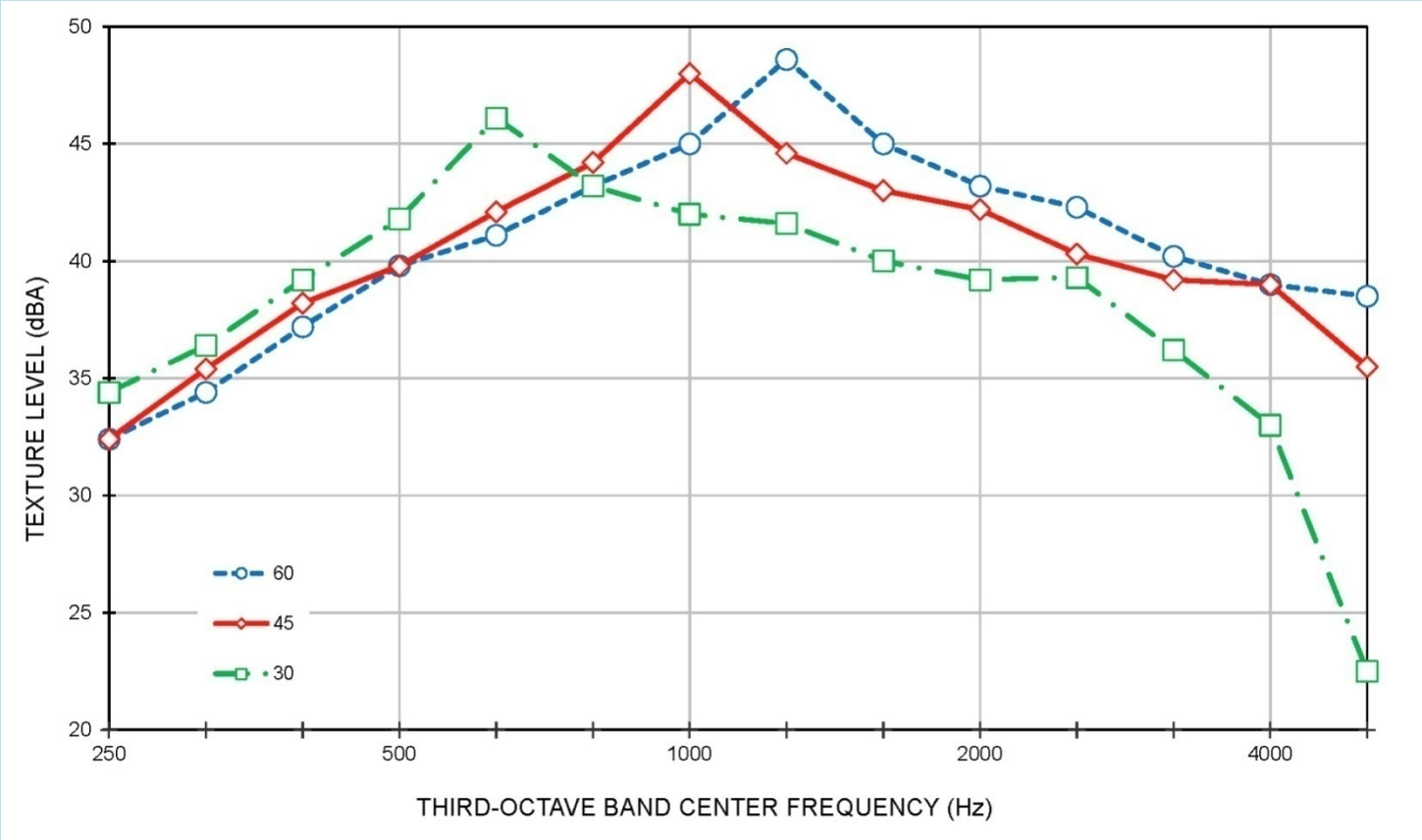
- Simultaneous measurement:
  - OBSI
  - Texture Level, $L_{tx}(\lambda)$
  - Speed
- Test speeds:
  - 30, 45, 60, 70+
  - Swept—coast down
- Range of pavement types

RECOMMENDATIONS

- Data Analysis:
  - A-Weighted Texture Level, $L_{Atx}(f)$
  - Skewness
  - Waterfall presentation
  - OBSI(f) = function($L_{Atx}(f)$,skewness)

SPECTRUM CHANGE with SPEED

due to frequency shift and A-weighting



Hypothetical Spectrum