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ICMPA9 • International Conference on Managing Pavement Assets

Three-Dimensional Surface Texture of Asphalt Pavements Containing Reclaimed Asphalt Pavement (RAP)

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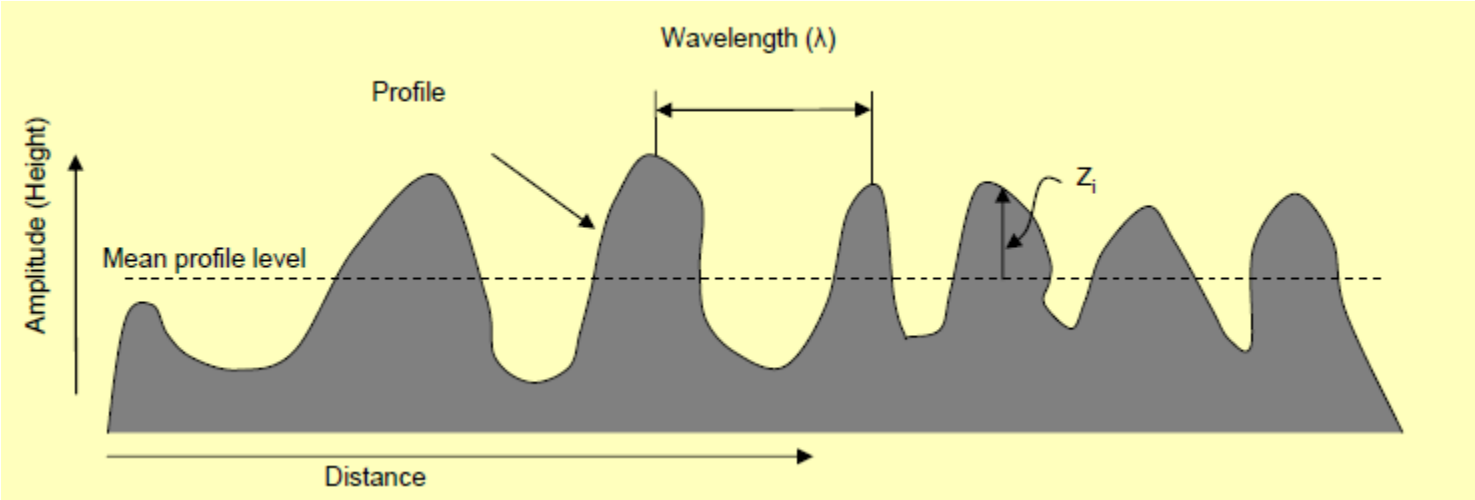
Outline

- Introduction
- Pavement Surface Texture Measurements
- Texture Parameters and Results
- Laboratory Tests on Cored Samples
- Conclusions

INTRODUCTION

Pavement Texture

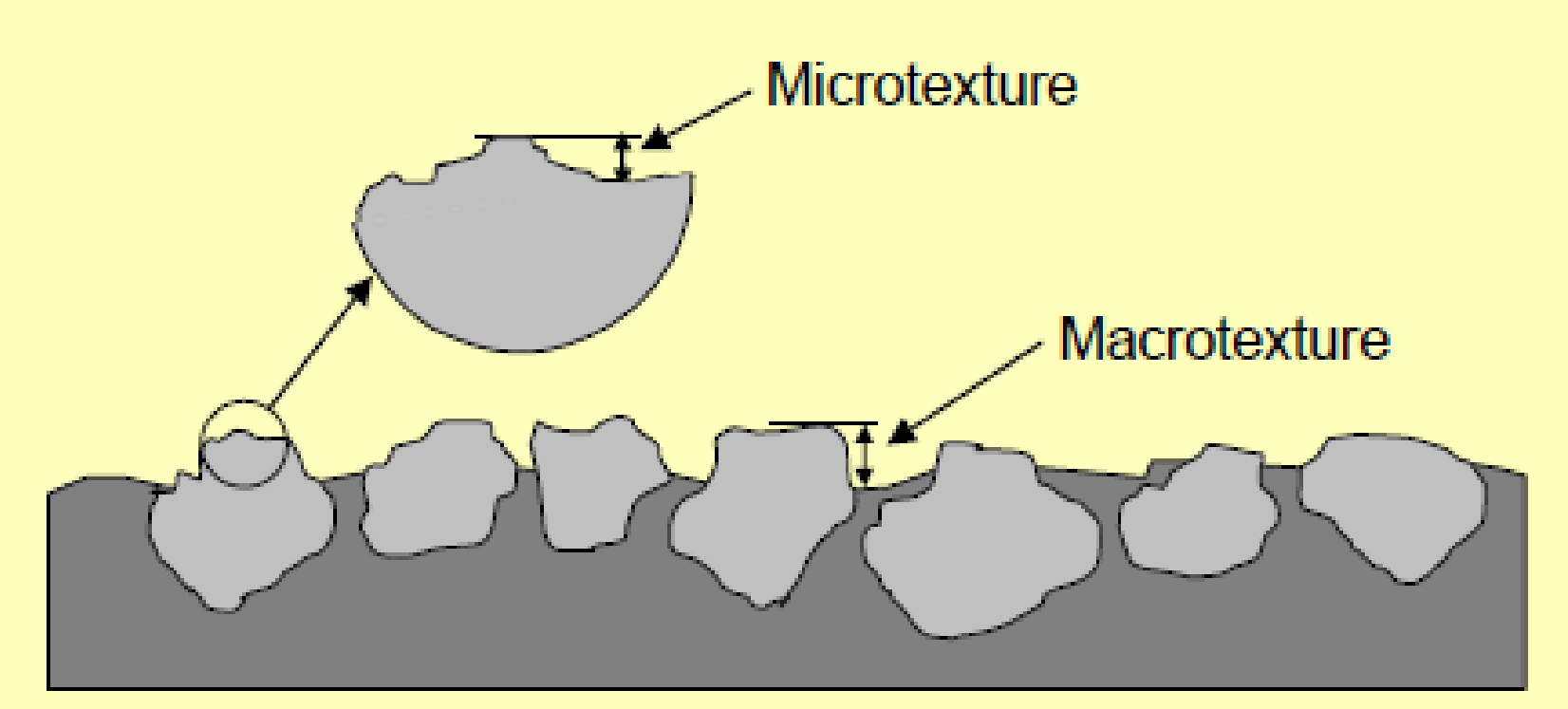
- Pavement texture is defined as “the deviations of the pavement surface from a true planar surface” (Hall et al. 2009).



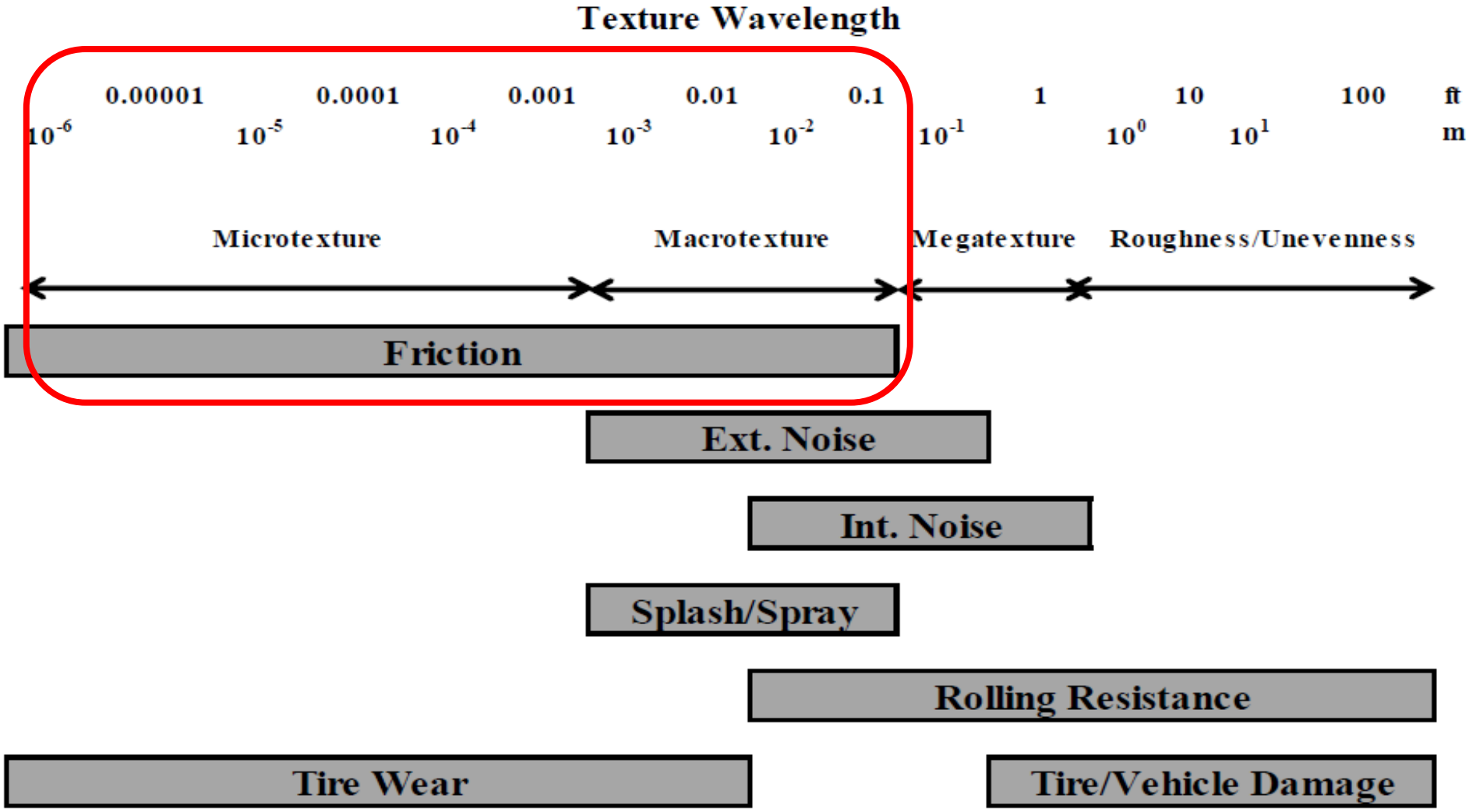
Texture Classification

Texture Classification	Relative Wavelengths, λ	Characteristics
Micro-texture	$\lambda < 0.5$ mm	Fine sand or surface roughness of large aggregate
Macro-texture	$0.5 \text{ mm} \leq \lambda < 50$ mm	Spaces and depths between aggregate particles
Megatexture	$50 \text{ mm} \leq \lambda < 500$ mm	Construction or pavement distress
Unevenness (Roughness)	$0.5 \text{ m} \leq \lambda < 50$ m	Construction or pavement distress

Micro- and Macro-texture



Importance of Texture



Source: Hall, J., Smith, K., Titus-Glover, L., Wambold, J., Yager, T., and Rado, Z. (2009b). Guide for Pavement Friction, National Cooperative Highway Research Program, Web-Only Document 108, Transportation Research Board, Washington, D.C.

Objectives

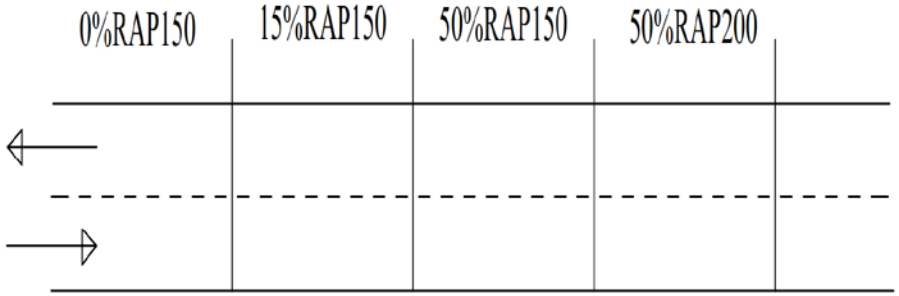
- Assess the impact of high RAP content on pavement surface texture after 5 years in service

- Evaluate the mechanical properties of extracted core samples containing RAP.

Test Site

4 Sections with various RAP content

- AADT = 25,000
- Two-lane rural highway
- 5 years old asphalt pavement in Manitoba, Canada.

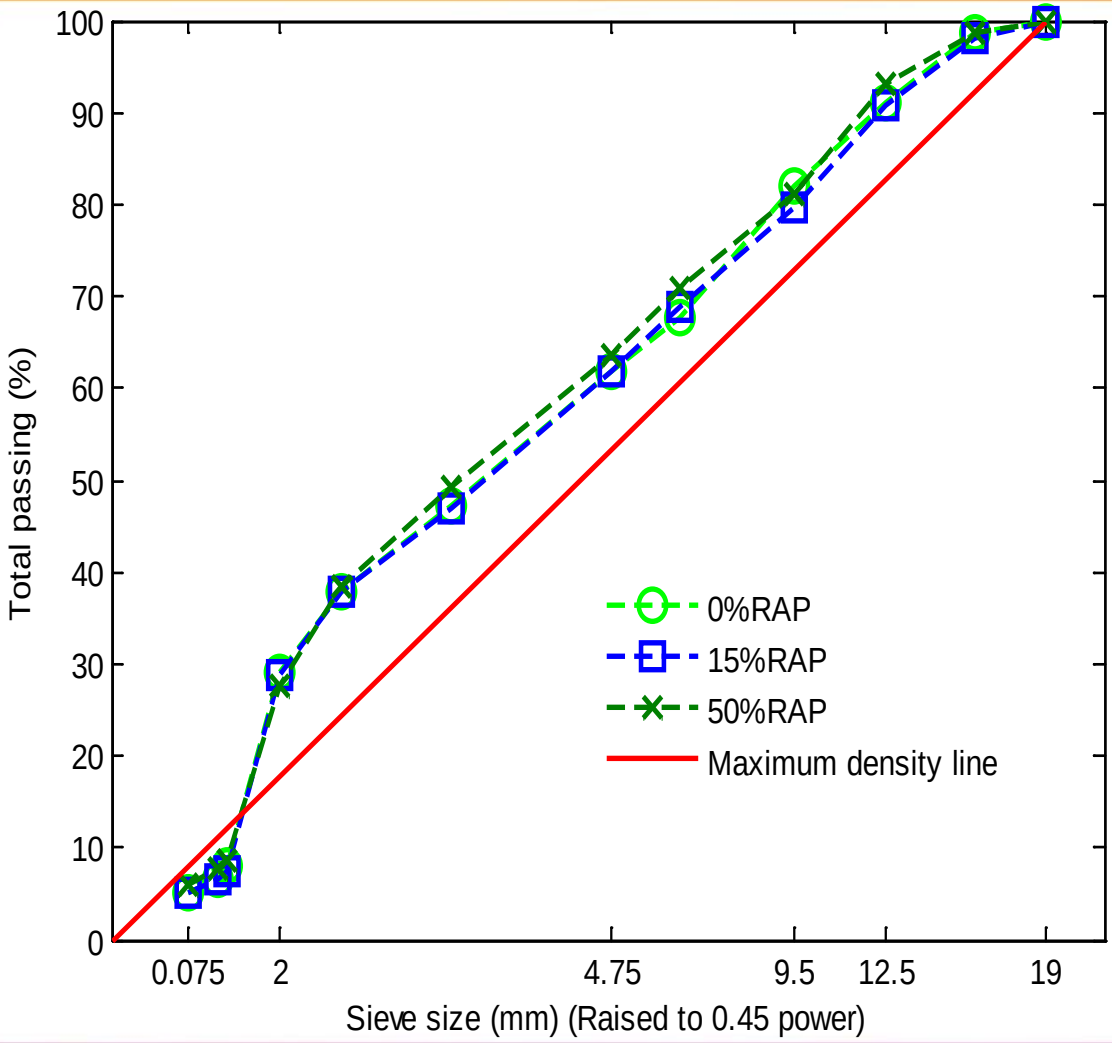


Mix Properties

- Pavement Sections with Various Percentages of RAP and Different Binders

Section	RAP content	Virgin binder used
0%RAP150	0%	Pen 150-200 (PG 58-28)
15%RAP150	15%	Pen 150-200 (PG 58-28)
50%RAP150	50%	Pen 150-200 (PG 58-28)
50%RAP200	50%	Pen 200-300 (PG 52-34)

Aggregate Gradation



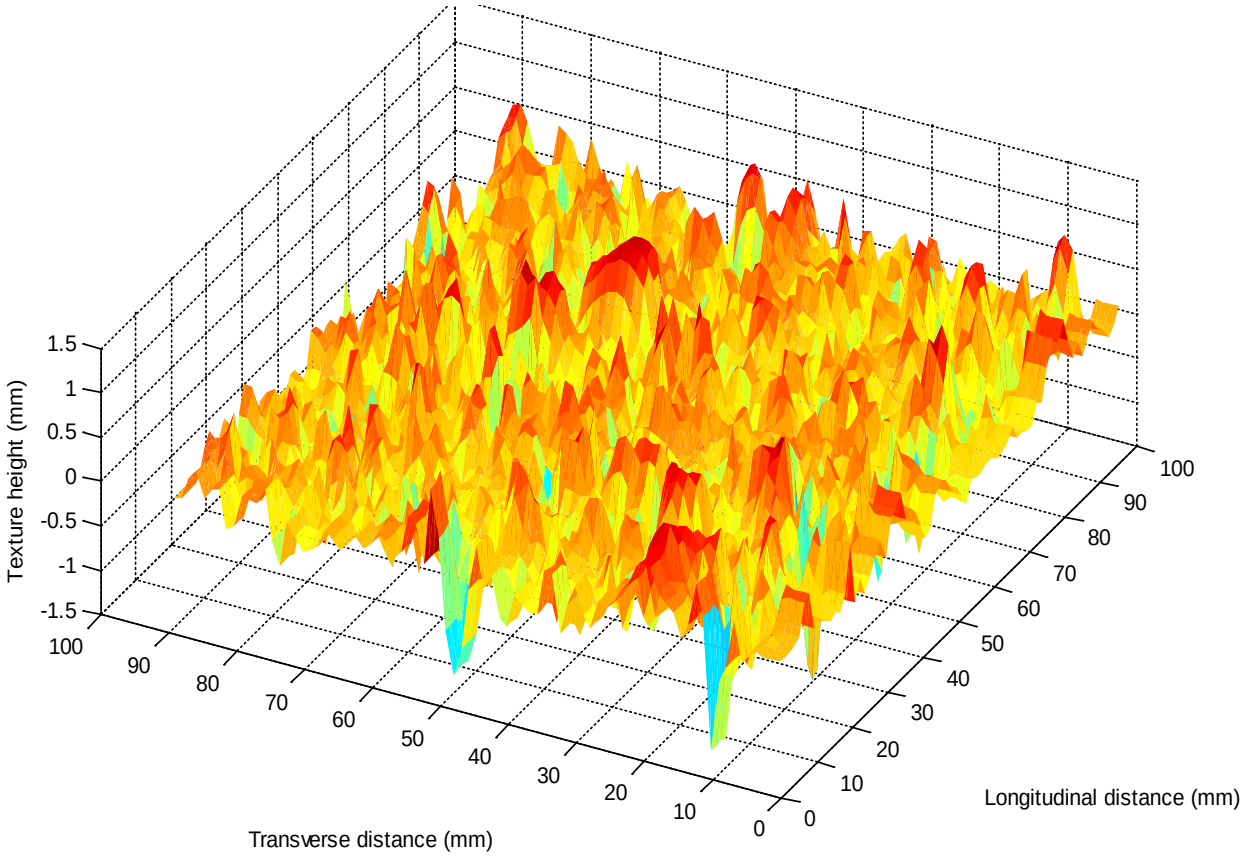
Pavement Surface Texture Measurements

3D Texture Measurement

(Portable Line-laser Scanner)

- Horizontal resolution < 0.05 mm
- Vertical accuracy better than 0.1 mm.
- Area of 100 mm × 100 mm
- 2448 × 2048 data points

Pavement Surface and its Recovered 3D Texture Heights



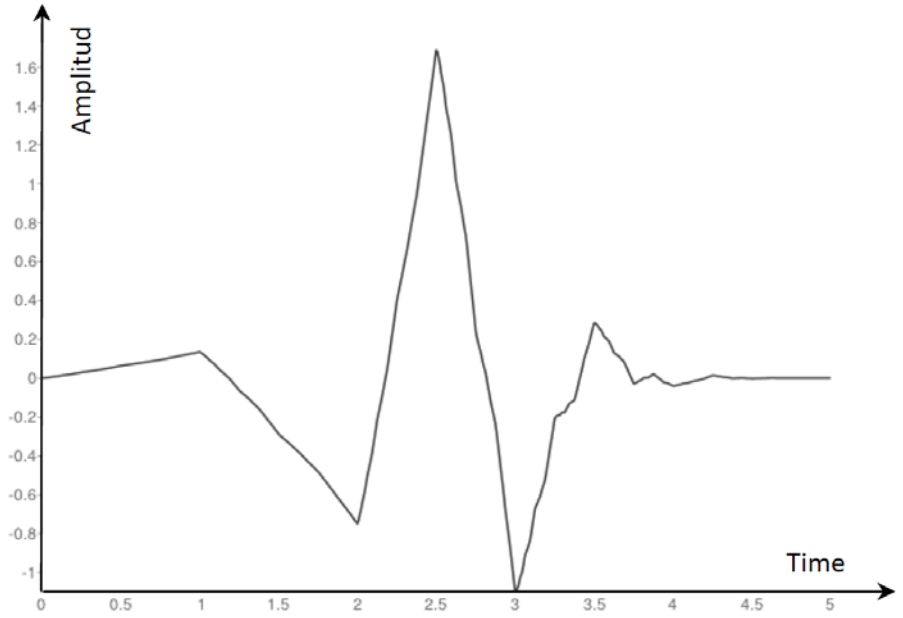
Texture Analysis

Discrete wavelet transform (DWT)

- The measured texture heights were decomposed into five levels by using DWT to define its micro-texture and macro-texture.

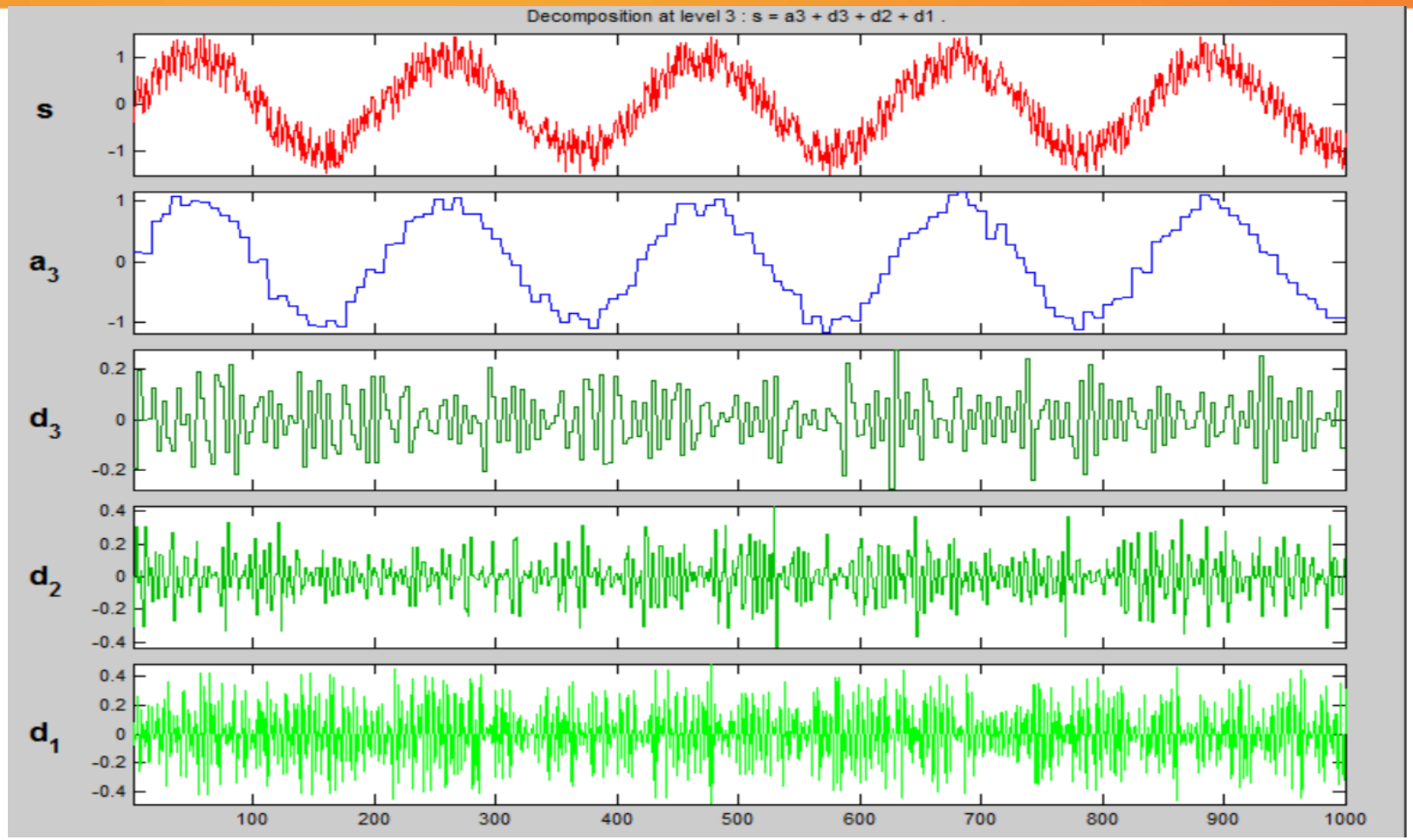
Duabechies:

Db3-wavelet function



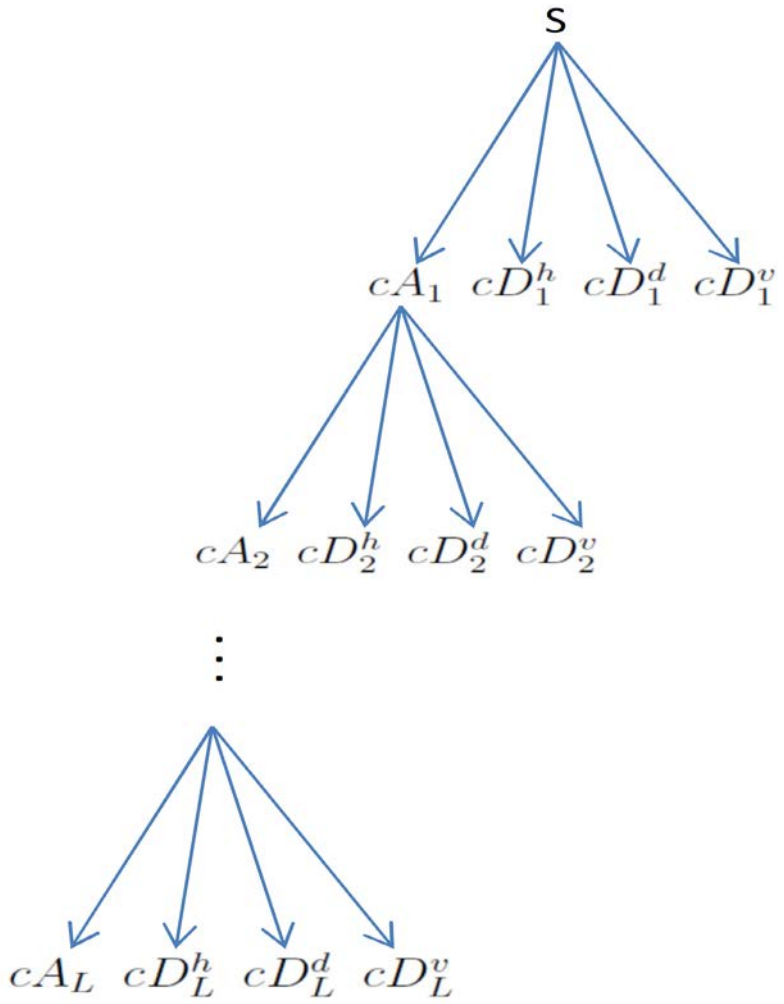
Texture Analysis

Decomposition Levels



$$S = a_3 + d_3 + d_2 + d_1$$

Decomposition Structure



Where

cA_j = approximation coefficients,
cD_j^h = horizontal detail coefficients,
cD_j^d = diagonal detail coefficients,
cD_j^v = vertical detail coefficients,
j = decomposition level, $j = 1...L$,
L = maximum decomposition level.

Texture Analysis

Decomposition levels and their wavelength

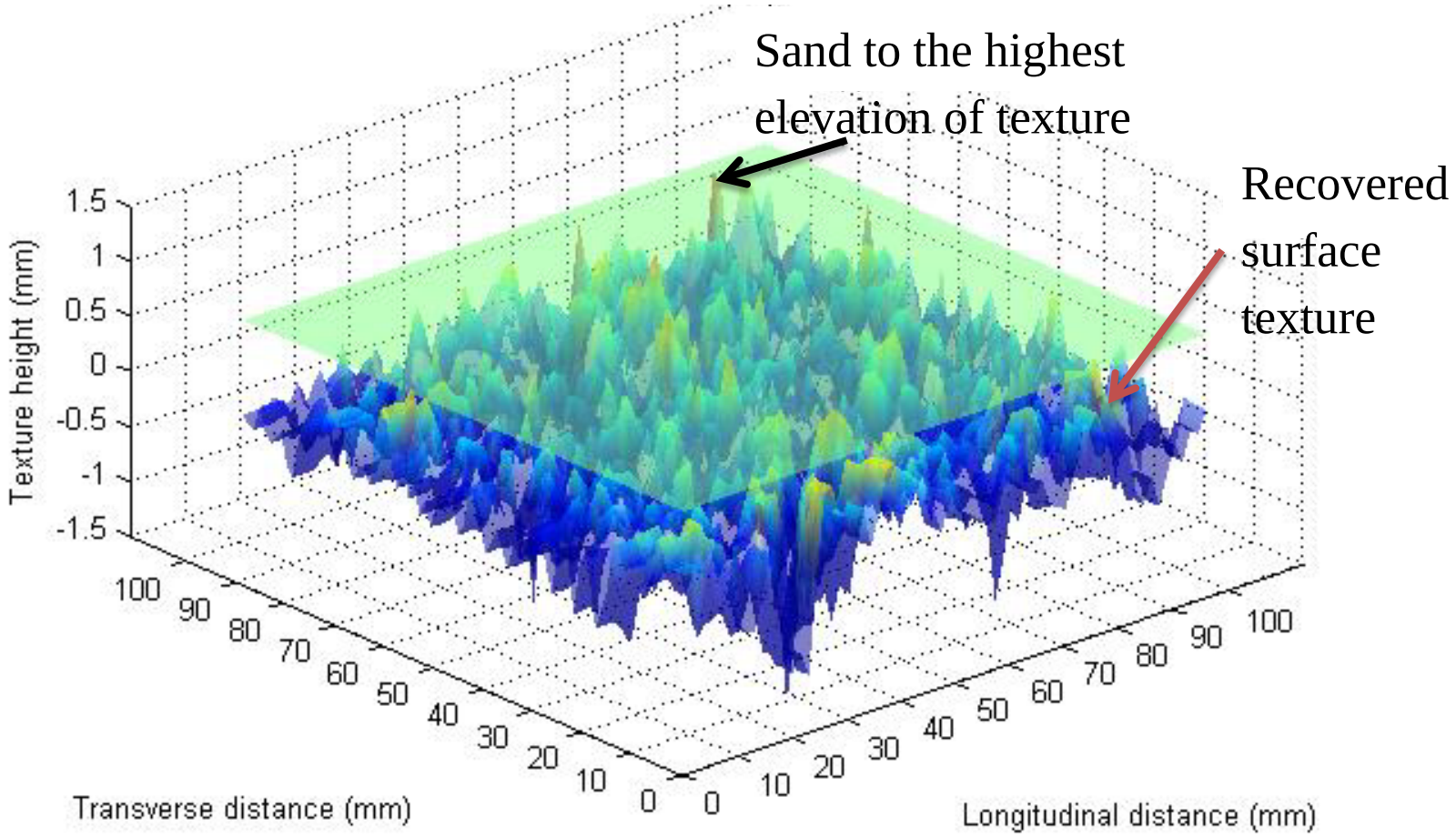
Decomposition levels	Level 1	Level 2	Level 3	Level 4	Level 5
Equivalent wavelength, λ (mm)	< 0.06	0.12	0.24	0.49	> 0.98
Texture classification	Micro-Texture				Macro-Texture

Texture Paramters and Results

3D Texture Paramateres

Texture parameter	Calculation formula	Category
Simulated mean texture depth (SMTD, mm)	$SMTD = h_{max} - \frac{1}{A}\sum_{i=1}^{M}\sum_{k=1}^{N}\frac{1}{3}a\,h_{ik}$	Macro-texture
Root mean square roughness (S_q, mm)	$S_q = \sqrt{\frac{1}{A}\sum_{i=1}^{M}\sum_{k=1}^{N}a\,h_{ik}^2}$	Macro-texture
Skewness (S_{sk}, unitless)	$S_{sk} = \frac{1}{AS_q^3}\sum_{i=1}^{M}\sum_{k=1}^{N}a\,h_{ik}^3$	Macro-texture
Kurtosis (S_{ku}, unitless)	$S_{ku} = \frac{1}{AS_q^4}\sum_{i=1}^{M}\sum_{k=1}^{N}a\,h_{ik}^4$	Macro-texture
Normalized power spectra energy (NPSE, mm^2/mm^2)	$NPSE = \sum_{j=1}^{L}NE_j$ $NE_j = \frac{1}{A}\sum_{i=1}^{M_j}\sum_{k=1}^{N_j}\left\{\frac{cD^d{}_j}{2^j}\right\}_{ik}^2$	Micro-texture

Simulated mean texture depth (SMTD, mm)



Sand Patch Method (SPM)

SPM→ mean texture depth (*MTD)* of pavement surface macro-texture.

$$MTD = \frac{4V}{\pi D^2}$$

where:

MTD = Mean texture depth, mm

V = Sample volume, mm³

D = Average material diameter, mm

Pavement Texture Results

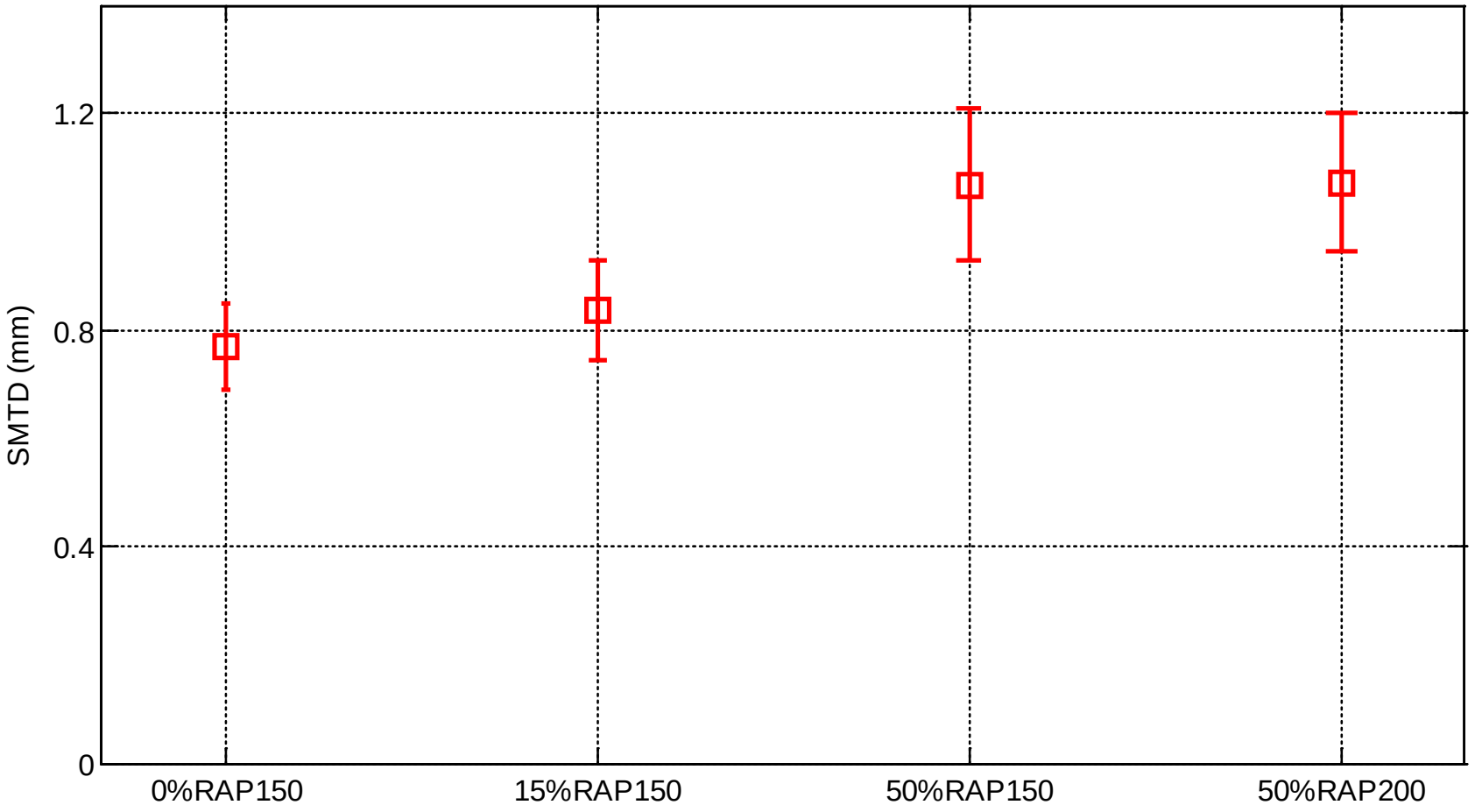
Section	SMTD (mm)	S_q (mm)	S_{sk}	S_{ku}	NPSE (mm^2/mm^2)
0%RAP150	0.77	0.22	-0.01	4.57	0.0615
15%RAP150	0.84	0.24	-0.01	4.74	0.0635
50%RAP150	1.07	0.30	-0.21	4.93	0.0666
50%RAP200	1.07	0.29	-0.18	5.14	0.0645

Factors Affecting Pavement Texture

- Maximum aggregate size
- Coarse and fine aggregate types
- Aggregate gradation,
- Mix air voids

SMTD (Macro-Texture)

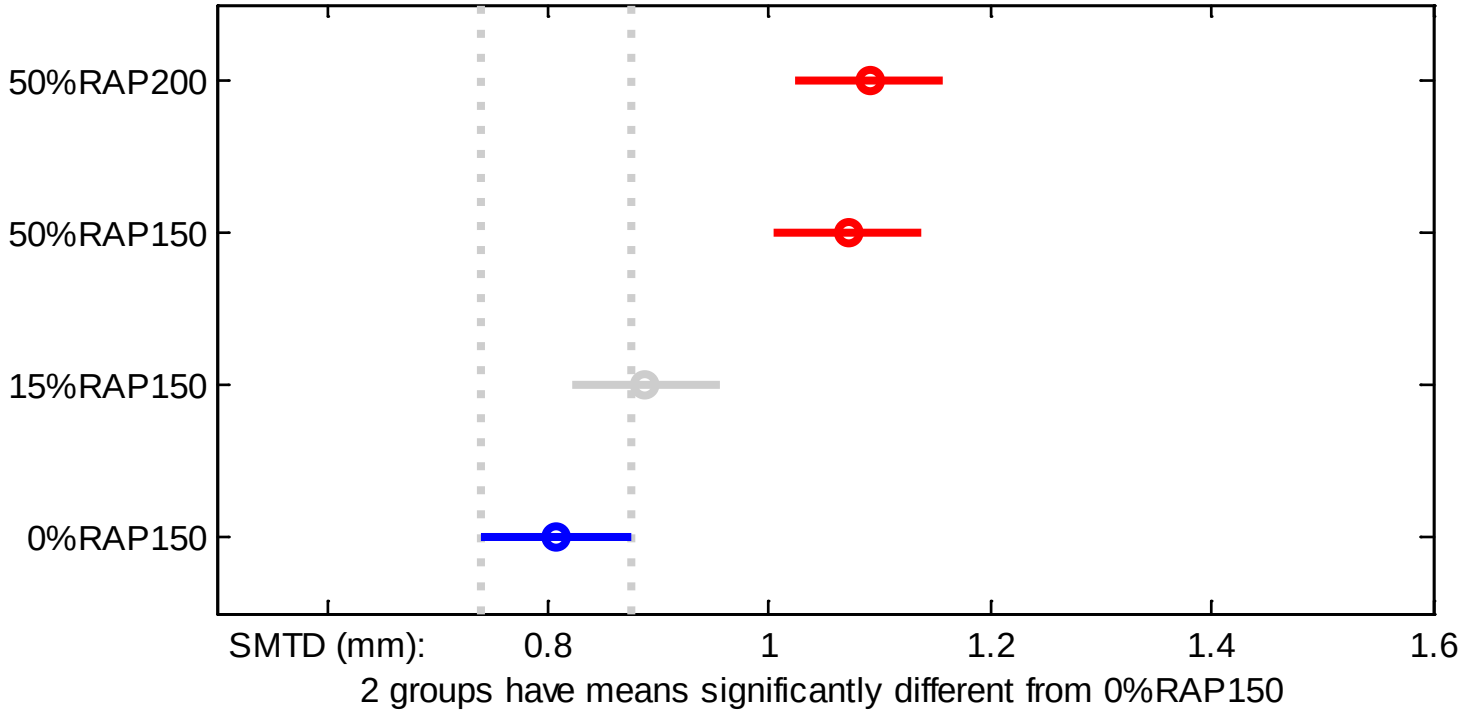
Mean and error bar



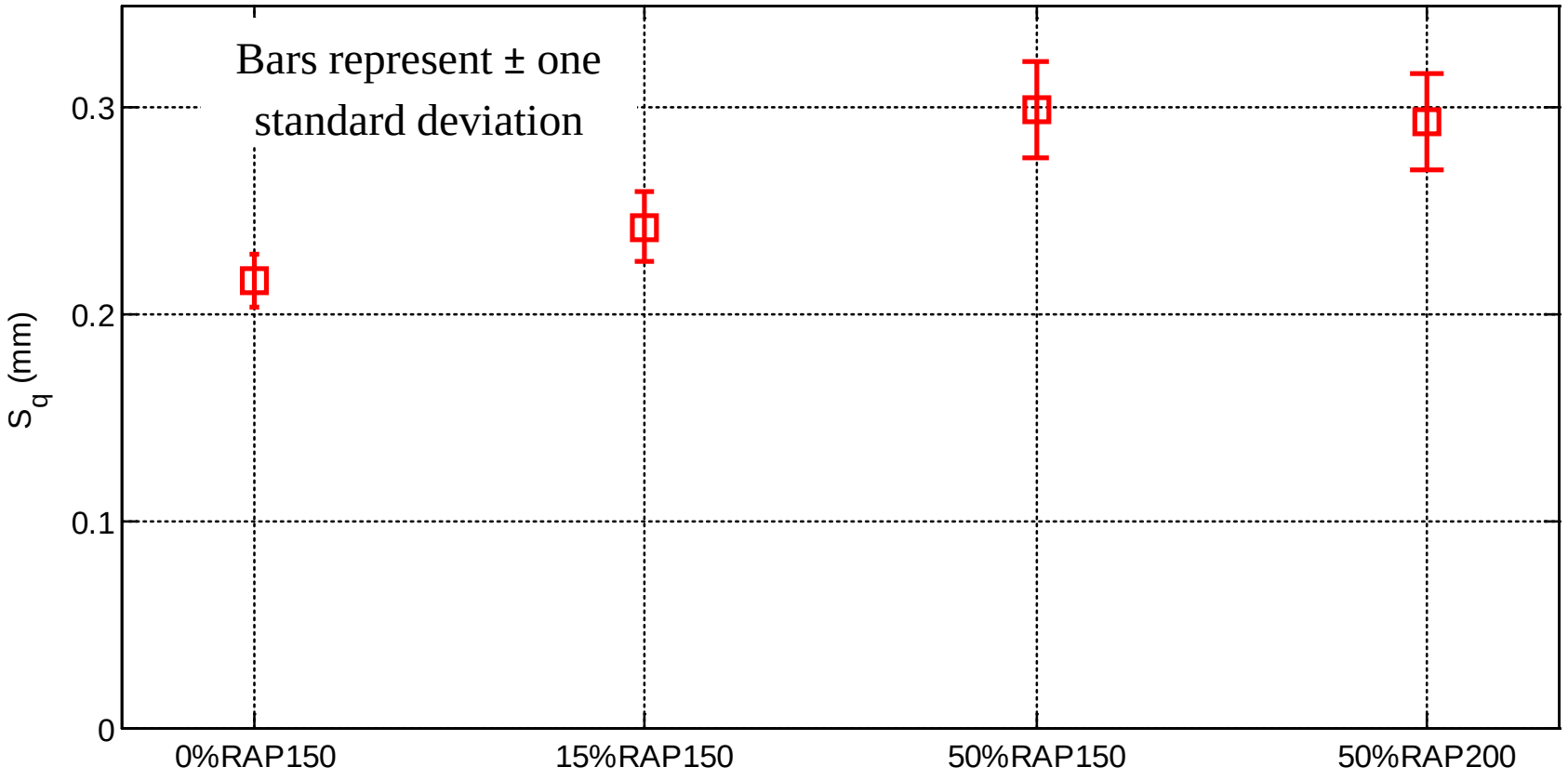
SMTD (Macro-Texture)

Multiple comparison at 95% confidence level

- Sections containing 50% RAP showed higher SMTD.
- Binder grade did not significantly influence texture height.

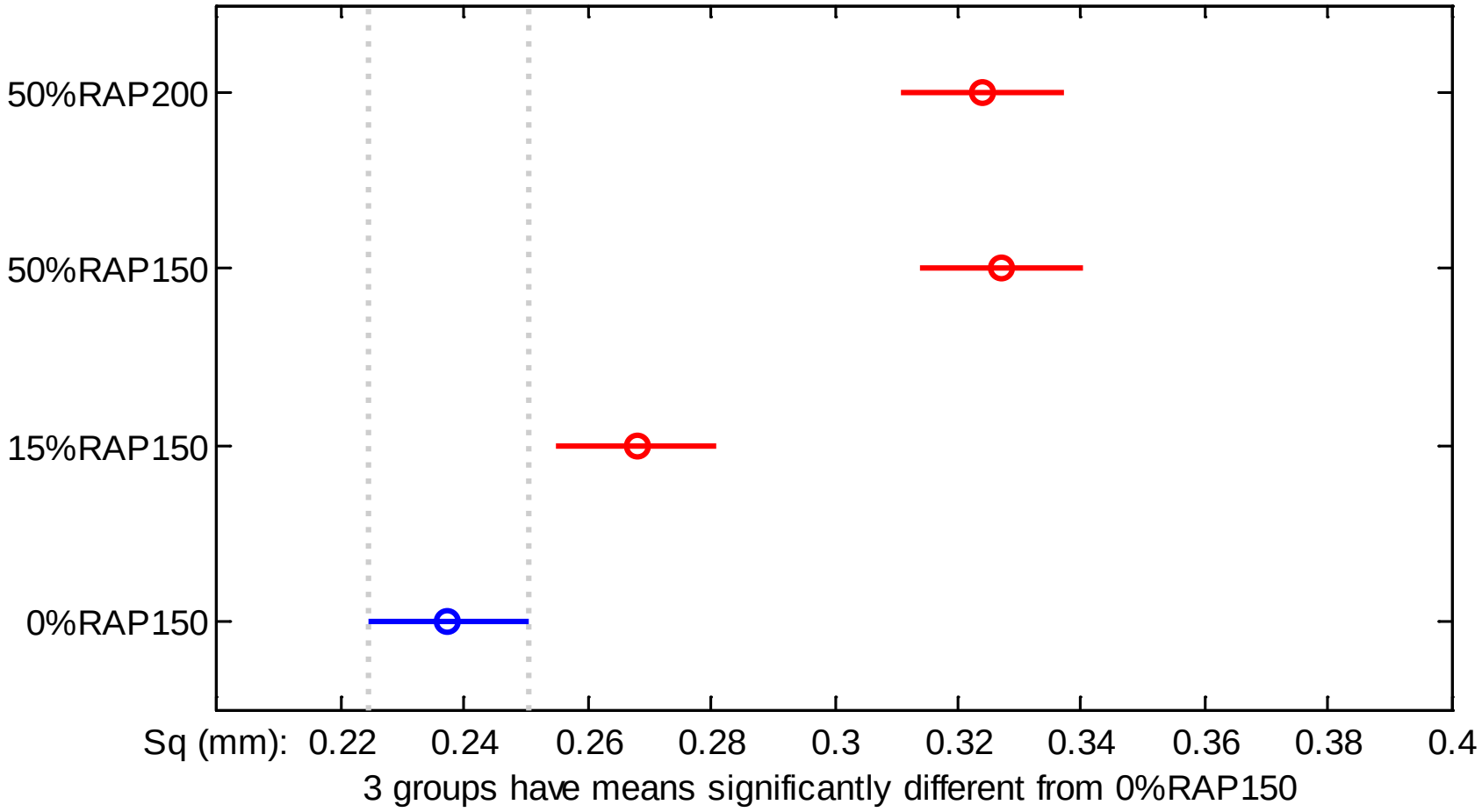


S_q (Macro-Texture)

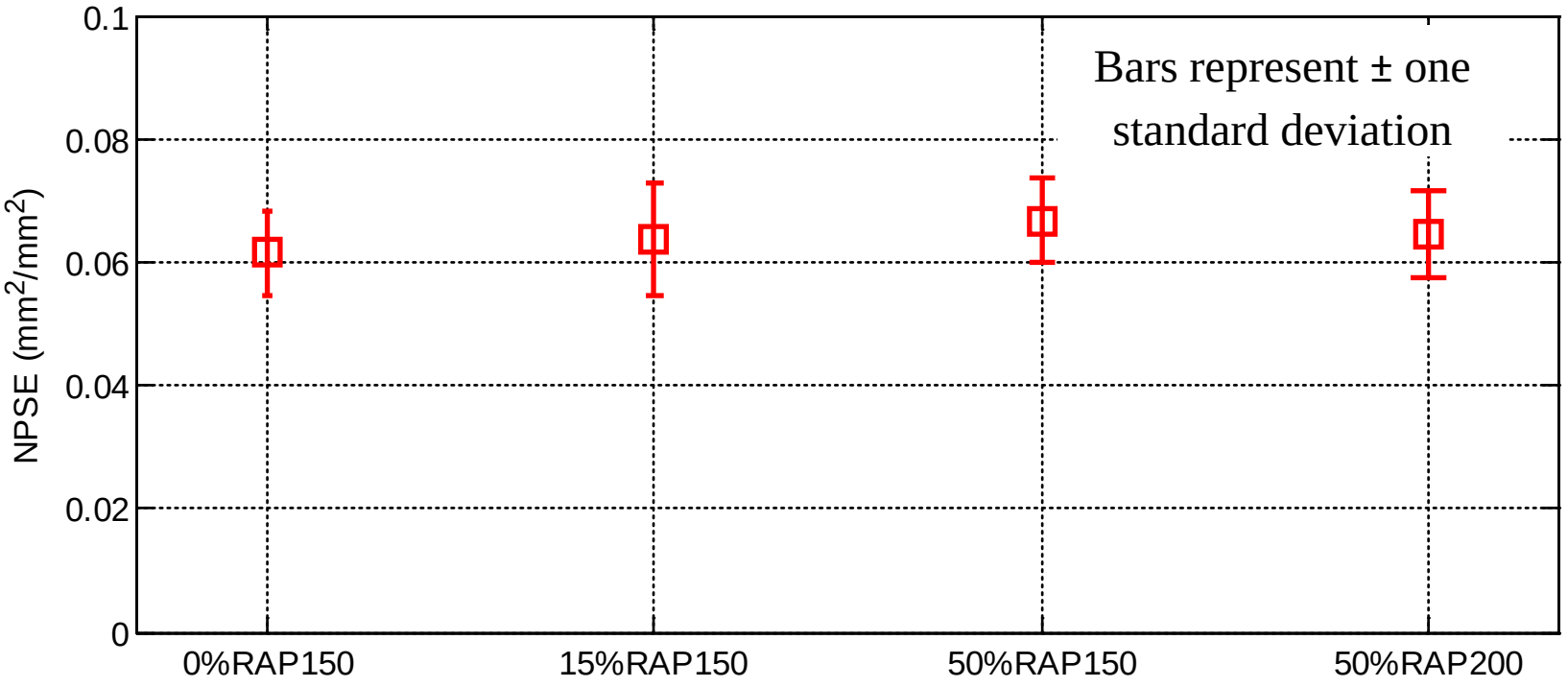


S_q (Macro-Texture)

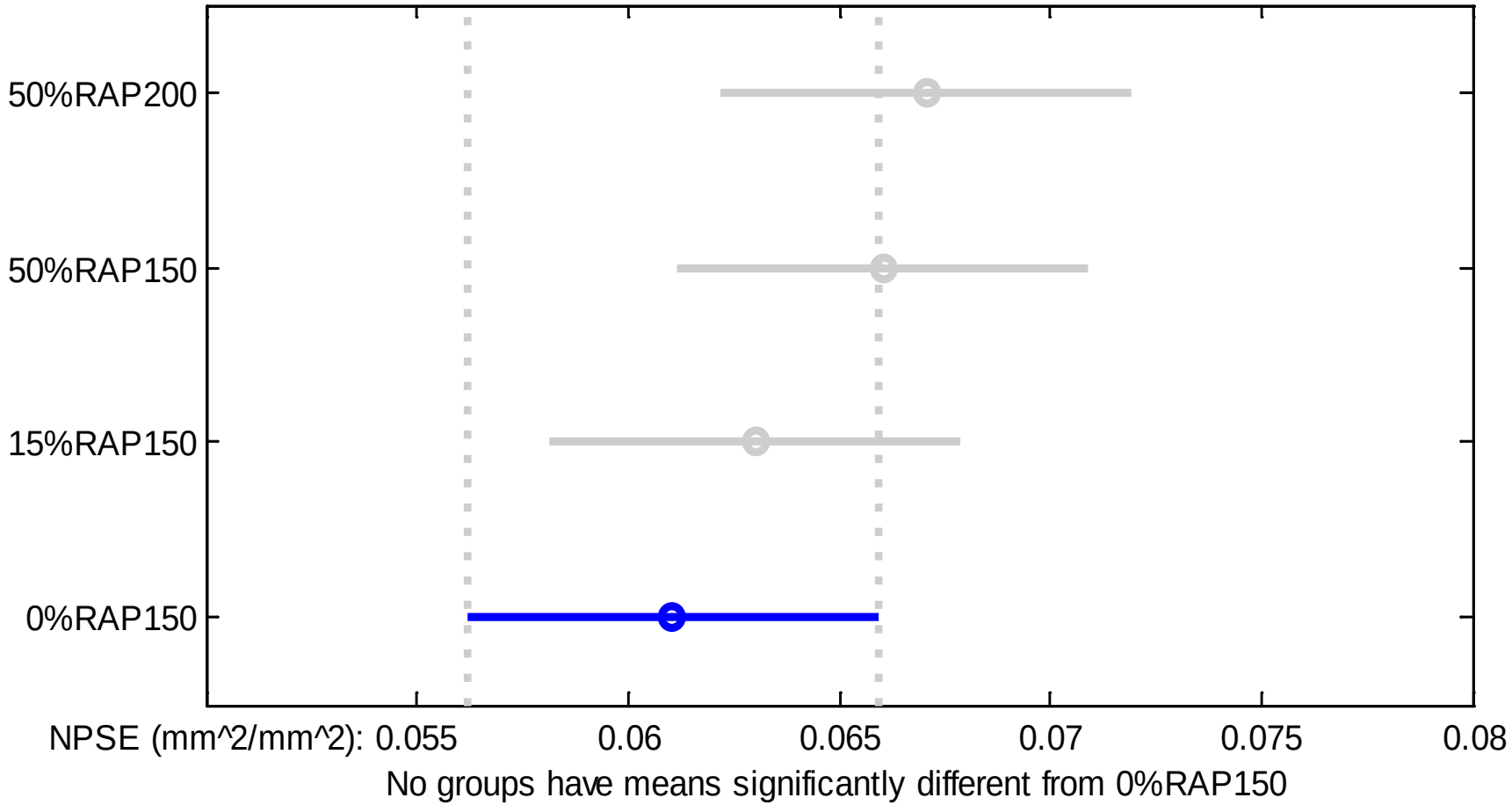
Multiple comparison at 95% confidence level



Normalized Power Spectra Energy (Micro-Texture)

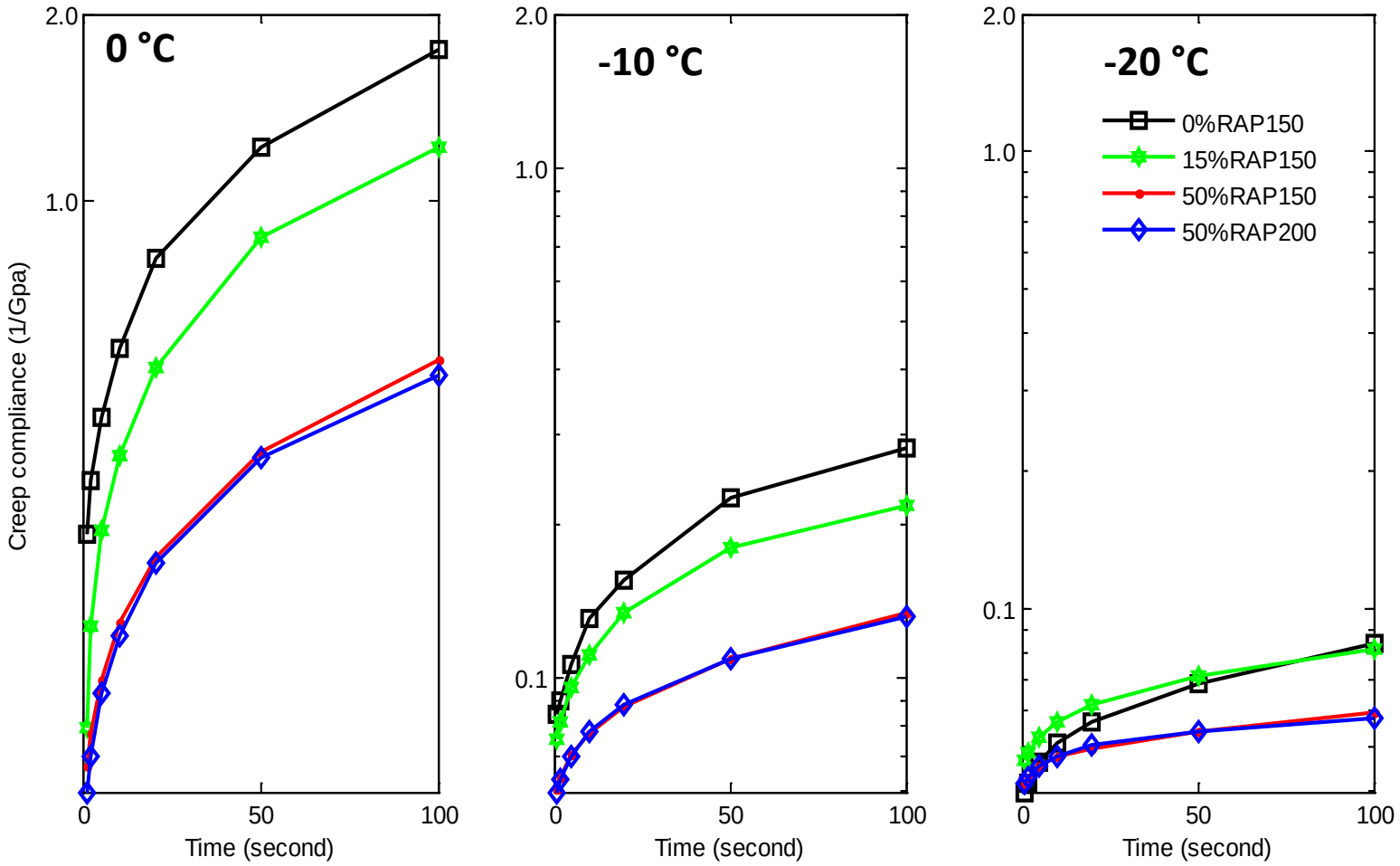


Normalized Power Spectra Energy (Micro-Texture)

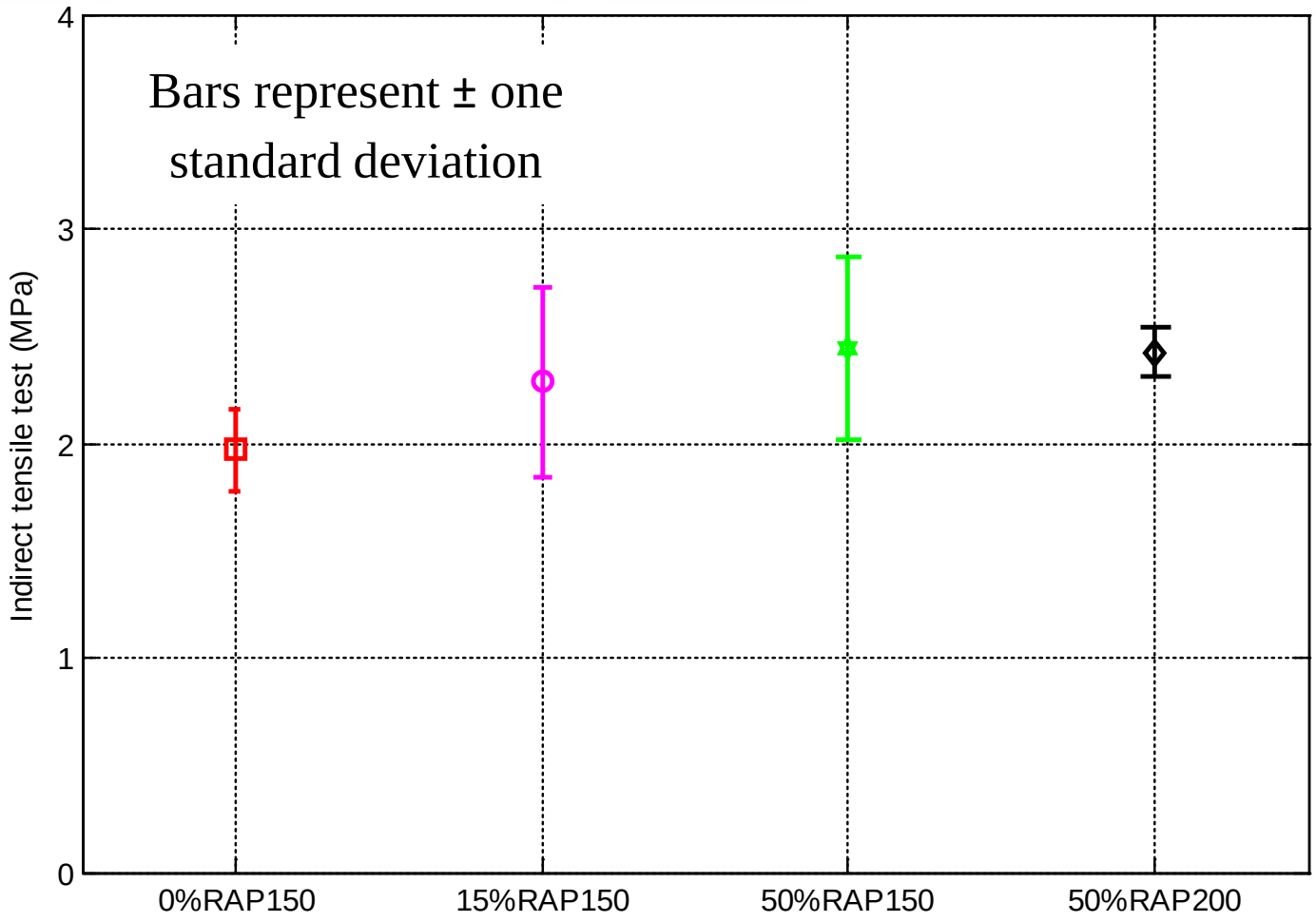


LABORATORY TEST ON CORED SAMPLES

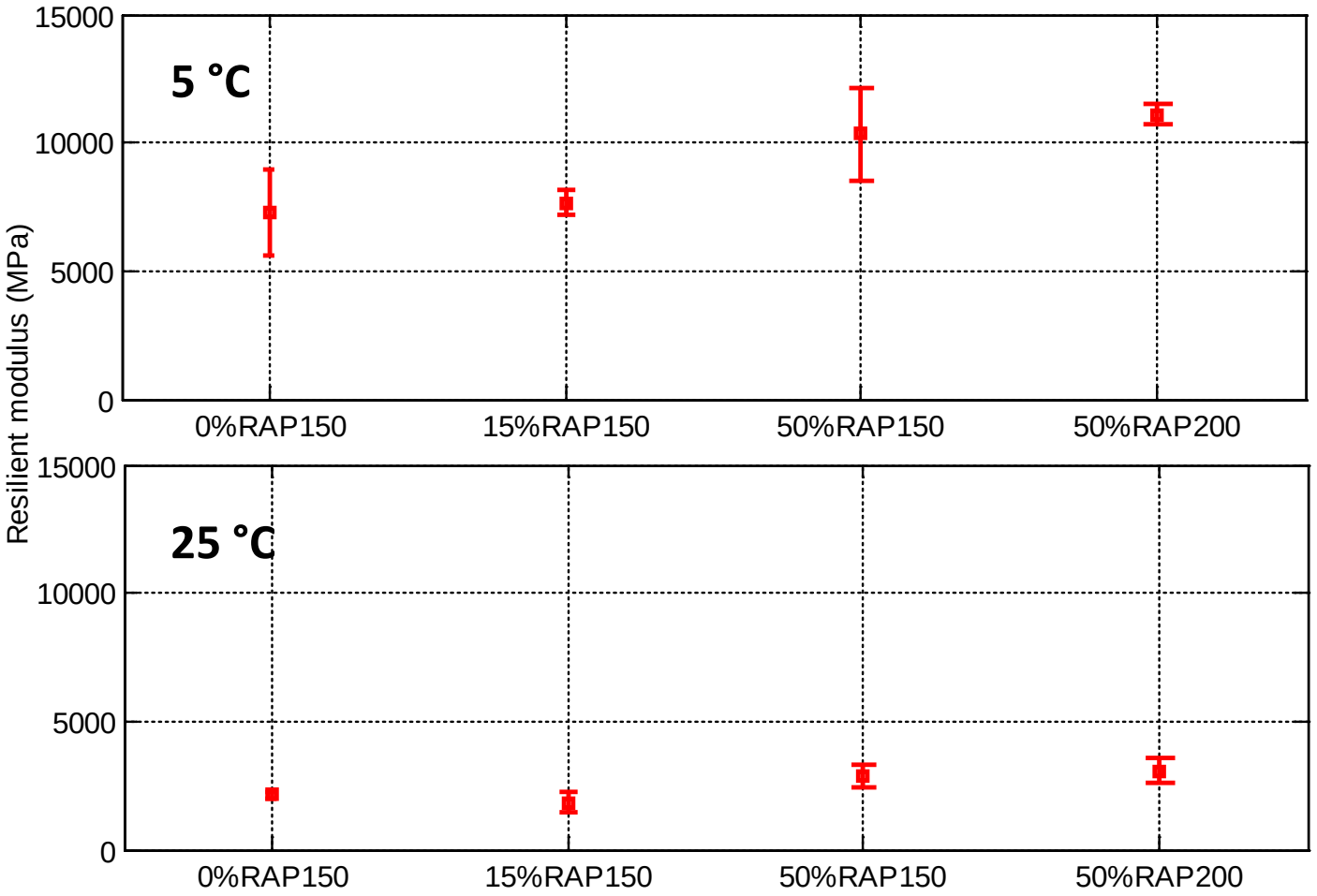
Creep Compliance Test Results



Indirect Tensile Test (MPa) at -10 ° C



Resilient Modulus (MPa)



Conclusions

- After 5 years of service, pavement sections with high RAP content (50%) showed better macro-texture compared to the lower RAP content (0%, 15%) sections.

- RAP did not have negative impacts on micro-texture of the pavement surface.

Conclusions (Cont'd)

- Softer binder did not have significant impact on either macro-texture or micro-texture.

- High RAP mixtures showed improvement in resilient modulus but less thermal cracking resisitance at low temperature.

Thanks for your attention.