Pavemetrics

Vision Technology for Inspection of Transportation Infrastructures

PAVEMETRICS Systems Inc.

150 Boulevard René-Lévesque Est, Suite 1820
Québec, Québec, CANADA
G1R 5B1

www.pavemetrics.com

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There are lies,

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Damned lies...

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... and specifications !

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Pavemetrics product line

LRMS
- Pavement Rutting

LCMS
- 3D Pavement Imaging
- Pavement Rutting
- Macro-Texture
- Pavement Cracking
- Pavement Roughness
- Road/Airport/Tunnel/Rail Inspection

LRIS
- Pavement Imaging

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200+ systems in 30+ Countries

SNC·LAVALIN

FUGRO

Abu Dhabi International Airport مطار أبوظبي الدولي

Georgia Tech

SINECO

Manitoba

Ontario MINISTRY OF TRANSPORTATION

NYC.gov always open

RAMBOLL

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

TRL Creating the future of transport

Stantec

Transports Québec

LCPC Laboratoire Central des Ponts et Chaussées

EUROCONSULT NUEVAS TECNOLOGÍAS

arrb GROUP

MANDLI COMMUNICATIONS INC

KICT 한국건설기술연구원 KOREA INSTITUTE of CONSTRUCTION TECHNOLOGY

Dynatest

THE UNIVERSITY OF ALABAMA

INTERNATIONAL CYBERNETICS
Where technology meets the road

COLAS

VirginiaTech 1872 *Invent the Future*

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LCMS – Certified Technology

Is NOT a prototype

It is a well used and certified system.

NEMA

TÜV SÜD ISO 9001

INTERNATIONAL CERTIFICATIONS ISO 9001

DEPARTMENT OF HEALTH & HUMAN SERVICES • USA FDA

FC CE

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LCMS Users 50+ systems

USA

- California - Caltrans
- Utah DOT
- Kentucky DOT
- Kansas DOT
- Tennessee DOT
- Nevada DOT
- Rhode Island DOT
- Illinois DOT
- Georgia Tech University
- Virginia Tech
- US Army Test Tracks
- University Mass. Lowell
- PennDOT
- City of Phoenix, AZ
- South Dakota DOT

Canada

- MTO – Ontario (Ministry of Transportation)
- MTQ – Quebec (Ministry of Transportation)
- Nova Scotia DOT
- SNC Lavalin - Qualitas
- Dessau - LVM Technisol
- TetraTech – EBA

Denmark, Belgium, Italy, Netherlands, Spain, Ireland, China, Japan, Qatar, India, New Zealand, Australia Sudan, Chile

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Integrators – North America

Dynatest (www.dynatest.com)
Enterinfo (www.enterinfo.com)
Fugro-Roadware (www.roadware.com)
ICC – (www.intlcybernetics.com)
Mandli – (www.mandli.com)

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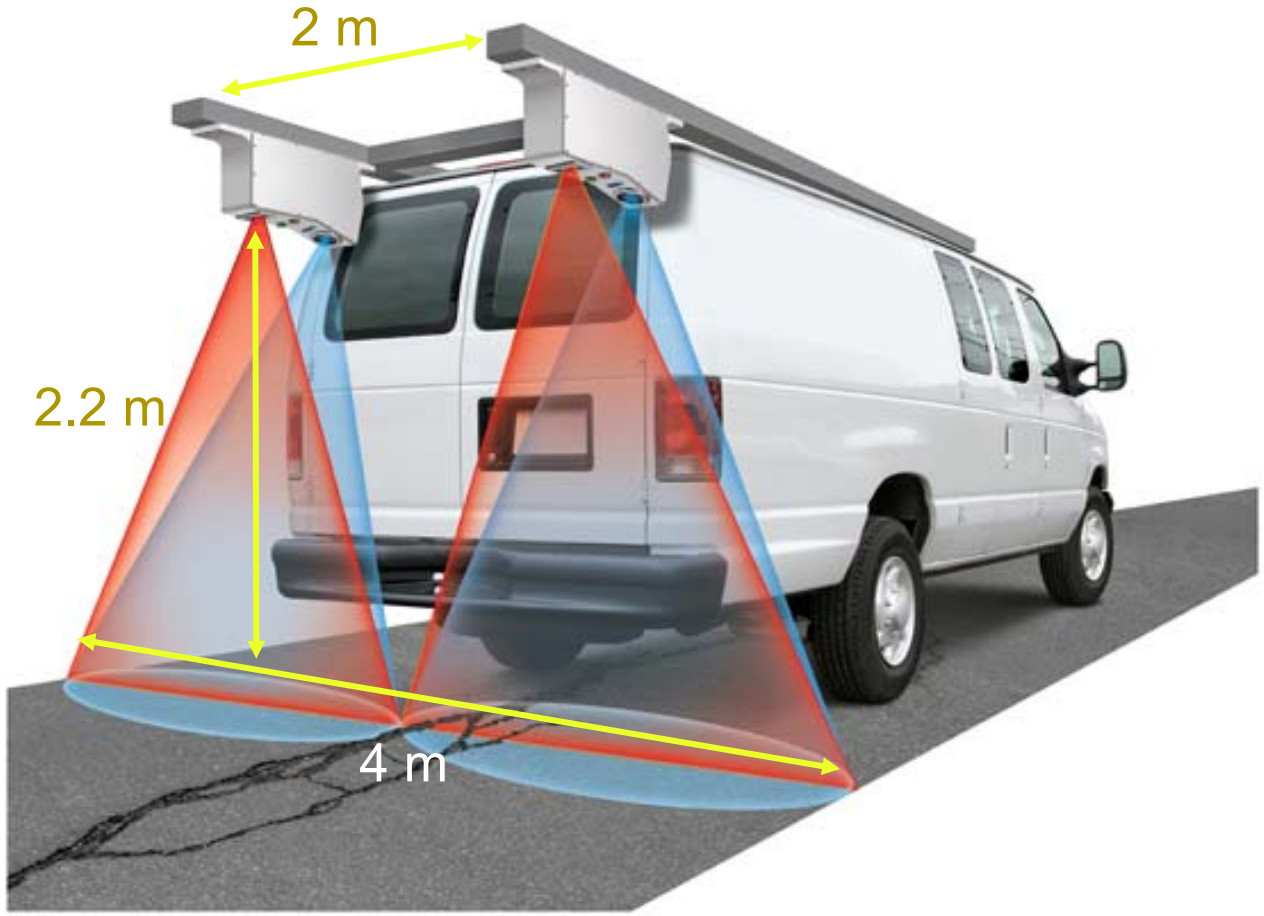
LCMS - System configuration



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Laser profiling (principle)

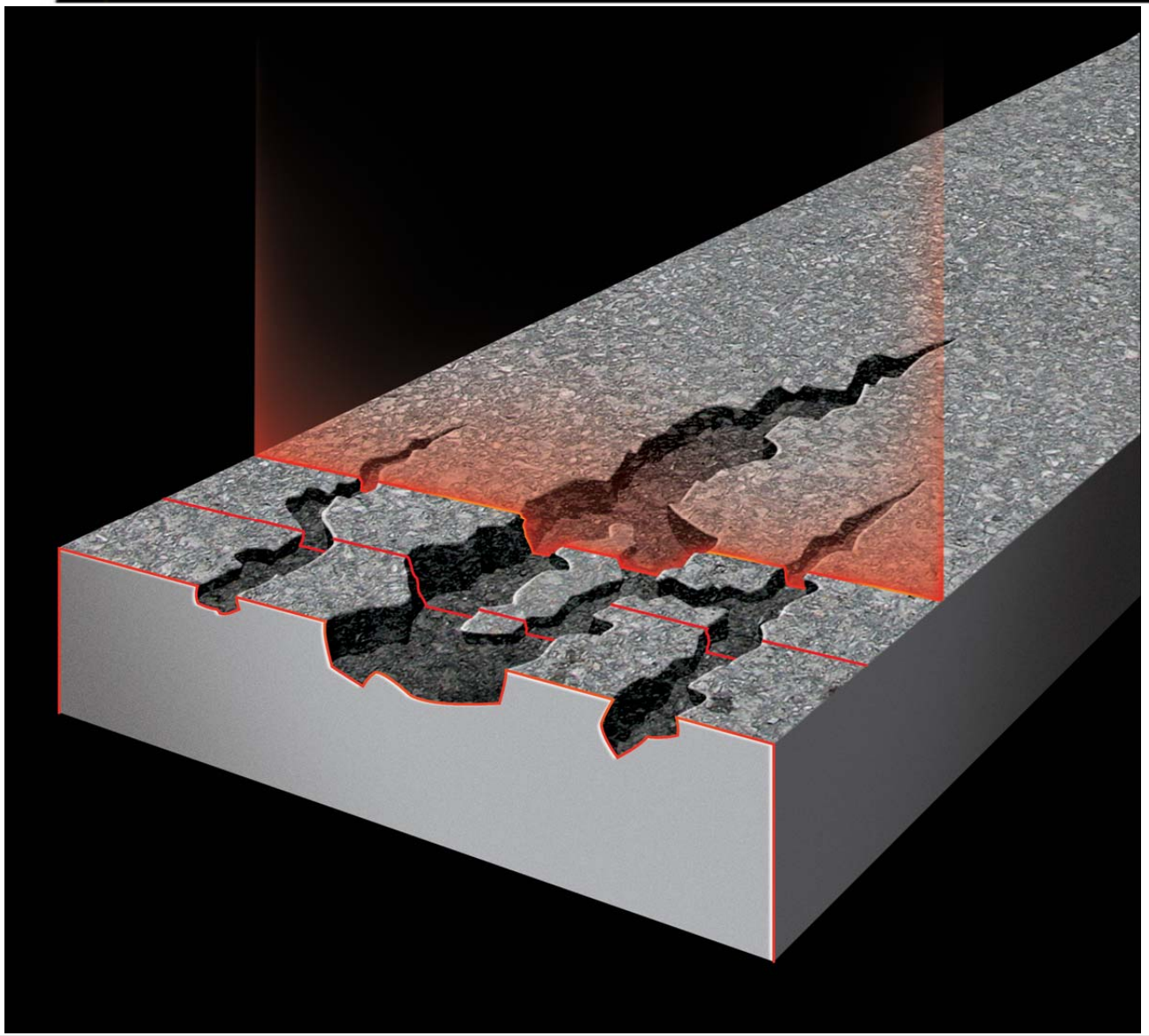

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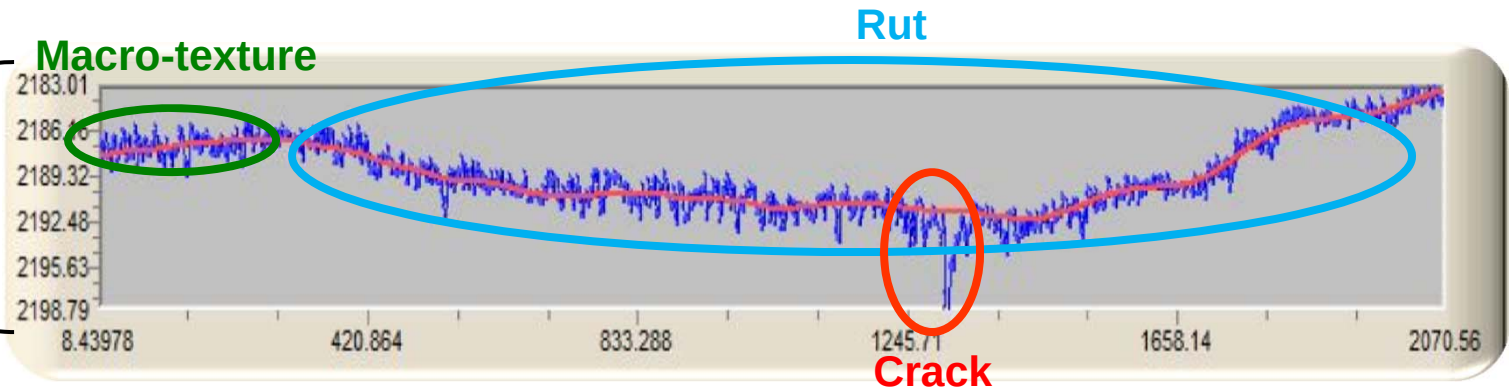
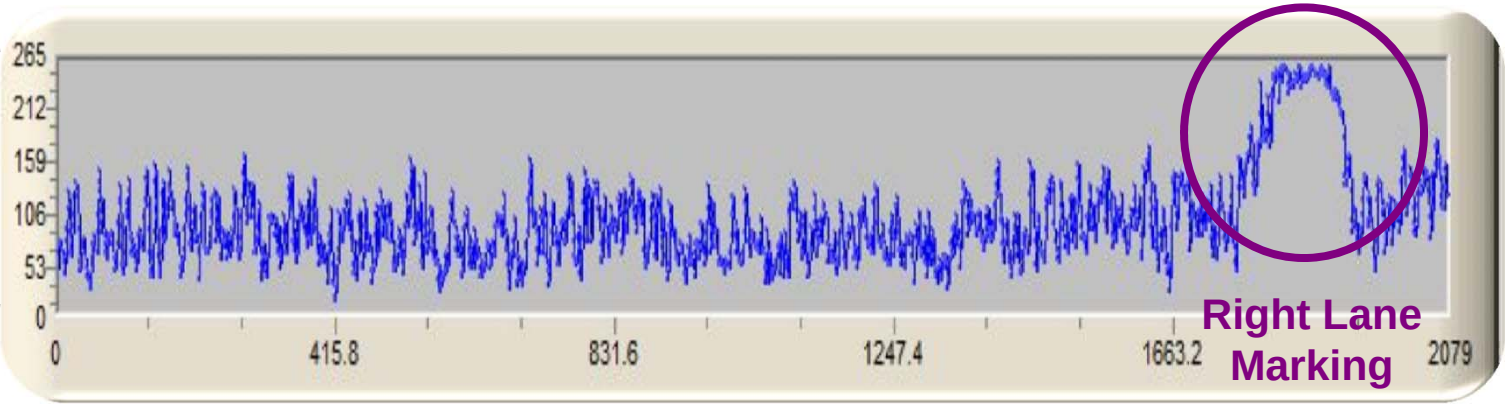
Image and Data Analysis

RANGE
Distance between Sensor and ground (in mm)



INTENSITY
Laser intensity (black = 0, white = 255)



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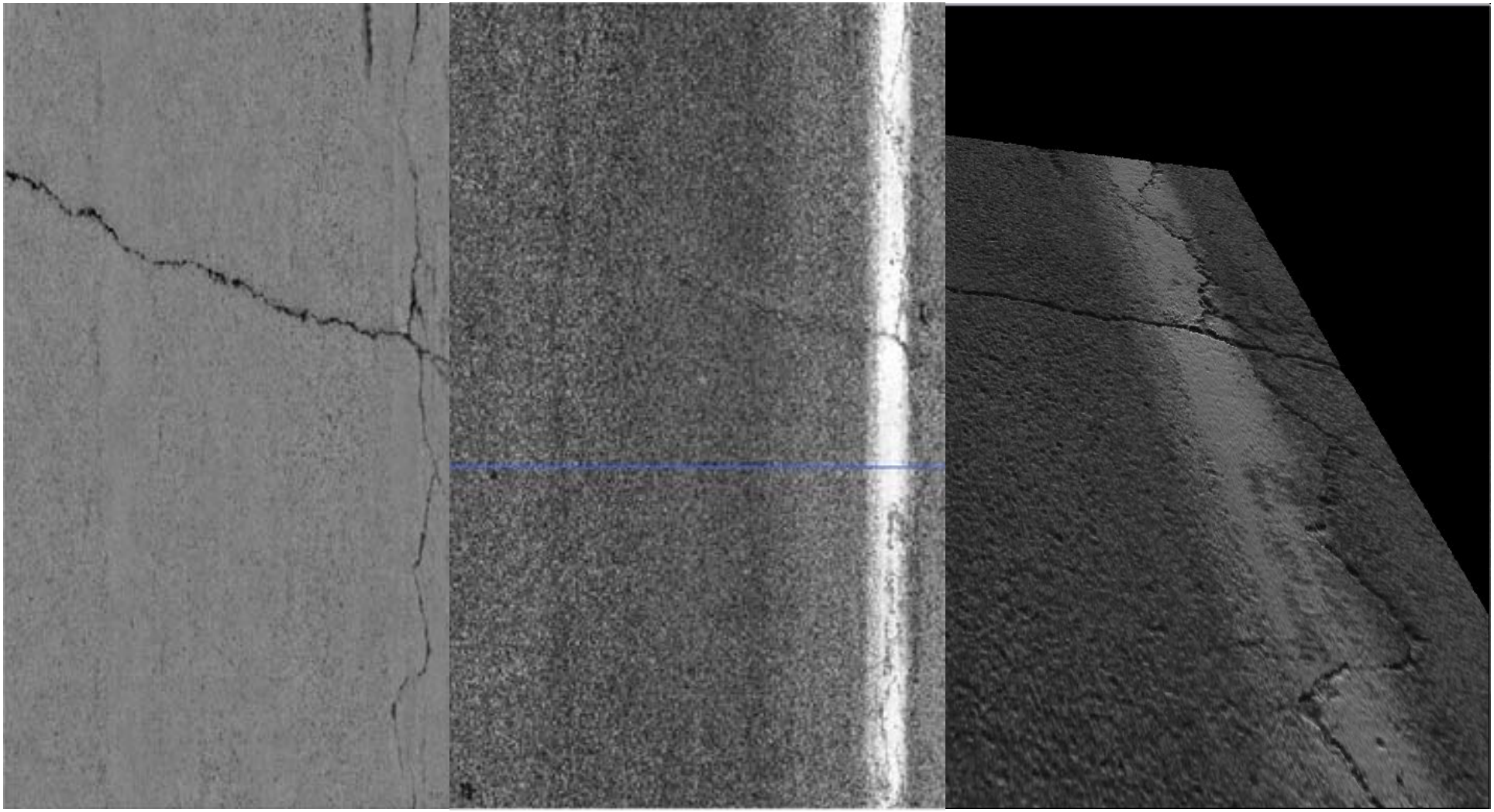
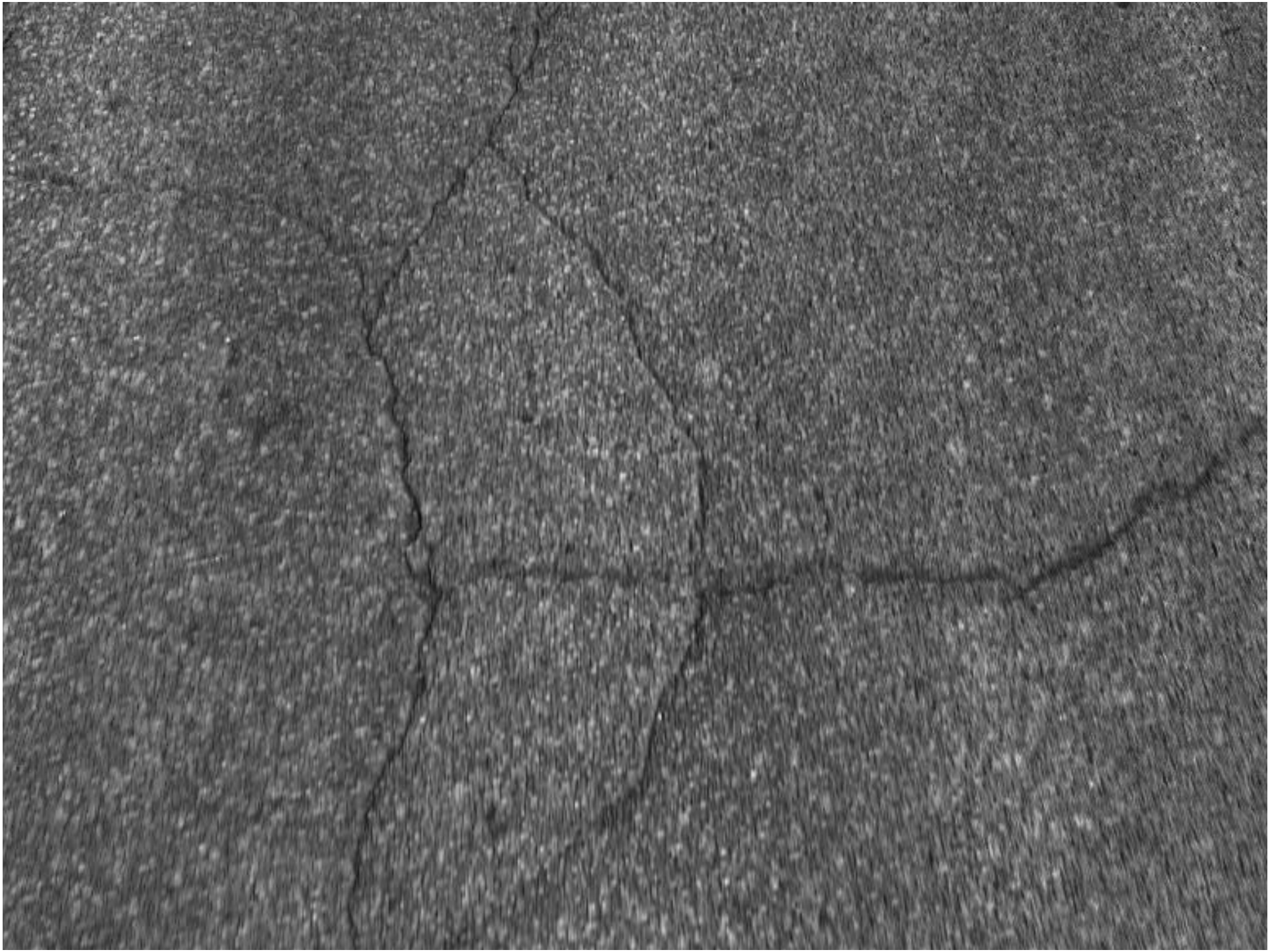
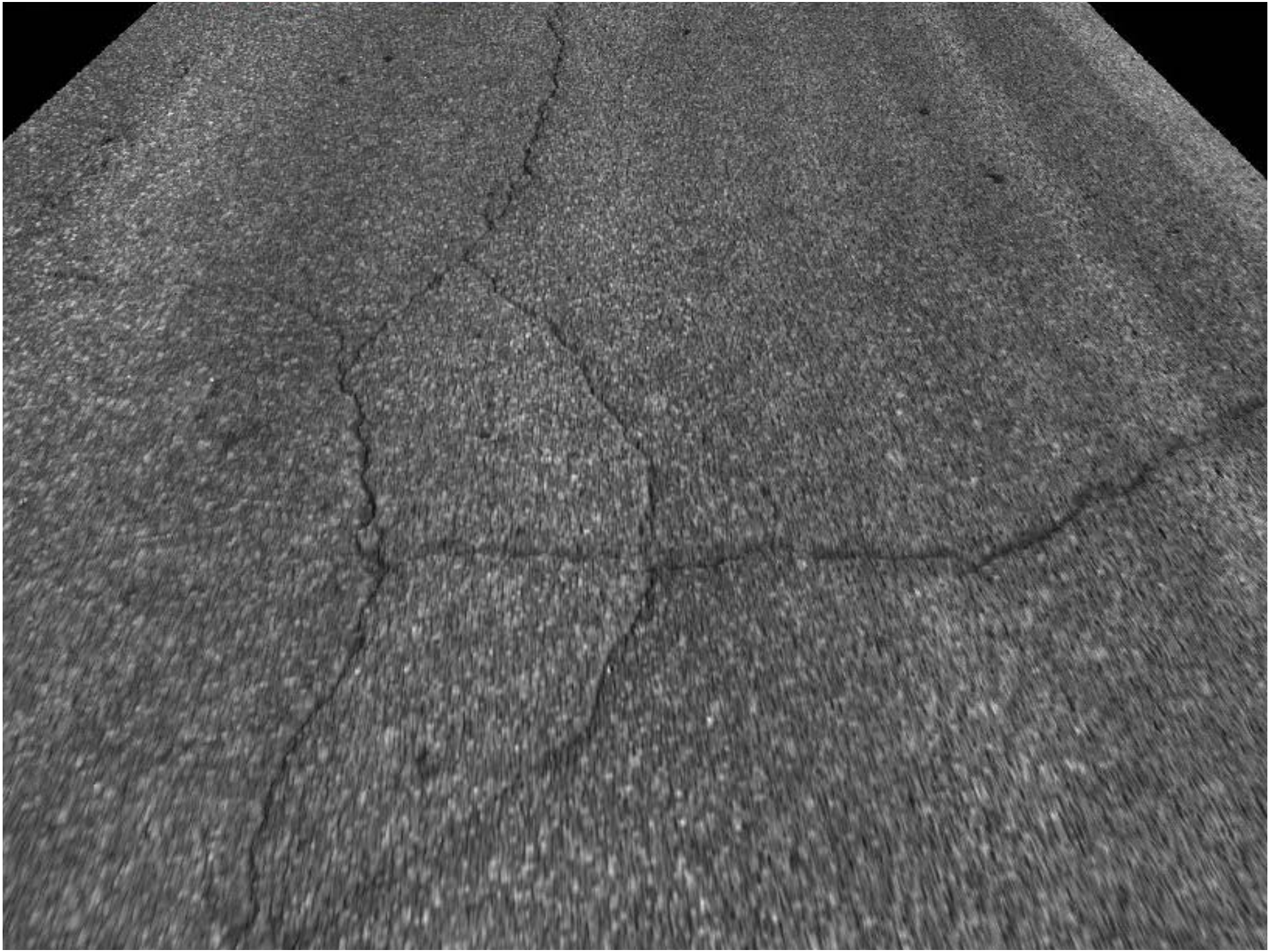
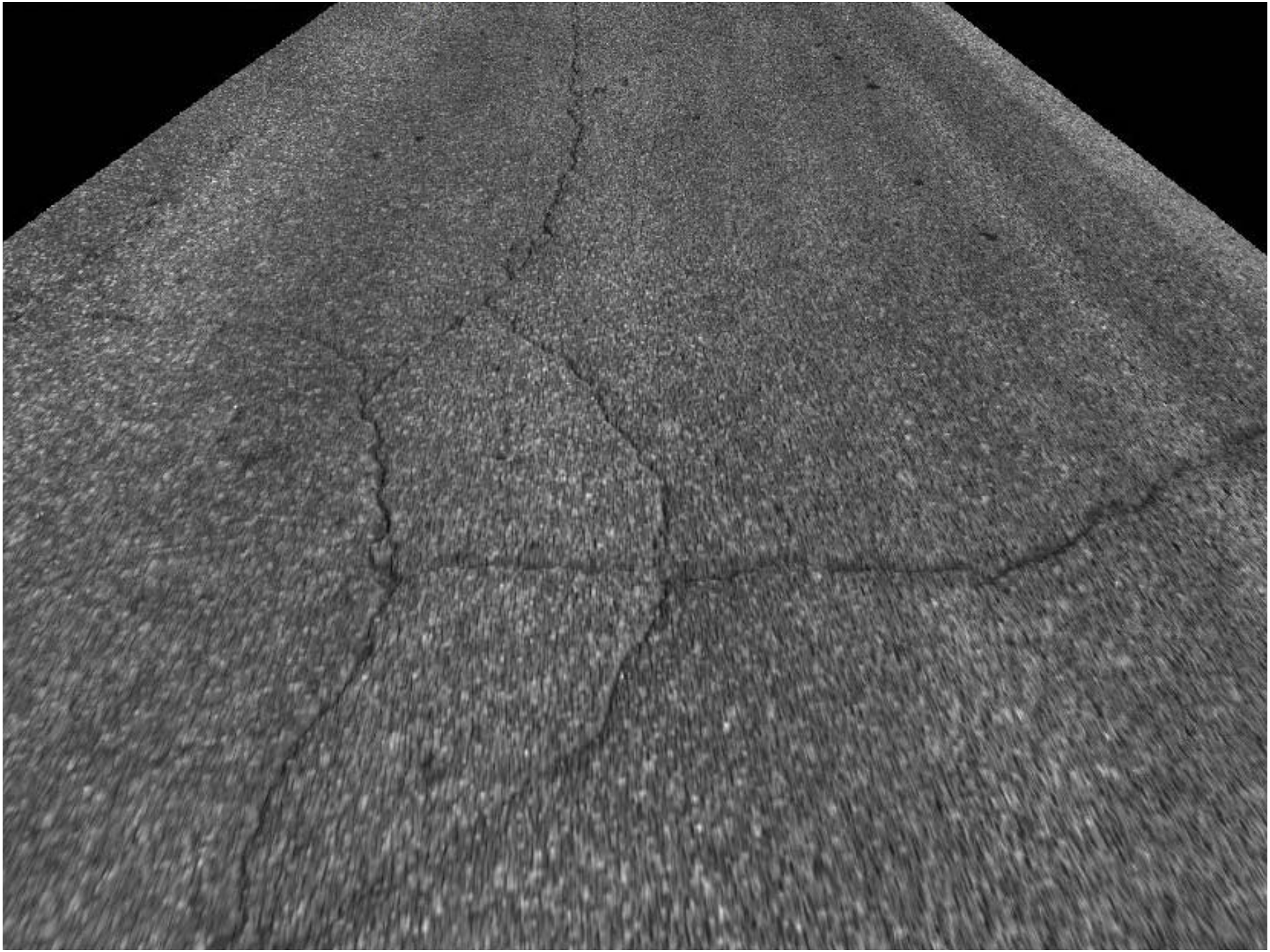
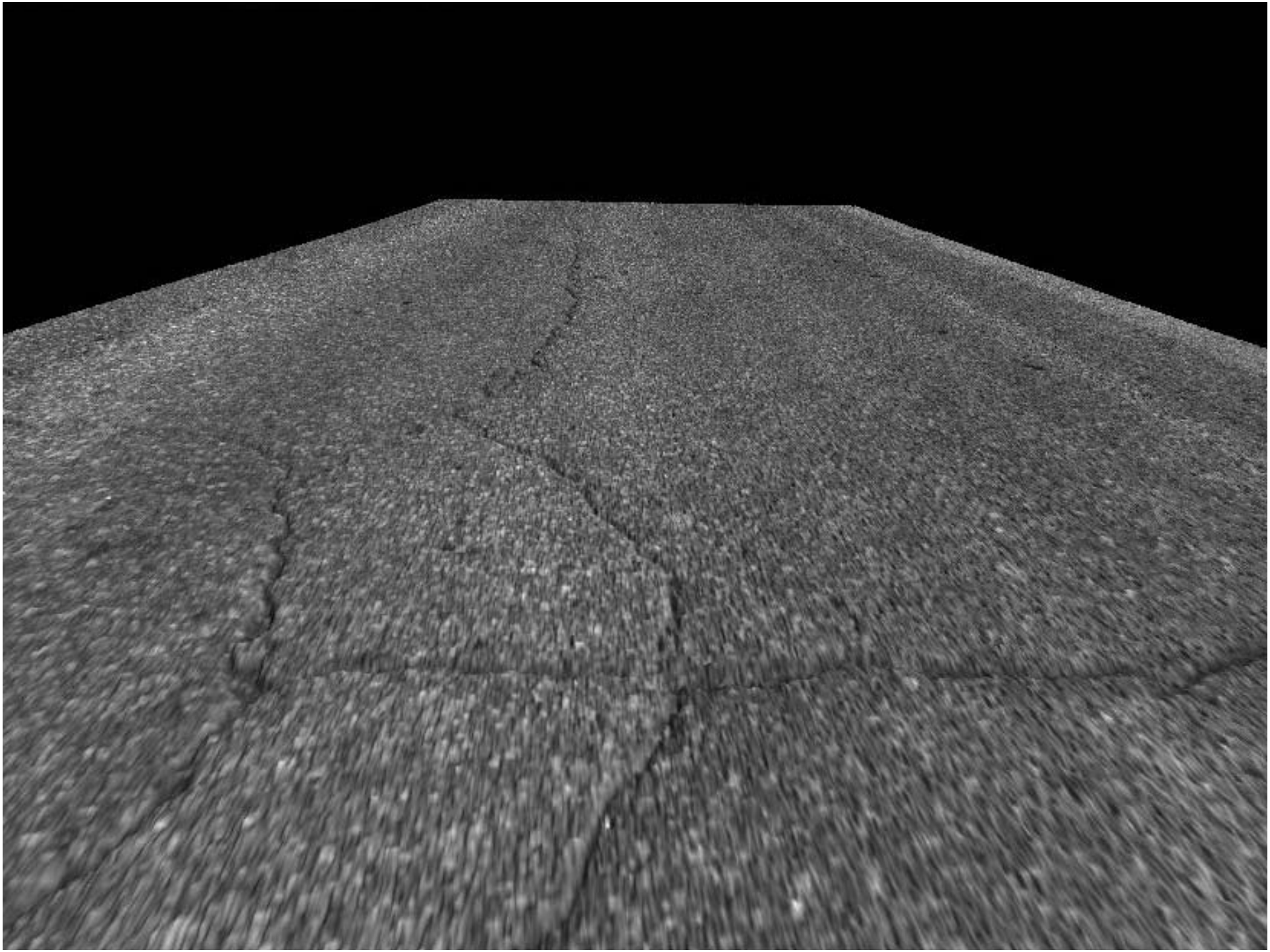
Range + Intensity = 3D !












SOFTWARE
IS
KEY !

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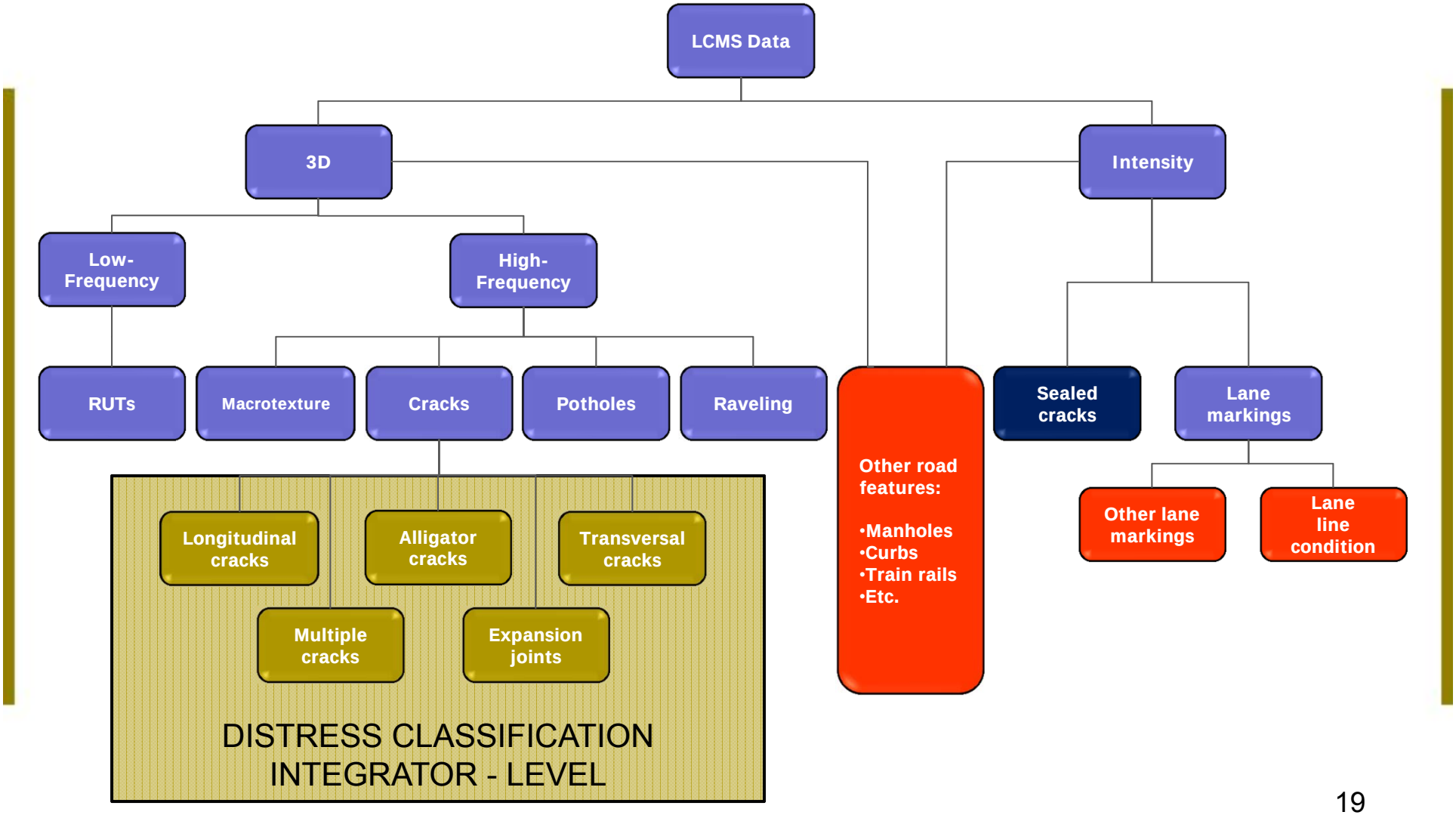
LCMS Data Processing Tree



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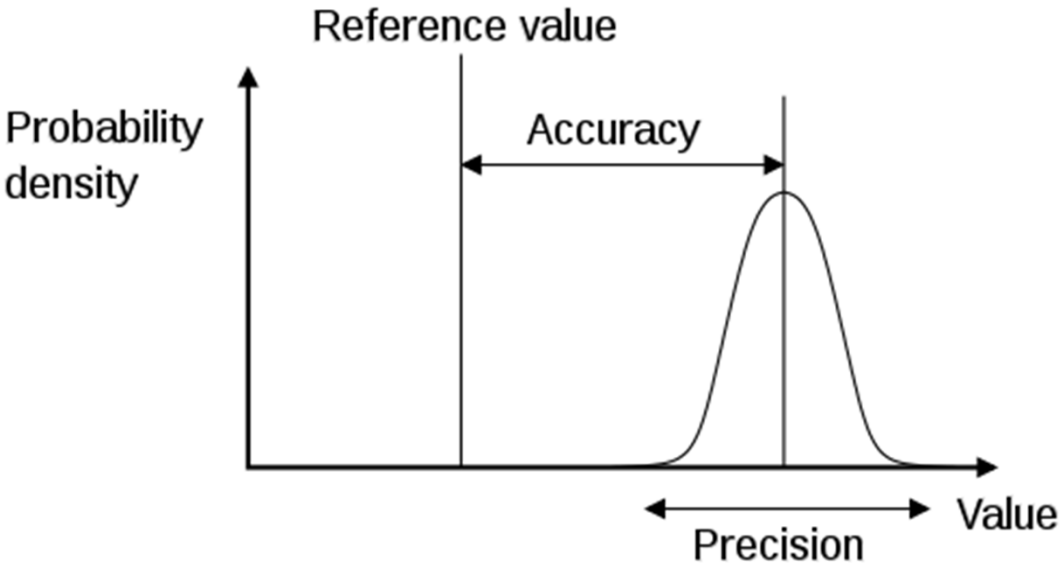
Specifications

Low accuracy, good trueness, poor precision

Low accuracy, poor trueness, good precision



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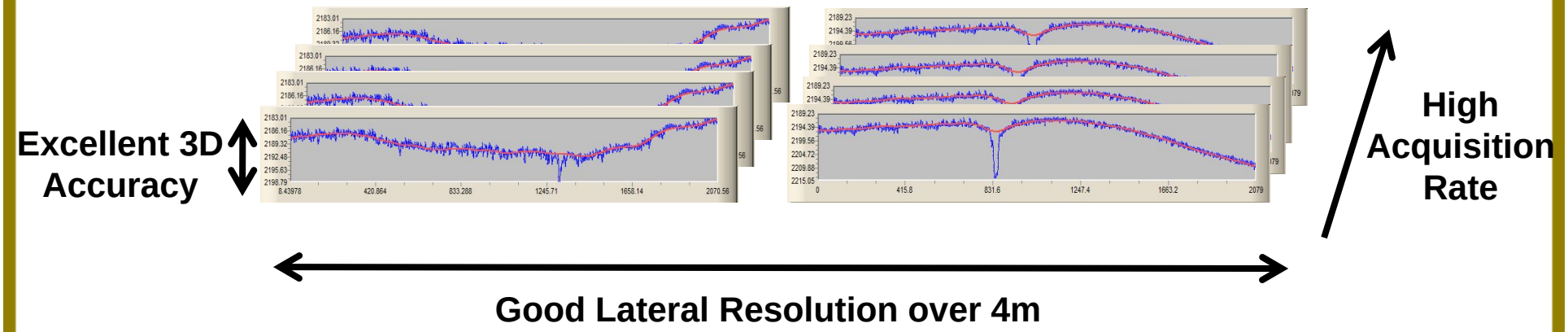
Specifications

In addition to accuracy and precision, measurements may also have a measurement resolution, which is the smallest change in the underlying physical quantity that produces a response in the measurement.

When measurements are repeated and averaged. In that case, the term standard error is properly applied: the precision of the average is equal to the known standard deviation of the process divided by the square root of the number of measurements averaged.

Specifications for DOT

What makes a good 3D sensor very good for road measurement?



DOT – USER NEEDS	
Acquisition Rate	100 km/h
Range Vertical Accuracy/Precision/ Resolution	< 1mm
Lateral Resolution	1 mm
Width of lane to scan	4m

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Specifications

LCMS Specifications	
Acquisition Rate	11,200 profiles/s
Number of points per profile	4000
Nbr of points/sec	45 MHz
Range Accuracy/Precision	0.5mm
Range Resolution	0.25mm
Lateral Resolution	1mm (FOV = 4m)

Single point lasers	
Nbr of points/s	16 kHz, 32kHz, 64kHz
Number of points per profile	1
Range Accuracy/Precision	?
Range Resolution	0.1mm

ASTM E950 – Longitudinal Profile

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TABLE 1 Longitudinal Sampling

Class 1 less than or equal to 25 mm [1 in.]
Class 2 greater than 25 mm [1 in.] to 150 mm [6 in.]
Class 3 greater than 150 mm [6 in.] to 300 mm [12 in.]
Class 4 greater than 300 mm [12 in.]

TABLE 2 Vertical Measurement Resolution

Class 1 less than or equal to 0.1 mm [0.005 in.]
Class 2 greater than 0.1 mm [0.005 in.] to 0.2 mm [0.010 in.]
Class 3 greater than 0.2 mm [0.010 in.] to 0.5 mm [0.020 in.]
Class 4 greater than 0.5 mm [0.020 in.]

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IRI vs range resolution

IRI values vs range resolution for three road sections

	Section 1		Section 2		Section 3	
Range resolution (mm)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)
0.5	1.24	1.80	1.40	1.71	3.32	3.85
0.25	1.24	1.79	1.40	1.71	3.30	3.83
0.1	1.24	1.78	1.39	1.70	3.30	3.83
Max. variation (%)	0.0	1.1	0.7	0.6	0.6	0.5

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IRI vs range resolution

IRI values vs range resolution for three road sections

	Section 1		Section 2		Section 3	
Range resolution (mm)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)
0.5	1.24	1.79	1.40	1.71	3.30	3.83
1	1.25	1.79	1.40	1.71	3.31	3.83
2	1.26	1.79	1.40	1.73	3.32	3.83
3	1.27	1.84	1.42	1.72	3.32	3.84
4	1.41	1.93	1.53	1.82	3.35	3.85
5	1.62	2.19	1.69	1.93	3.45	3.86
6	1.93	2.47	1.97	2.19	3.54	4.03
Max. variation (%)	55.6	38.0	40.7	28.1	7.3	5.2

- Longitudinal resolution: 25 mm
- Shaded cells: IRI variation > 5%

World Bank (and DOT) – Longitudinal Profile specs

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Lasers

Minimum No. of Sensors	2 - one in each wheel path
Minimum Sampling Frequency	16 kHz
Minimum Bandwidth	2 kHz = approx 0.5 inch at 60mph
Spot Size	0.2-5mm
Minimum Resolution	0.2mm
Accuracy	± 0.5mm
Measuring Range	± 100mm
Stand Off	≥300mm

Accelerometers

No of Sensors	2 - one with each laser;
Minimum Measuring Range	±2G
Minimum Resolution	10µG
Minimum Bandwidth	DC -300Hz

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Ride quality - specs

Ride is perceived as most comfortable when the natural frequency is in the range of 60 to 90 cycles per minute (CPM), or about 1 Hz to 1.5 Hz.

When the frequency approaches 120 CPM (2 Hz), occupants perceive the ride as harsh. Consequently, the suspension of the average family sedan will have a natural frequency of about 60 to 90 CPM.

A high-performance sports car will have a stiffer suspension with a natural frequency of about 120 to 150 CPM (2 to 2.5 Hz).

US DOT – Longitudinal Profile specs

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An accelerometer with a minimum +/- 4G range shall be used to obtain vertical body movement, and a laser sensor shall be used for measuring the displacement between the vehicle body and the pavement for each wheel path. Road profile measurements are then obtained by summing the body movement with the appropriate body road displacements.

The lasers used for IRI measurements shall have spot size measurements seventeen (17) millimeter (mm) with a two hundred (200) mm measurement range and three hundred (300) mm standoff. The IRI is then calculated in accordance with the World Bank Specifications.

IRI vs accelerometers dynamic range

IRI values vs dynamic range for three road sections

	Section 1 (low roughness)		Section 2 (med. roughness)		Section 3 (high roughness)	
Range resolution (g)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)	Left IRI (m/km)	Right IRI (m/km)
±5	1.24	1.79	3.30	3.83	7.25	9.09
±3	1.24	1.79	3.30	3.83	7.25	9.09
±2	1.24	1.79	3.30	3.83	7.27	9.11
±1	1.24	1.77	3.33	3.81	7.30	9.32
Max. variation (%)	0.0	1.1	0.9	0.5	0.7	2.5

Macrotexture : Mean Profile Depth (ASTM E1845-01)

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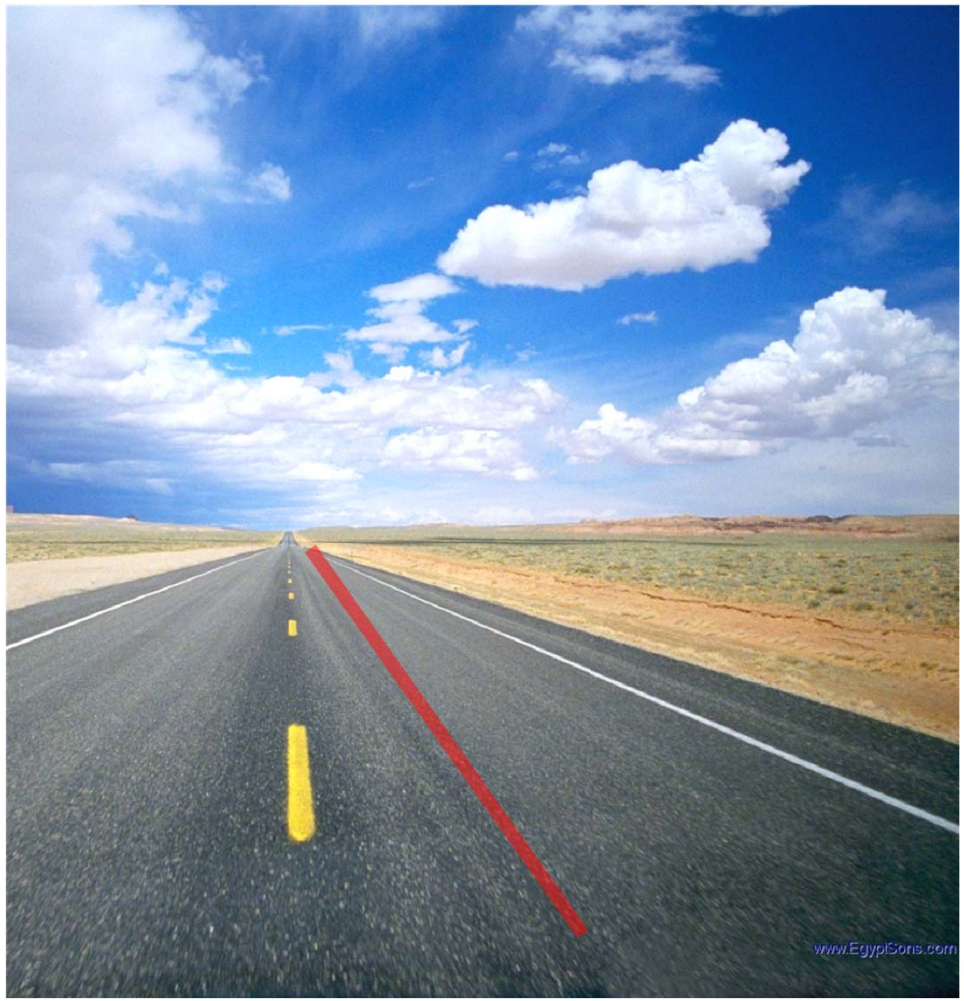
Specifications:

- 32kHz or 64kHz laser
- 1mm point spacing (minimum)
- 0.05 mm vertical resolution
- Low pass filtering 2.5mm features removed. 5mm+ features kept intact.



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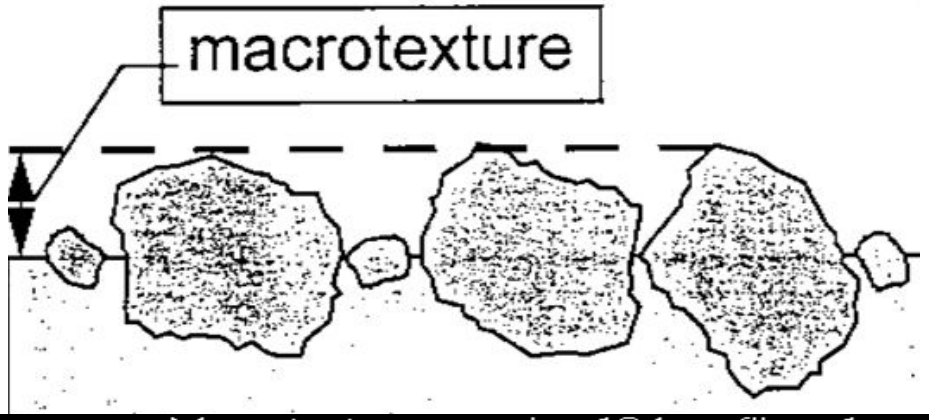
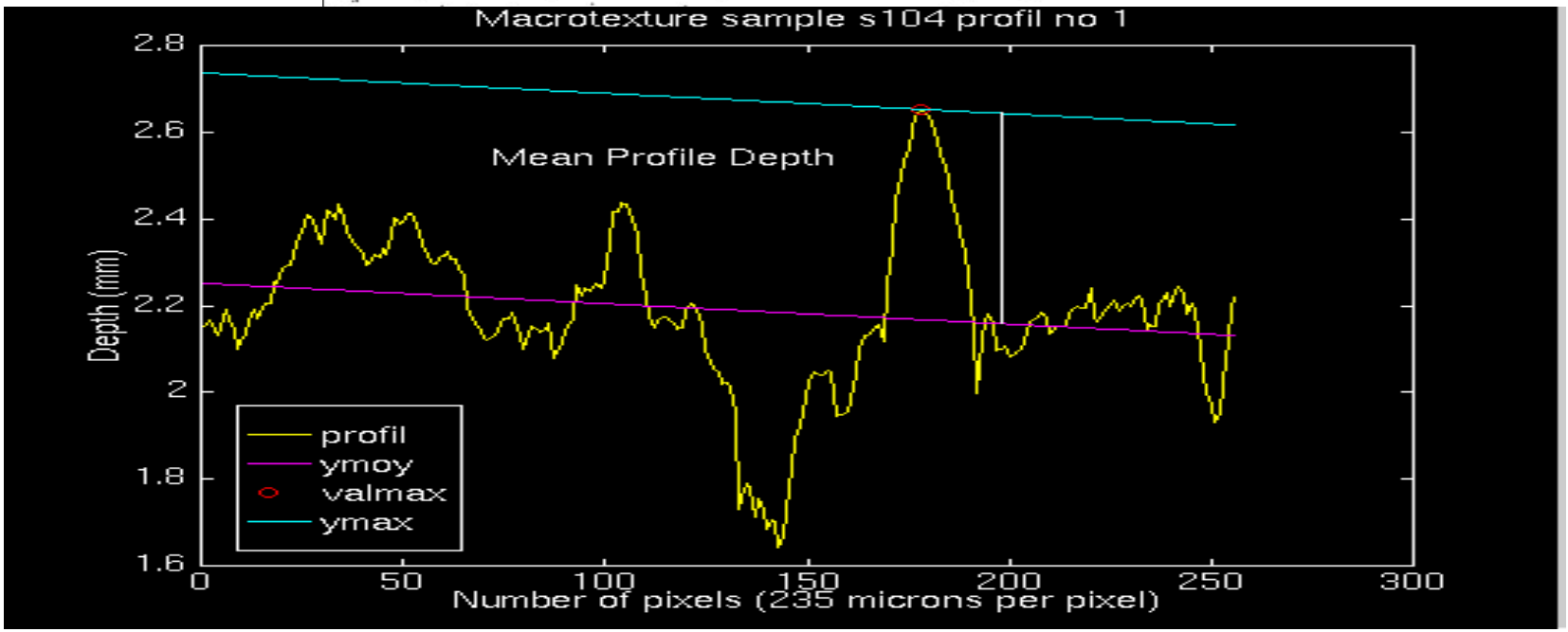
Macrotexture : Mean Profile Depth (ASTM E1845-01)





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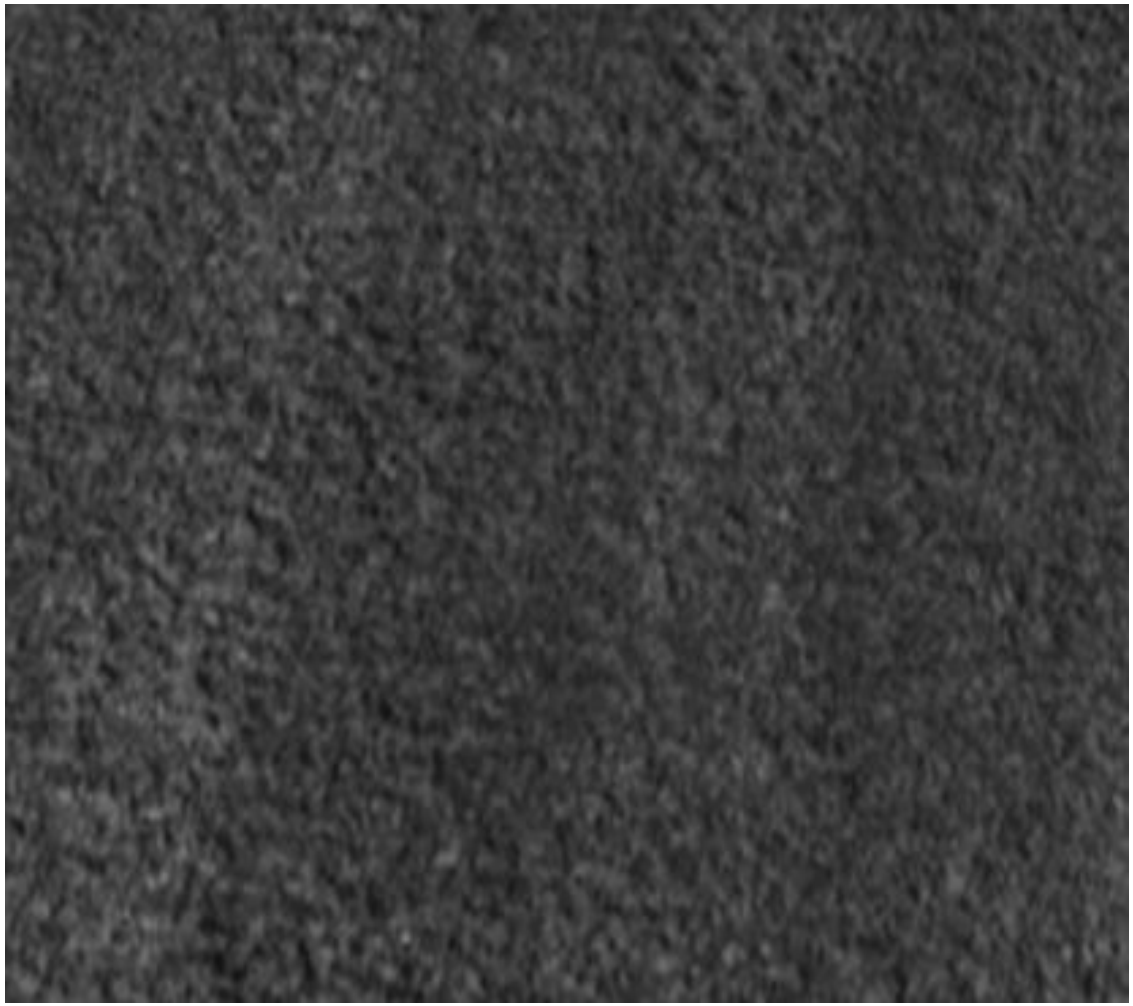
Macrotexture



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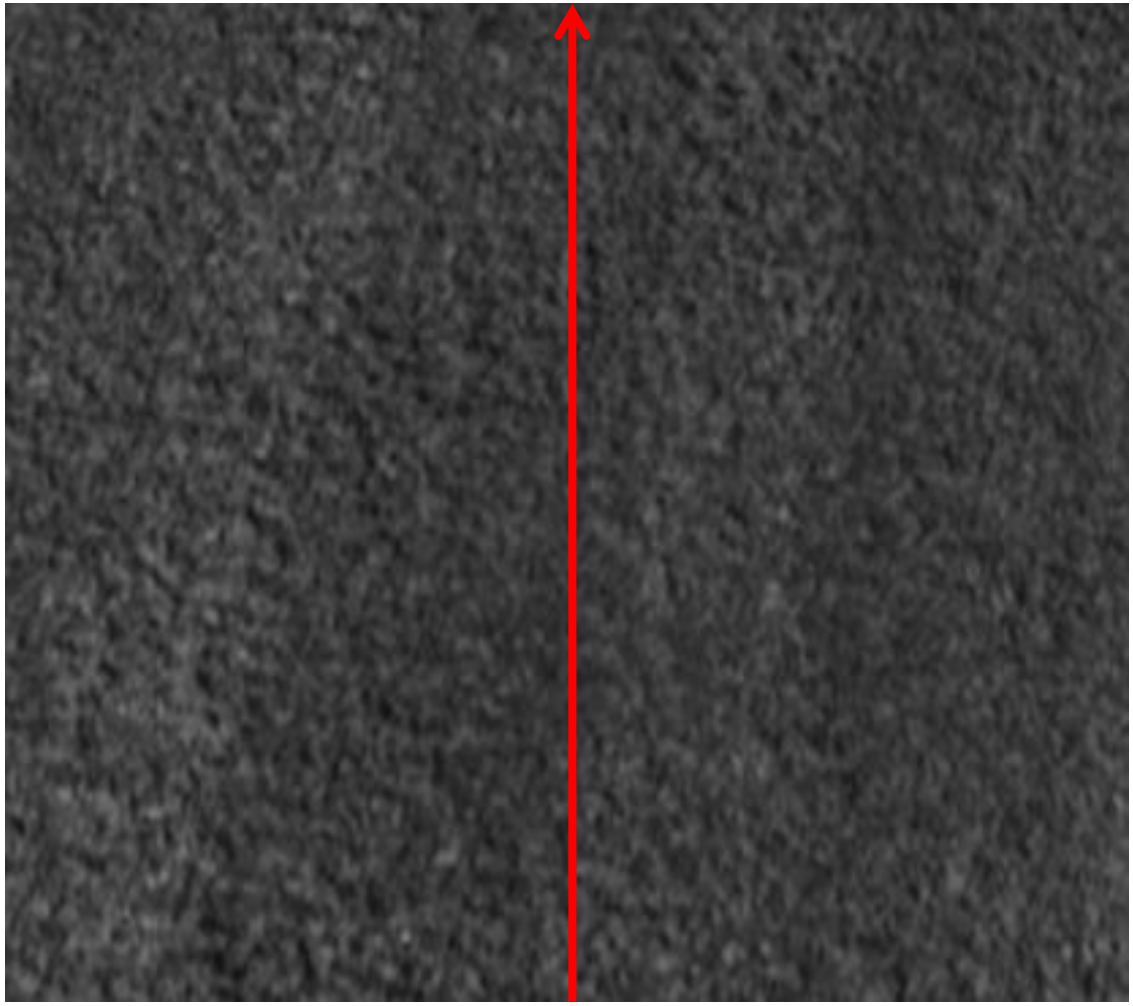
Macrotexture



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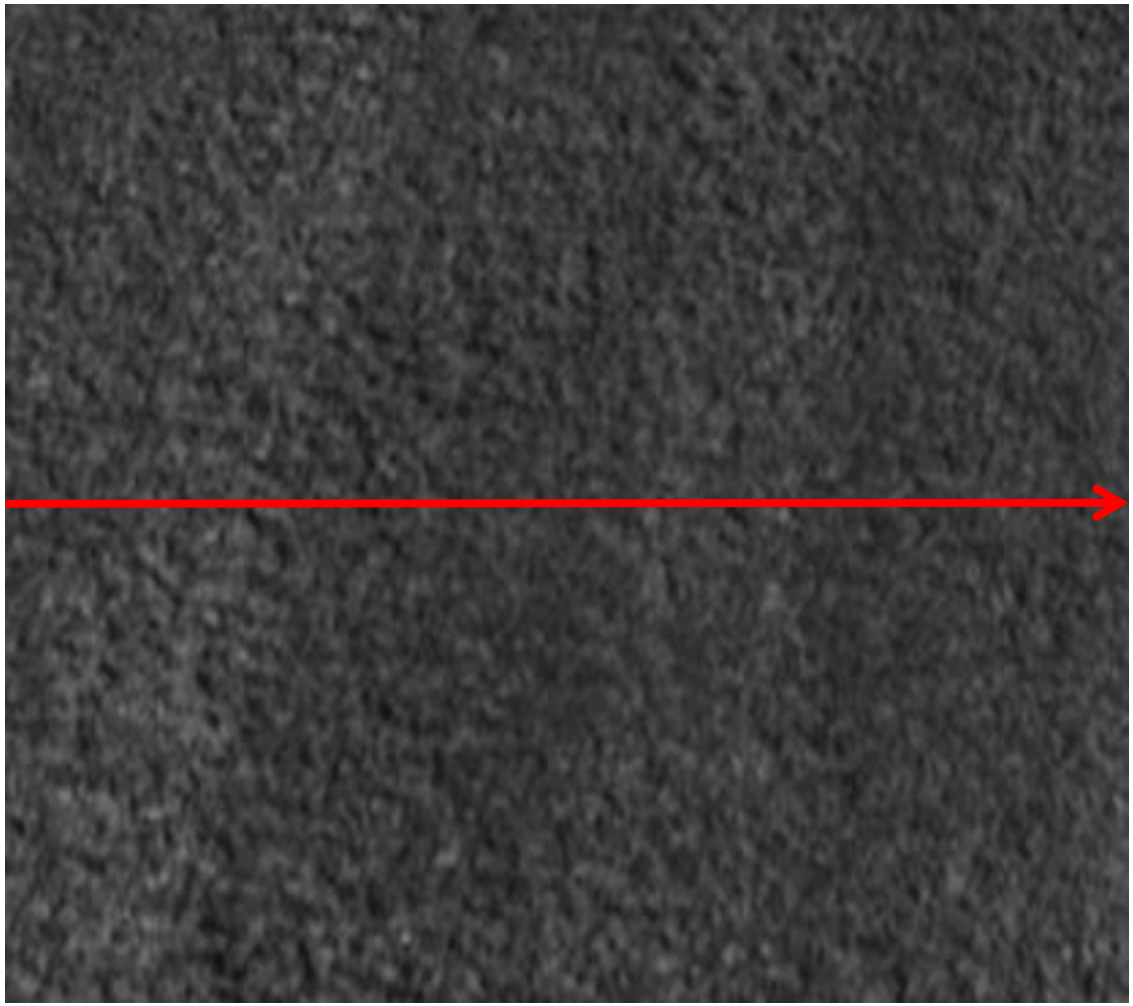
Macrotexture



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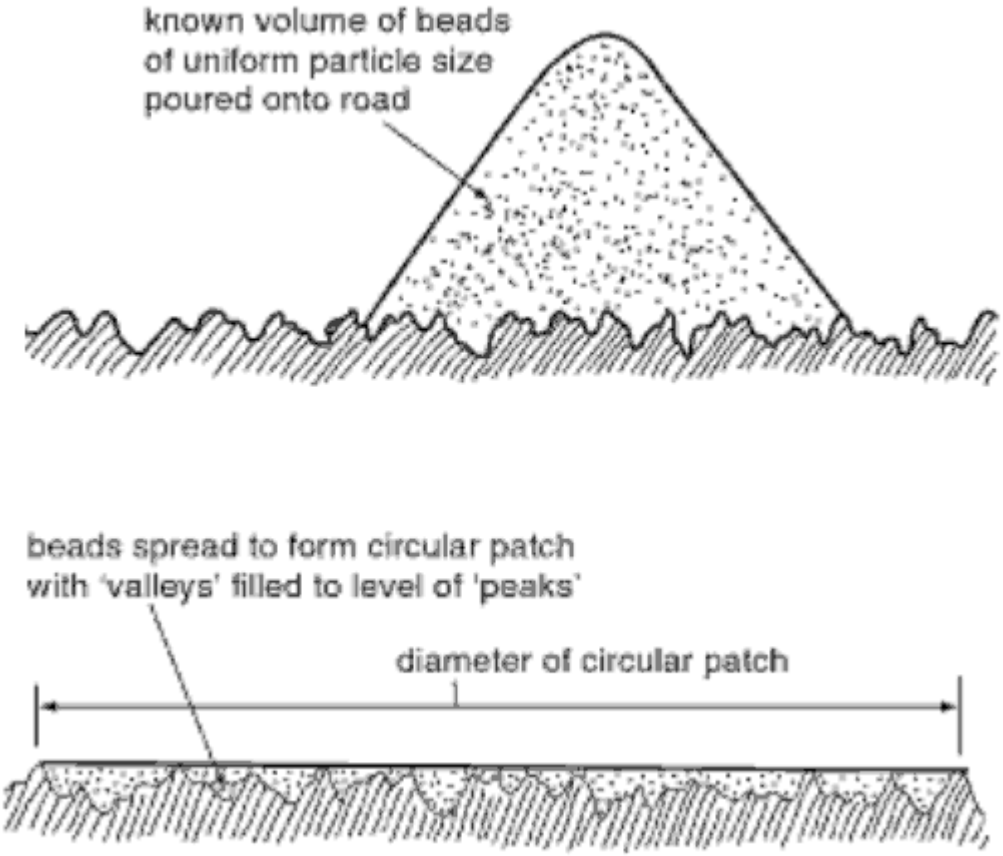
Macrotexture : Sand patch method (MTD) (ASTM E965)



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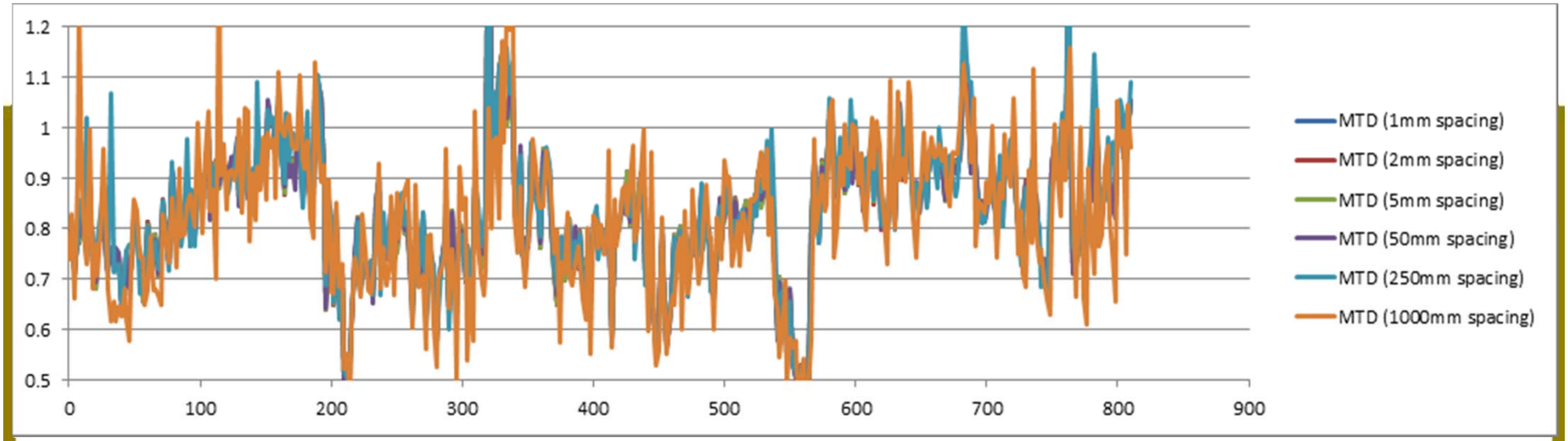
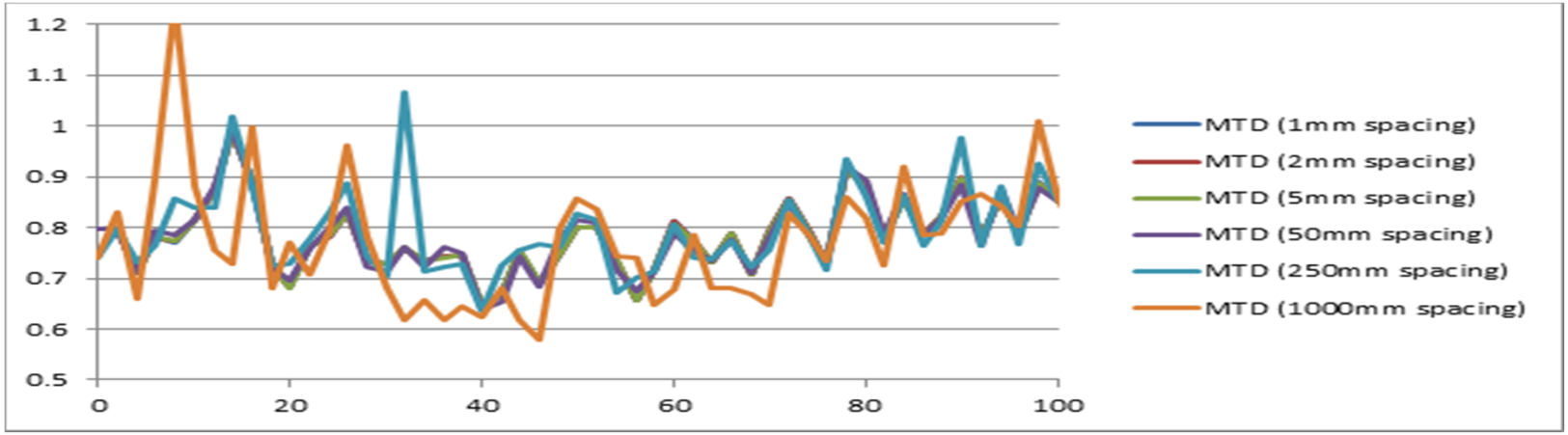
MPD single profile vs surface





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DOES IT WORK FOR YOU ?

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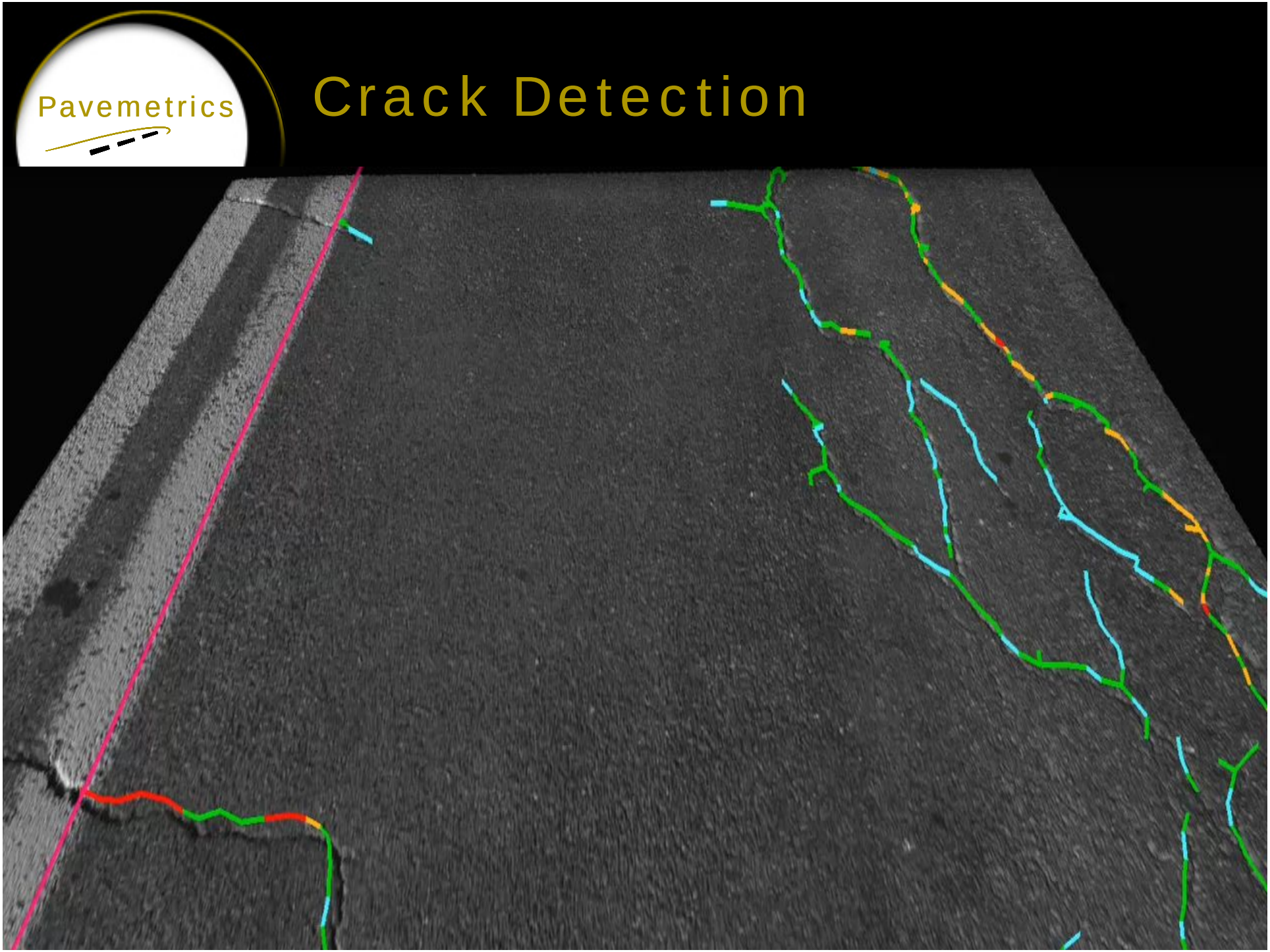
Crack Detection



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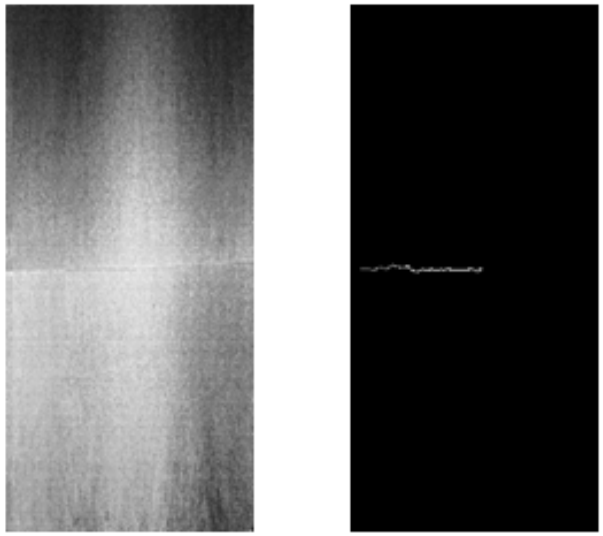
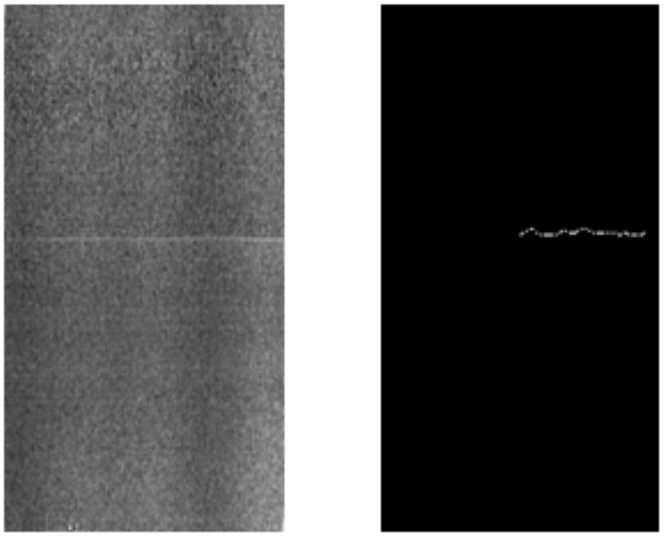
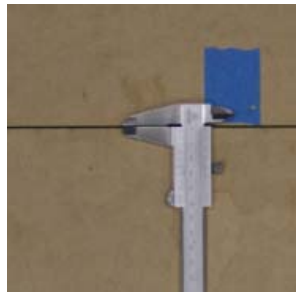
LCMS crack detection tests

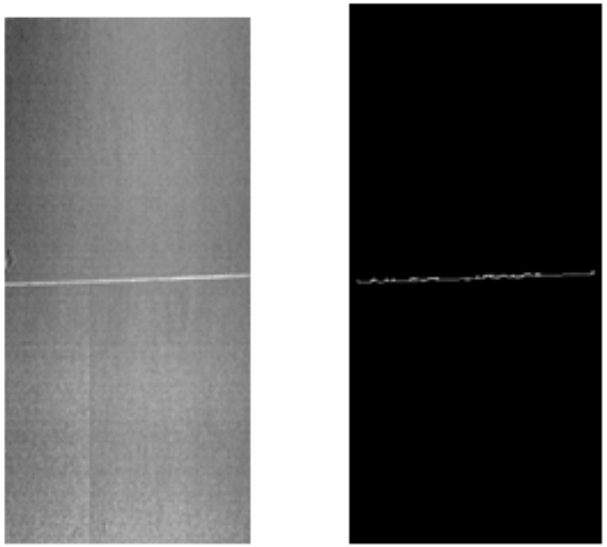


(a) 1mm (daytime)

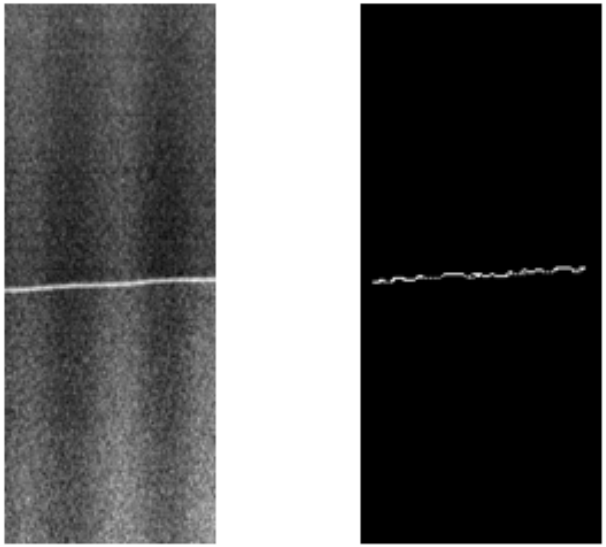


(b) 1mm (night)





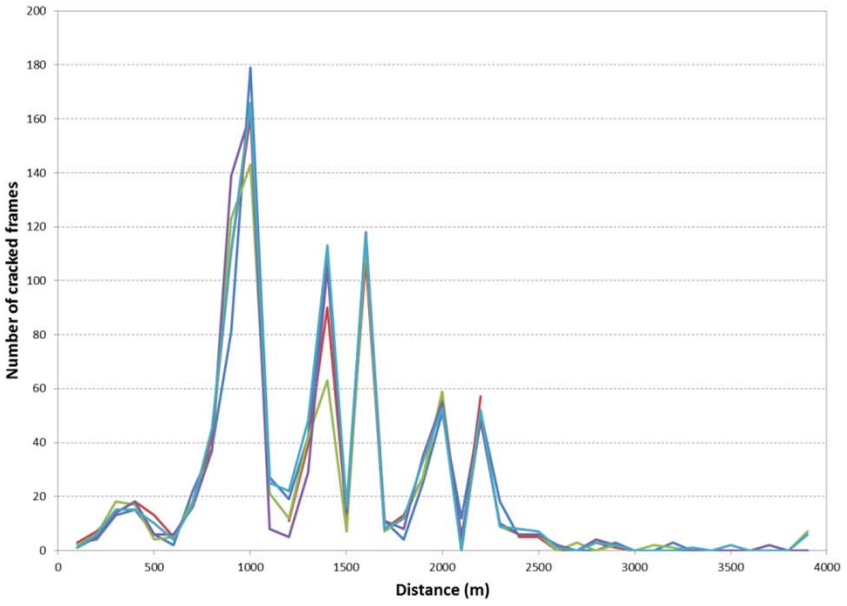
(c) 2mm (daytime)

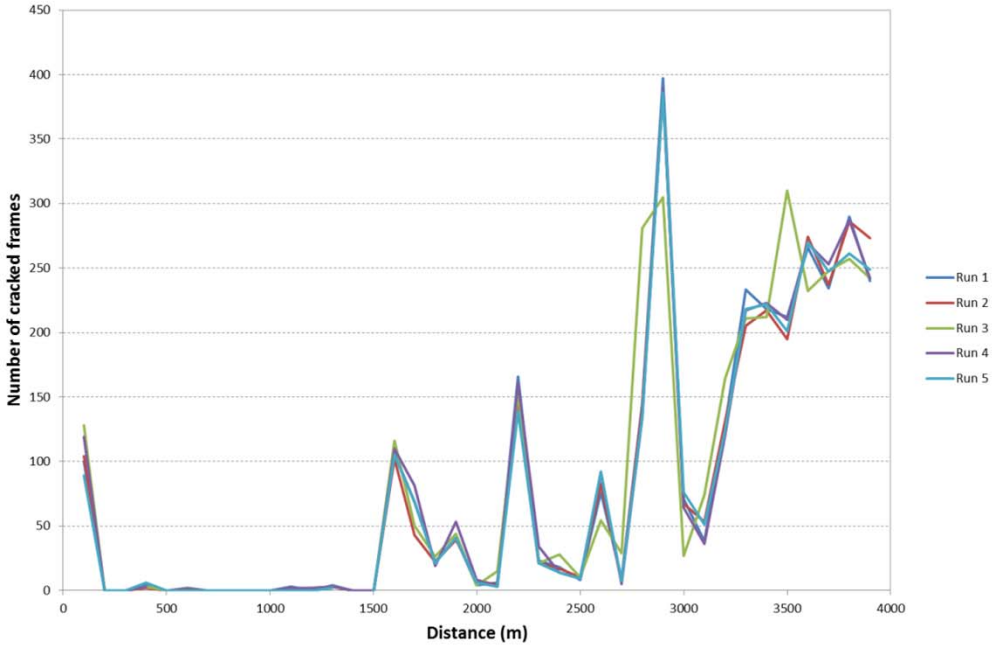


(d) 2mm (night)

LCMS repeatability DGA test site – ARRB - Australia

		Run 1	Run 2	Run 3	Run 4	Run 5
Eastbound	r^2	0.968	0.997	0.972	0.983	0.992
Westbound	r^2	0.994	0.992	0.929	0.992	0.992





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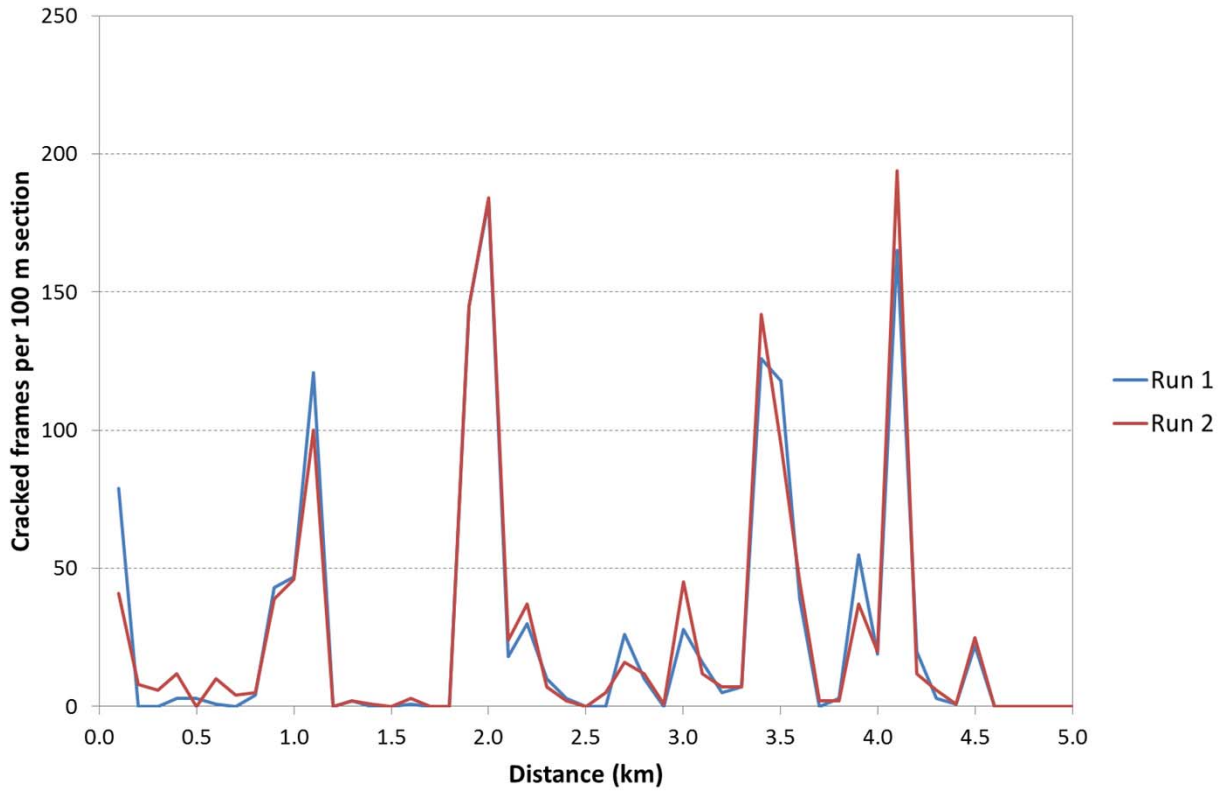
LCMS repeatability on a section of sprayed seal surface (r^2 =0.96)



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Results – network level visual evaluation

District #	Total (sections)	Results (manual classification)							
		Number of images (10m sections)				Proportion (%)			
		Good	Average	Bad	NA	Good	Average	Bad	NA
84	35288	34144	310	144	690	96,8	0,9	0,4	2,0
85	4243	4101	53	51	38	96,7	1,2	1,2	0,9
86	147903	144040	516	1520	1827	97,4	0,3	1,0	1,2
87	149926	138453	1170	5728	4575	92,3	0,8	3,8	3,1
88	189097	183010	1064	2002	3021	96,8	0,6	1,1	1,6
89	125003	121835	442	2015	711	97,5	0,4	1,6	0,6
90	123653	116930	2980	2434	1309	94,6	2,4	2,0	1,1
91 & 92	215513	213142	197	956	1218	98,9	0,1	0,4	0,6
Total	**990626**	**955655**	**6732**	**14850**	**13389**	**96,5**	**0,7**	**1,5**	**1,4**

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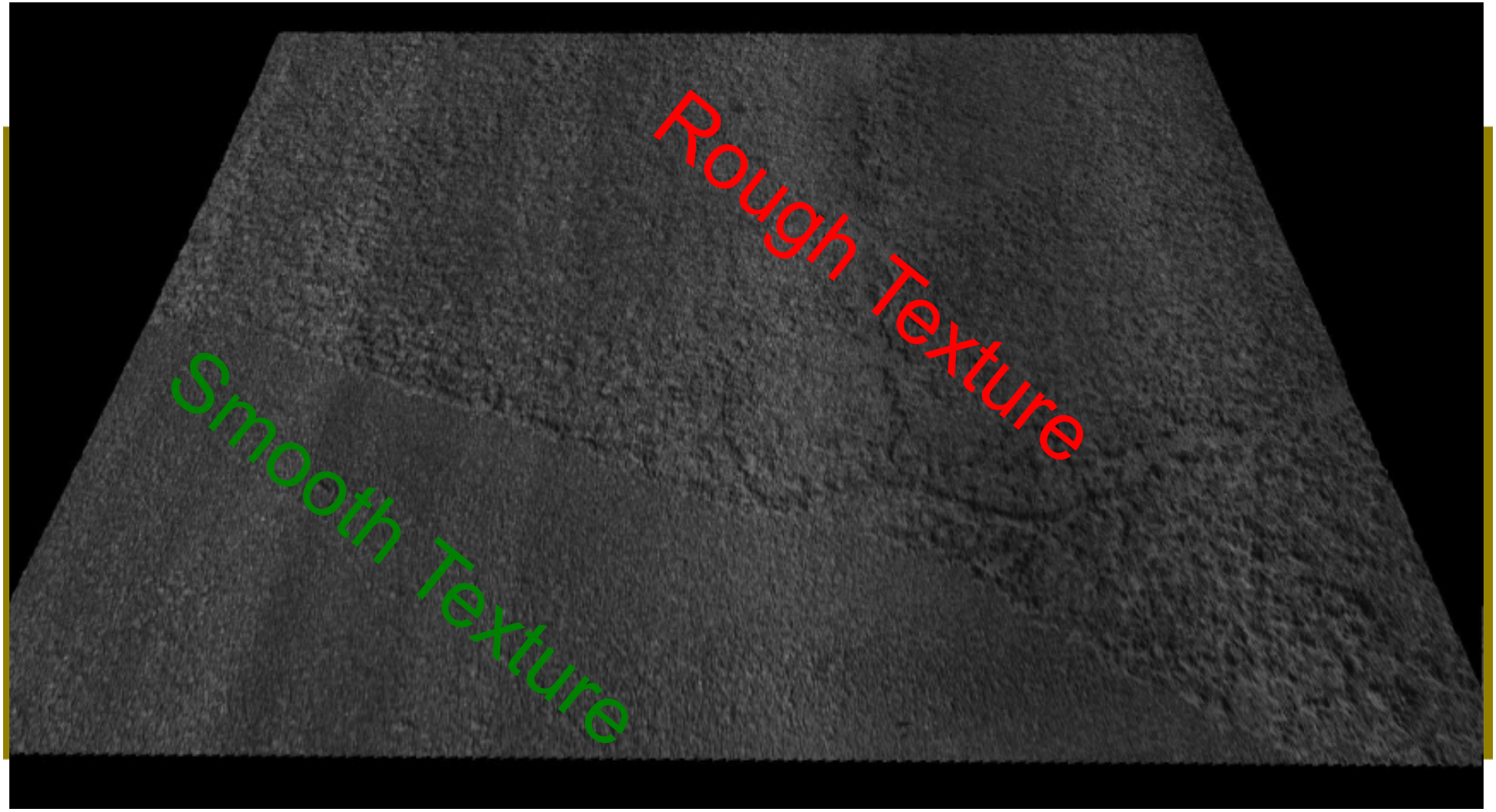
Macrotexture



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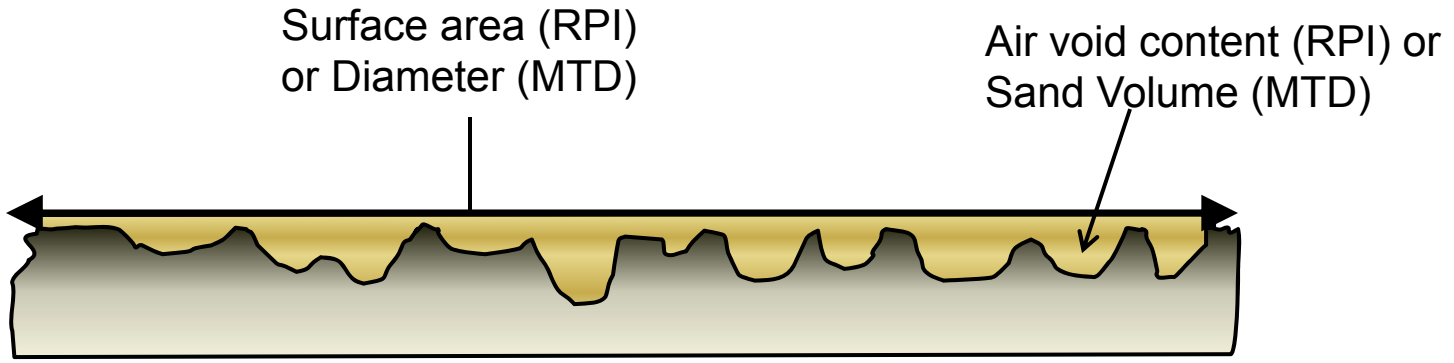
Macrotexture – RPI
Digital Sand Patch Method

RPI - Road Porosity Index = (Volume under the surface – Ravelling - Cracks) divided by a surface area



$$RPI = \frac{(Vol_{air\ void} - Vol_{ravelling} - Vol_{cracks})}{Area_{Total}}$$

Macrotexture – LCMS Digital Sand Patch Method

Pros:

- Network survey is possible at 100kmh
- Full lane width is measured
  - 5 AASHTO bands
- Great repeatability
  - Automatic lane marking detection

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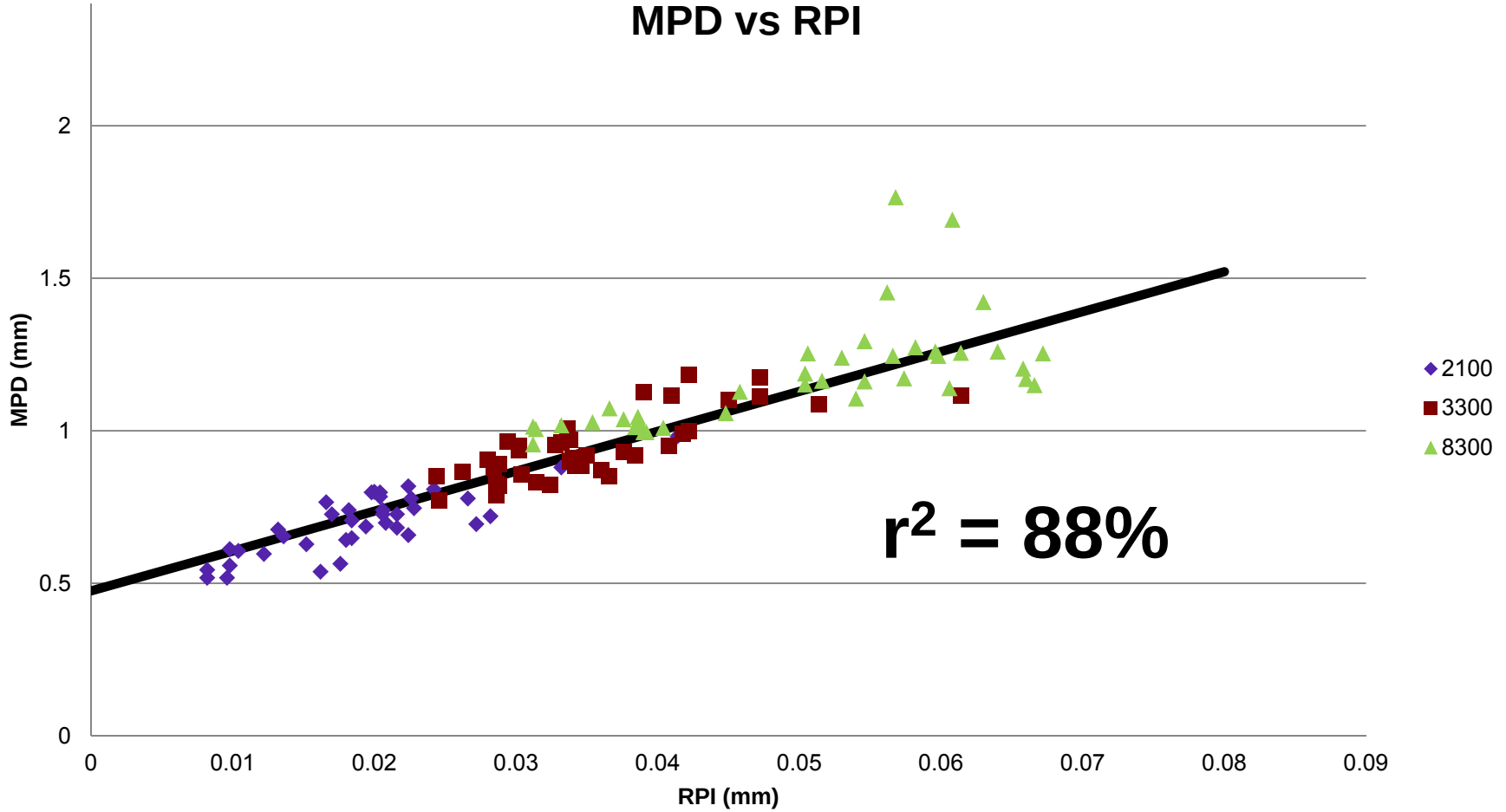
Macrotexture – Correlation between MPD and RPI



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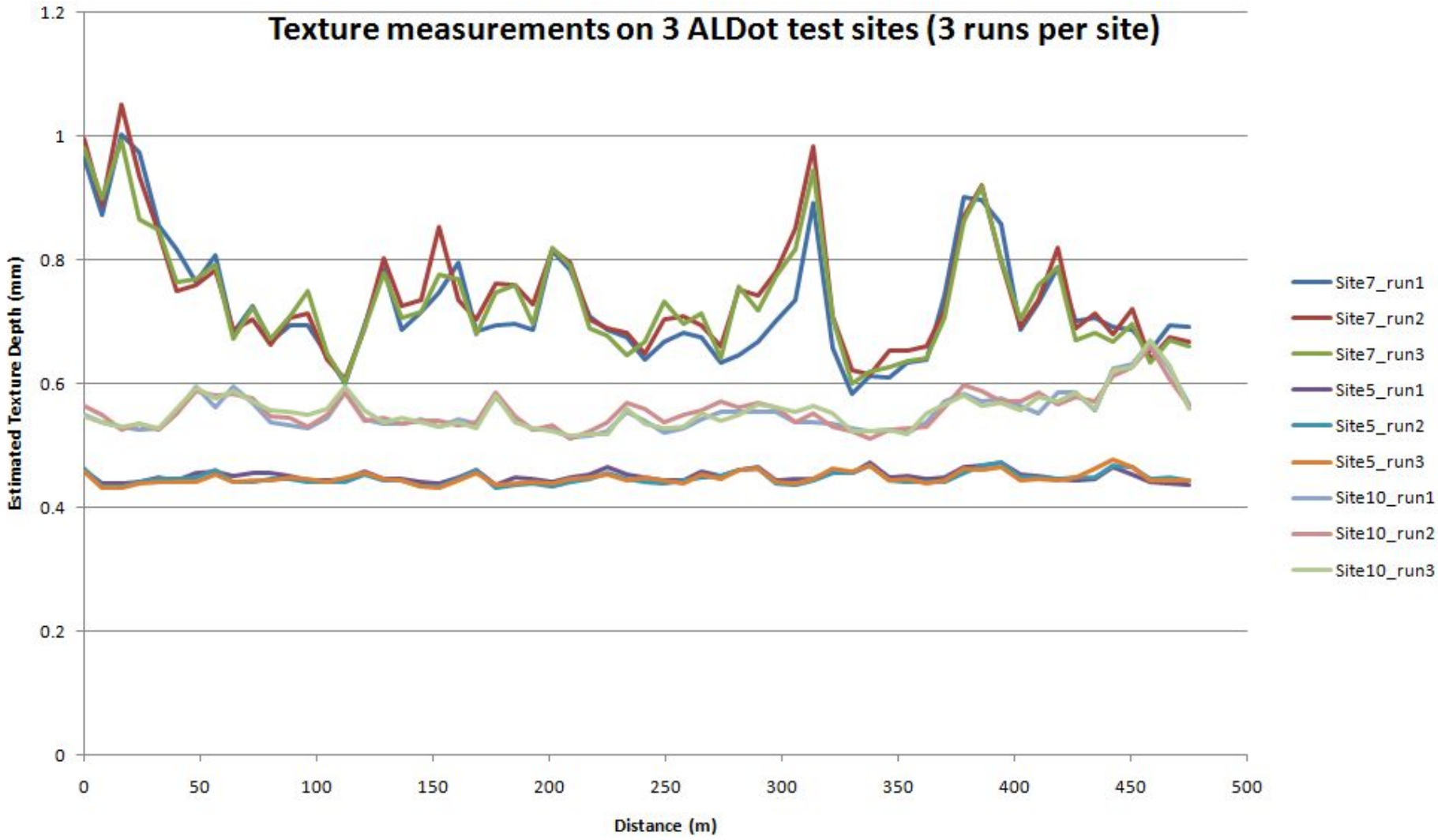
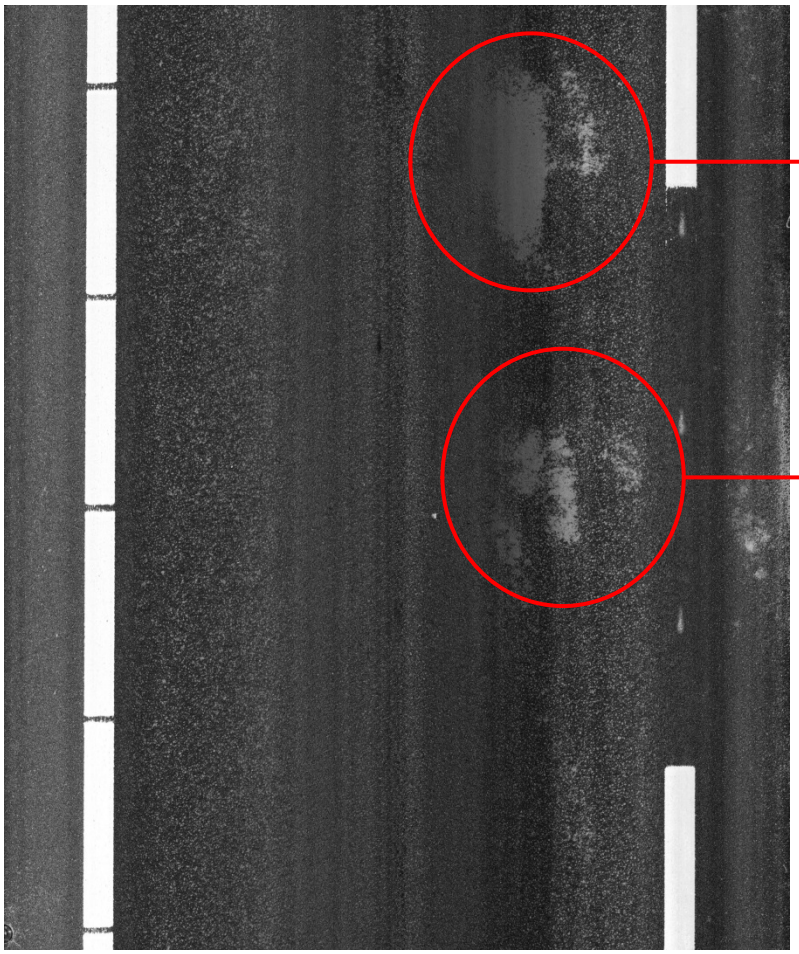
Repeatability – RPI measurement



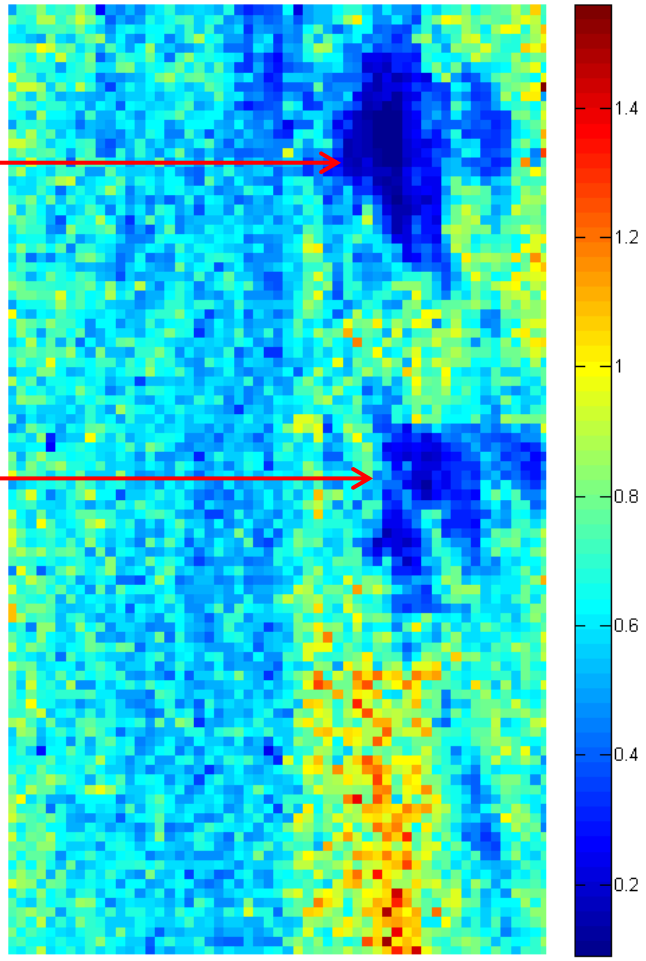
Pavemetrics

Macrotexture: bleeding

Intensity image



Texture image (MTD, mm)



Pavemetrics

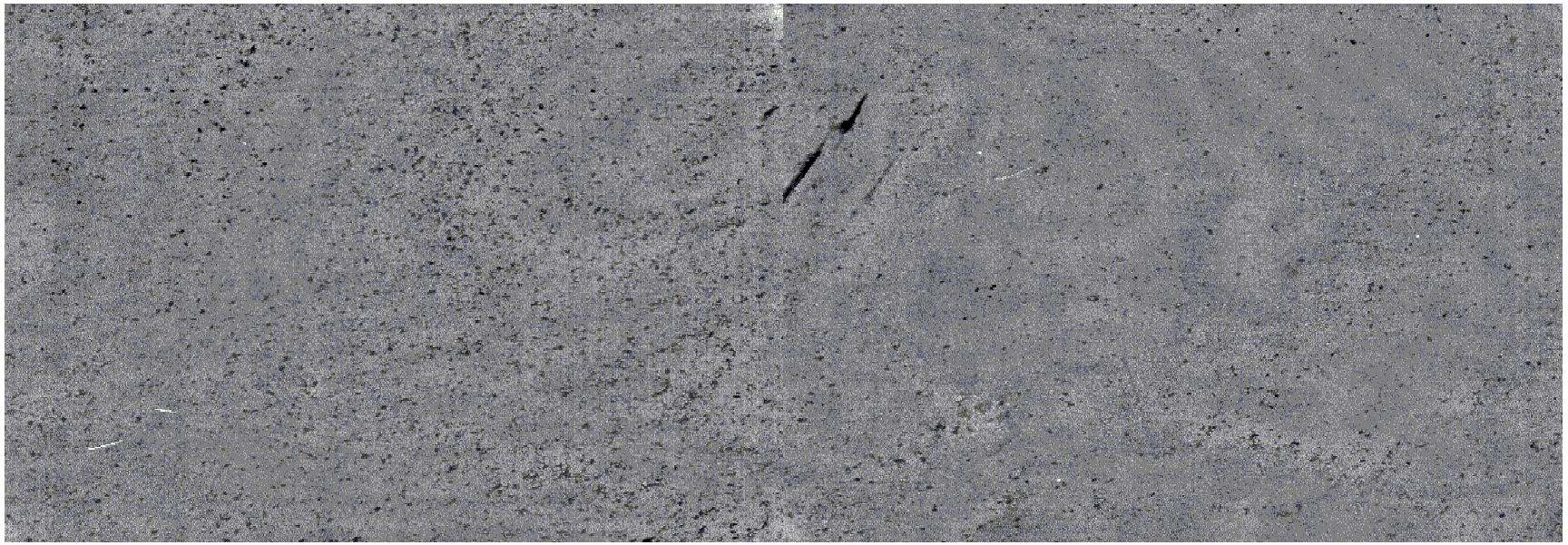
Ravelling Index - RI

Ravelling Index (RI) = The volume of aggregate loss per surface area

$$RI = V_{aggregate\ loss} / A_{Total}$$

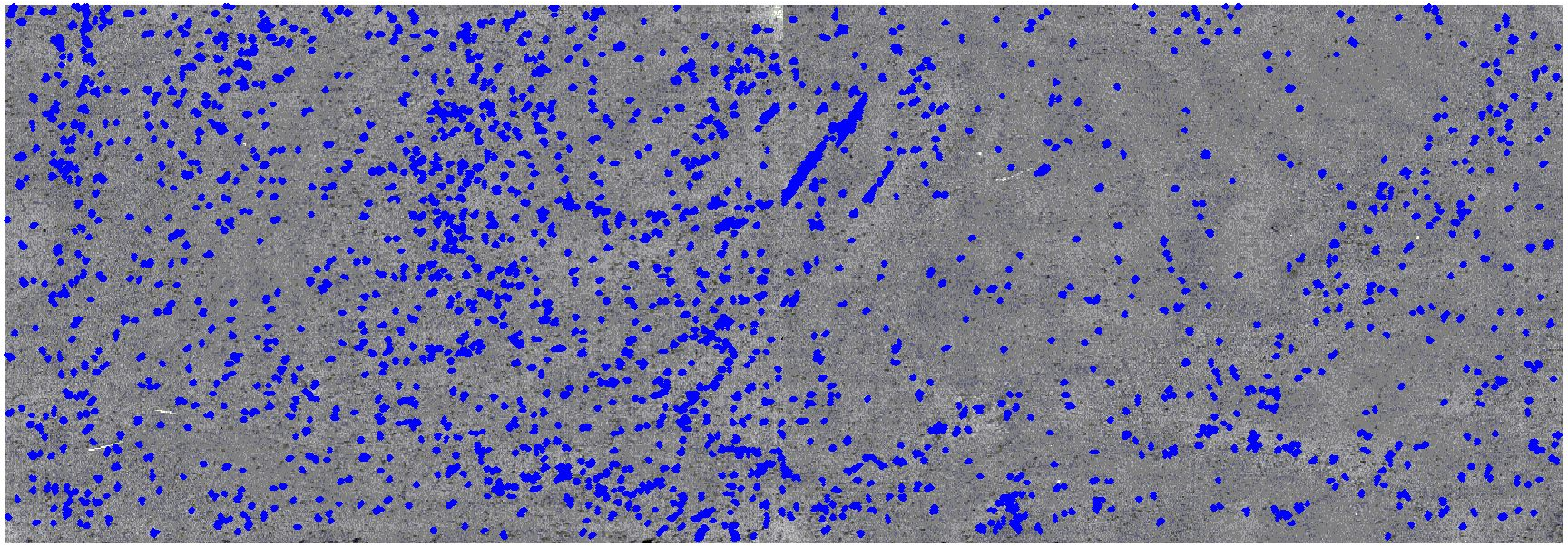
Pavemetrics

Aggregate loss detection

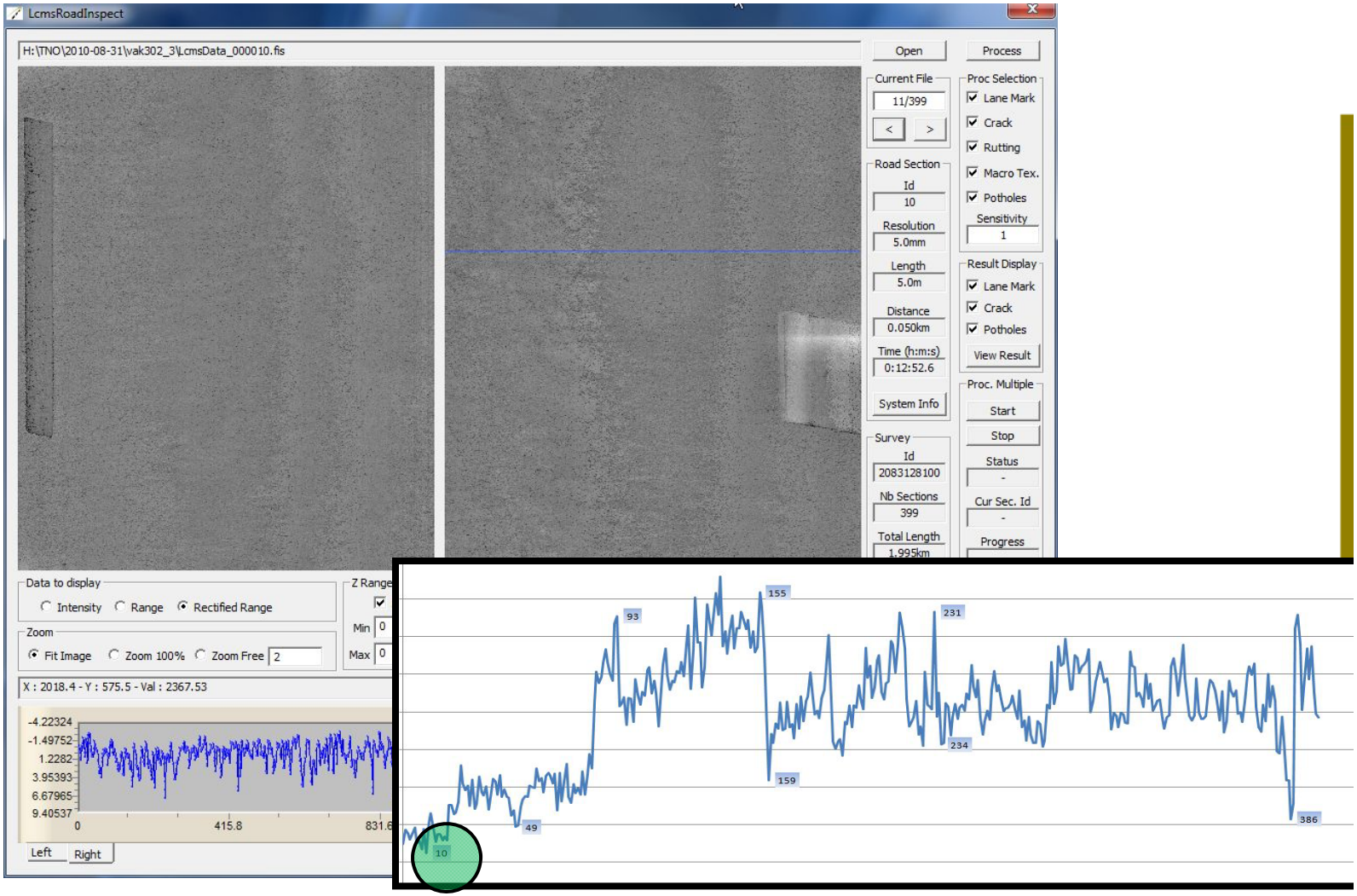


Pavemetrics

Aggregate loss detection

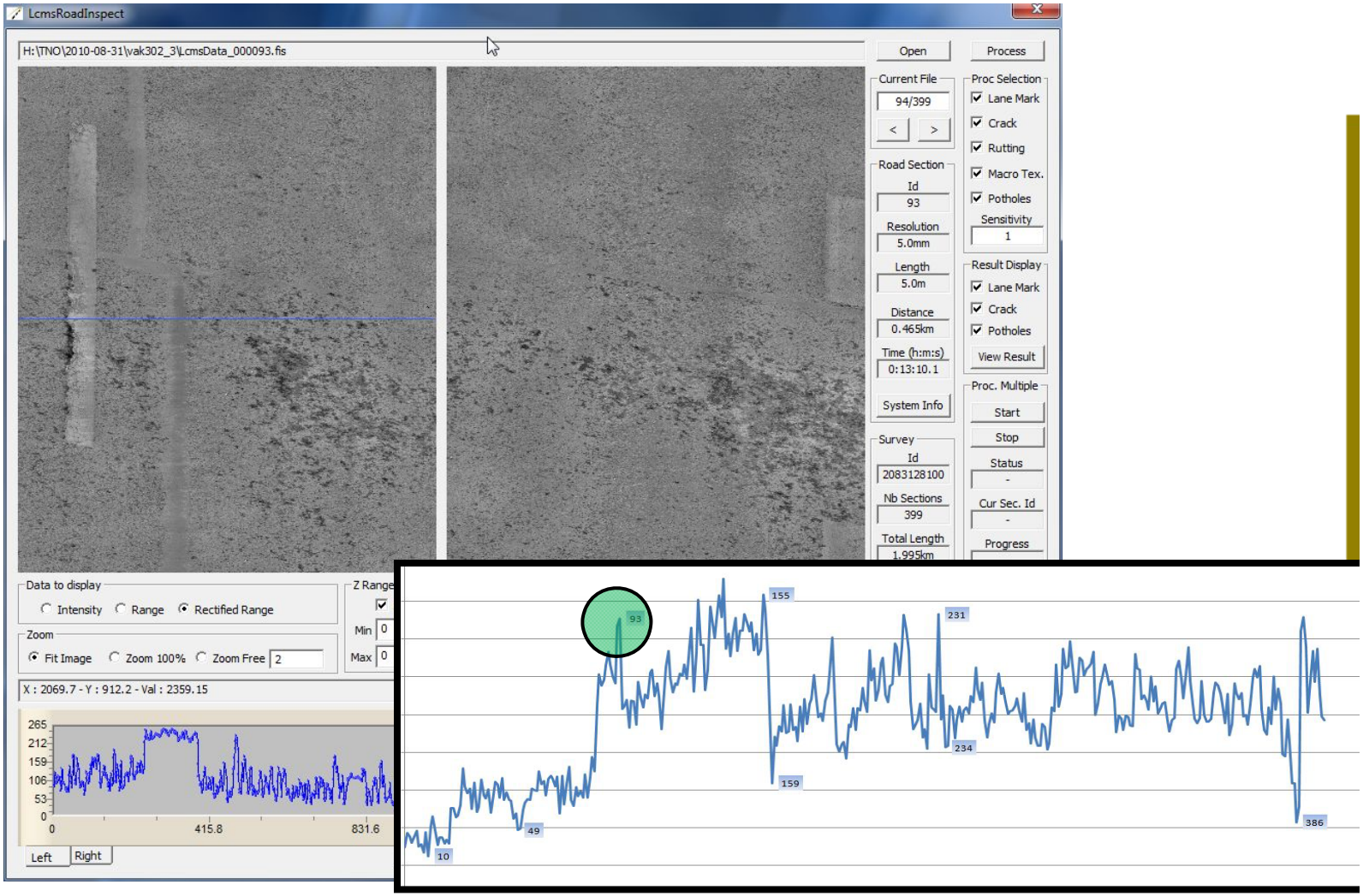


RI – Road test – Porous Asphalt in the Netherlands



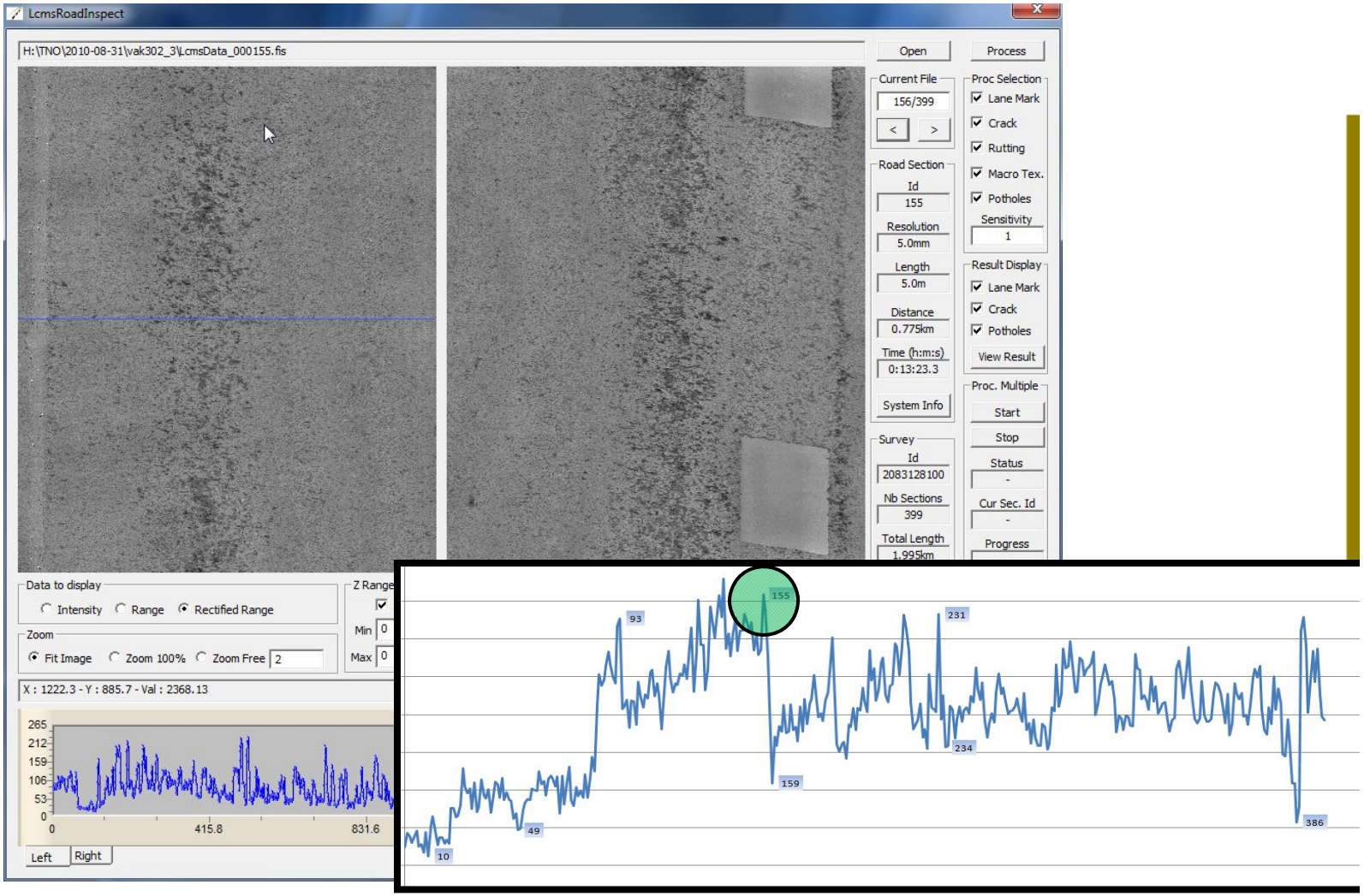
Pavemetrics

Road Section #93 : Transition between Ravelling and new pavement (Range)



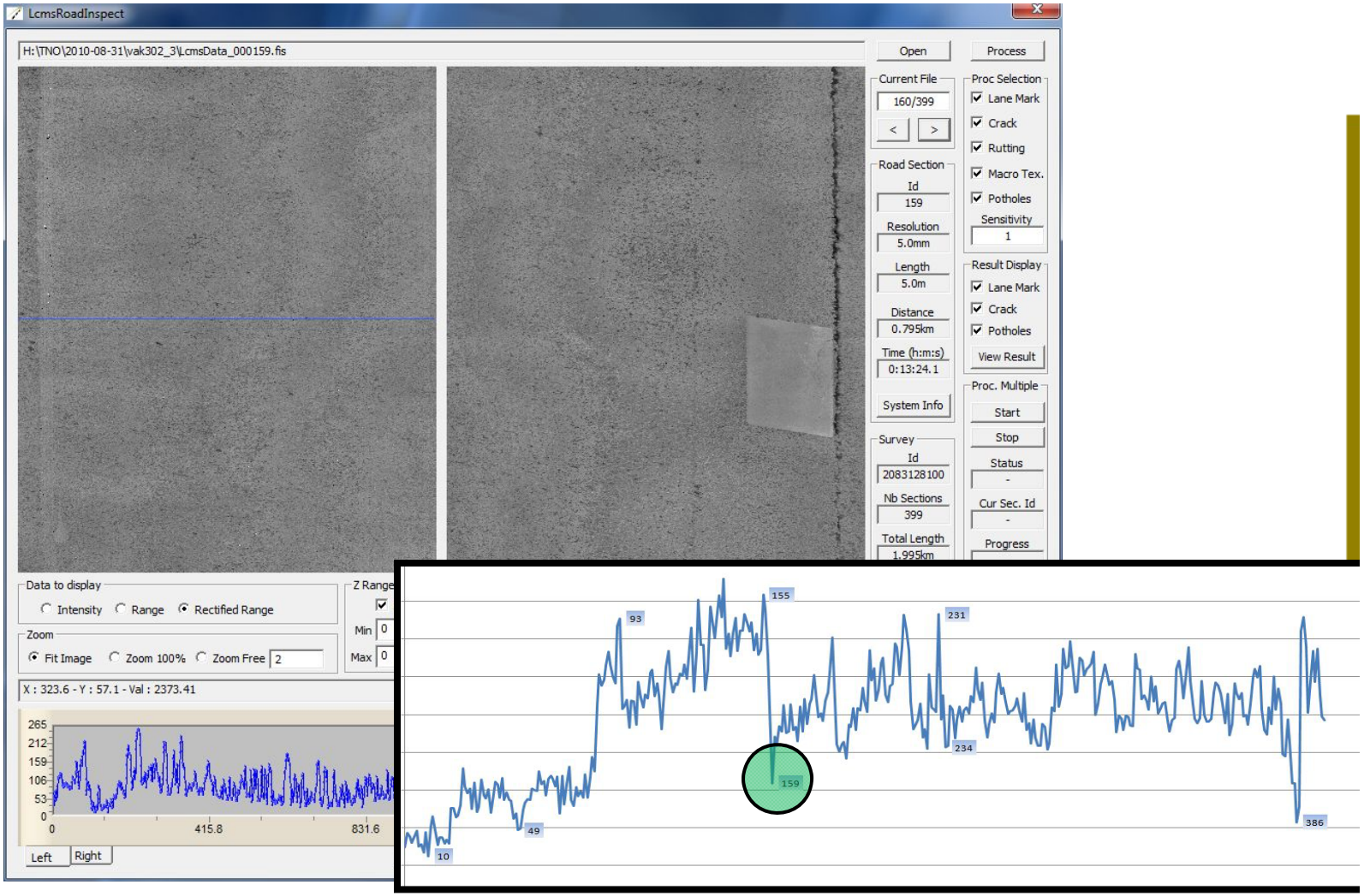
Pavemetrics

Road Section #155 : Raveling patch



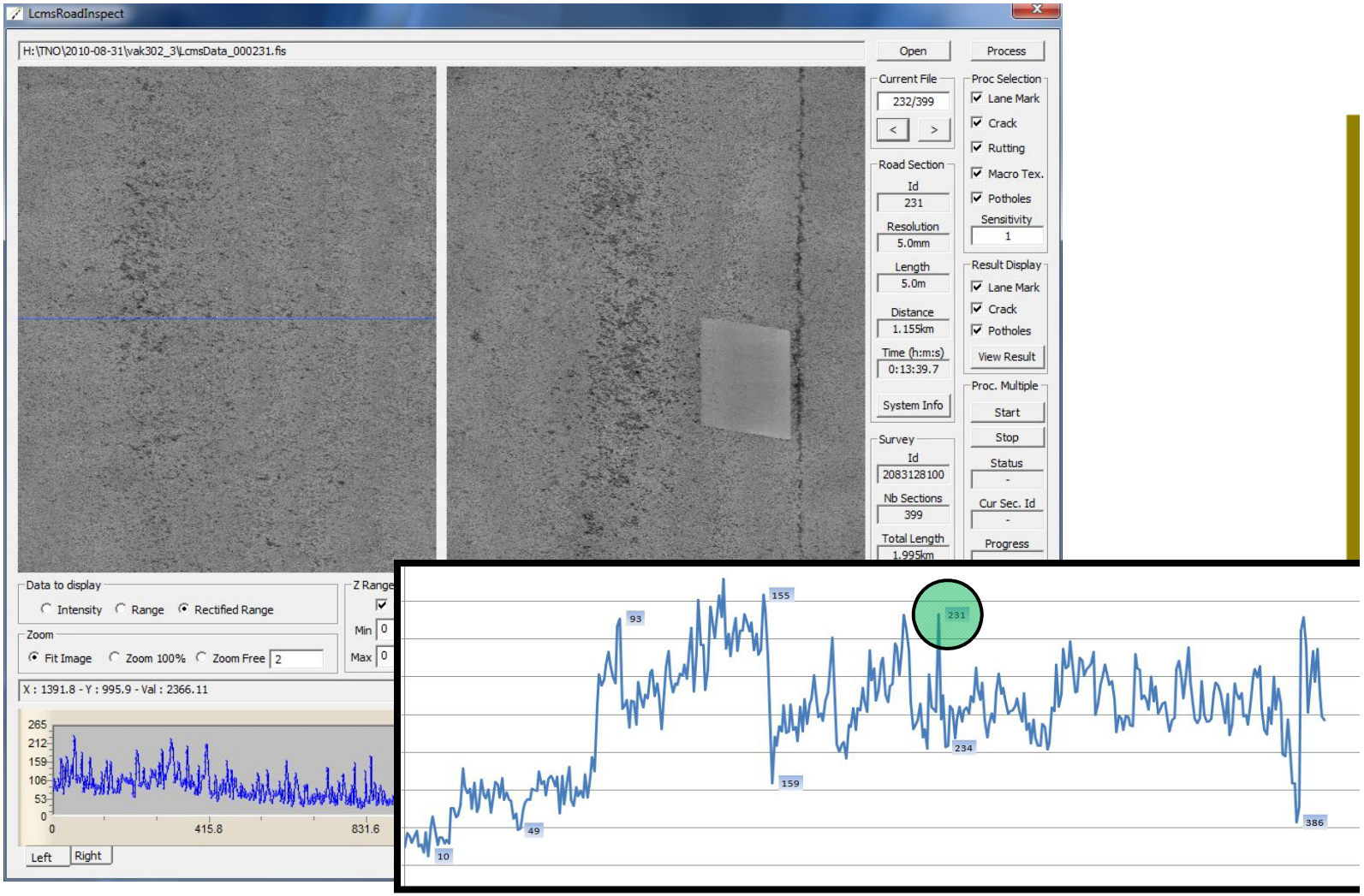
Pavemetrics

Road Section #159 : Smooth texture



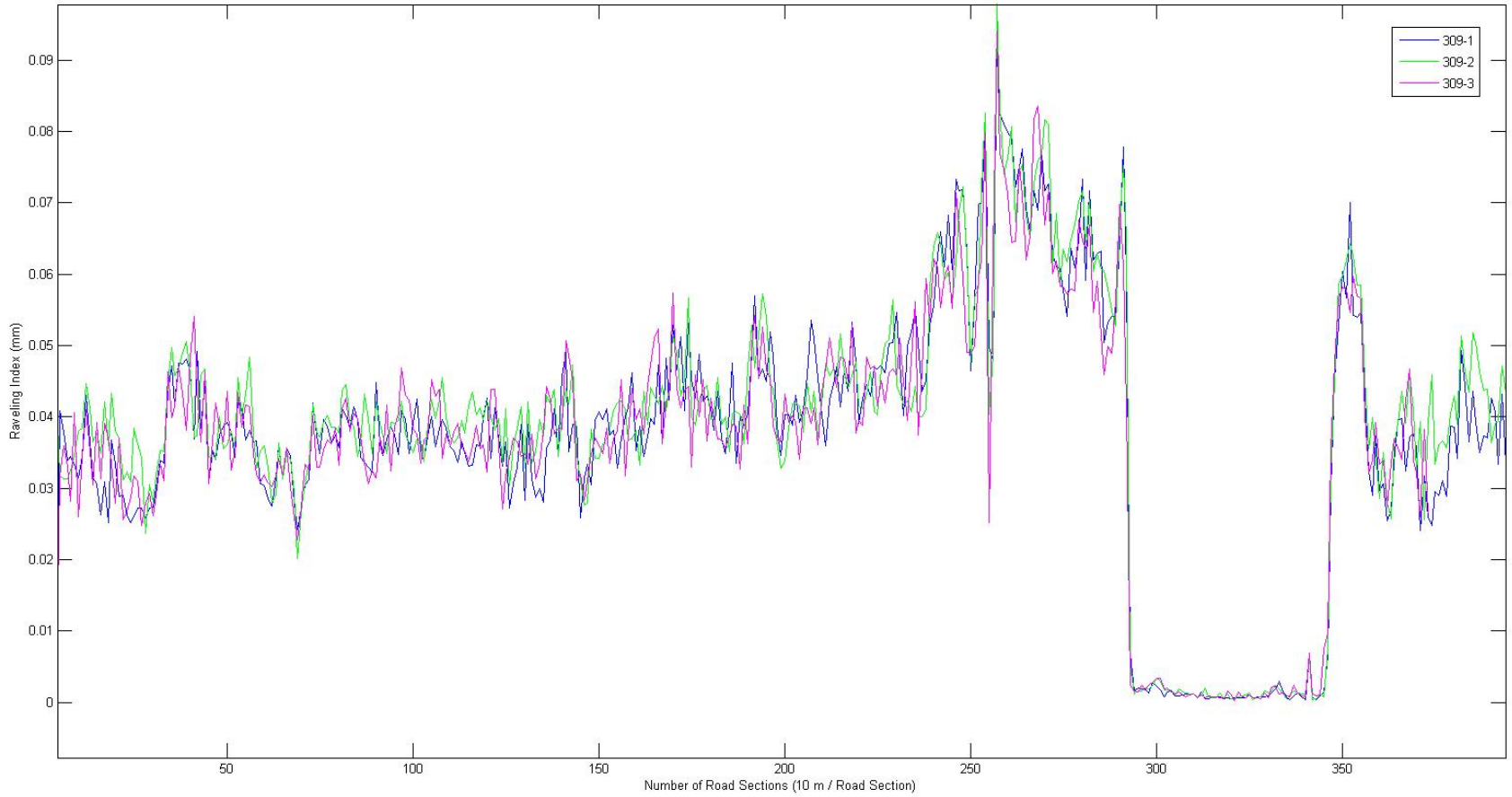
Pavemetrics

Road Section #231 : Raveling patch



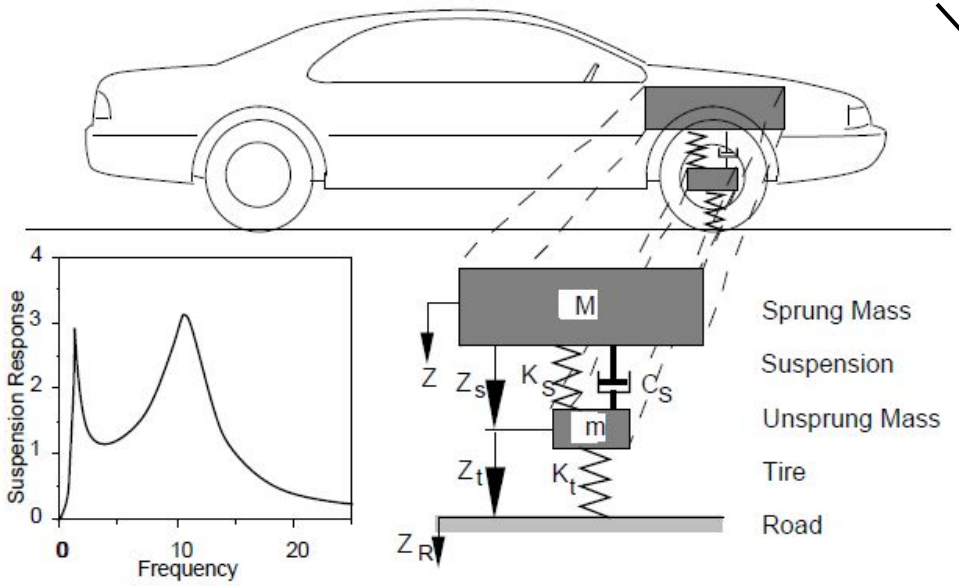
Pavemetrics

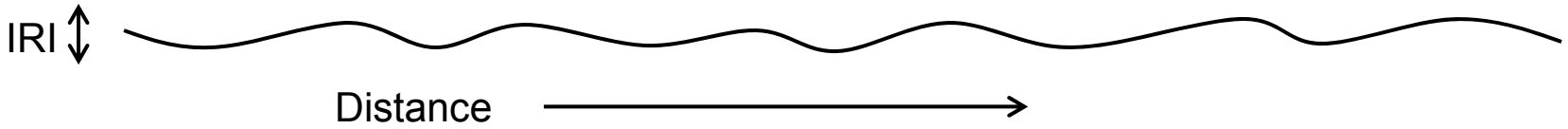
Ravelling Index - Repeatability (Porous asphalt Netherlands)



IRI – Longitudinal profile

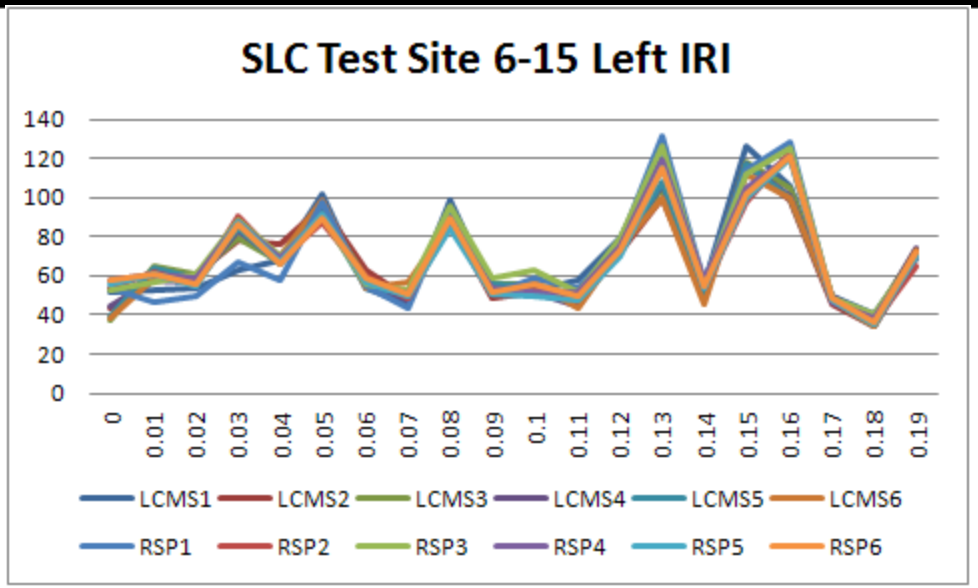
Longitudinal profile and
International Roughness Index (IRI)

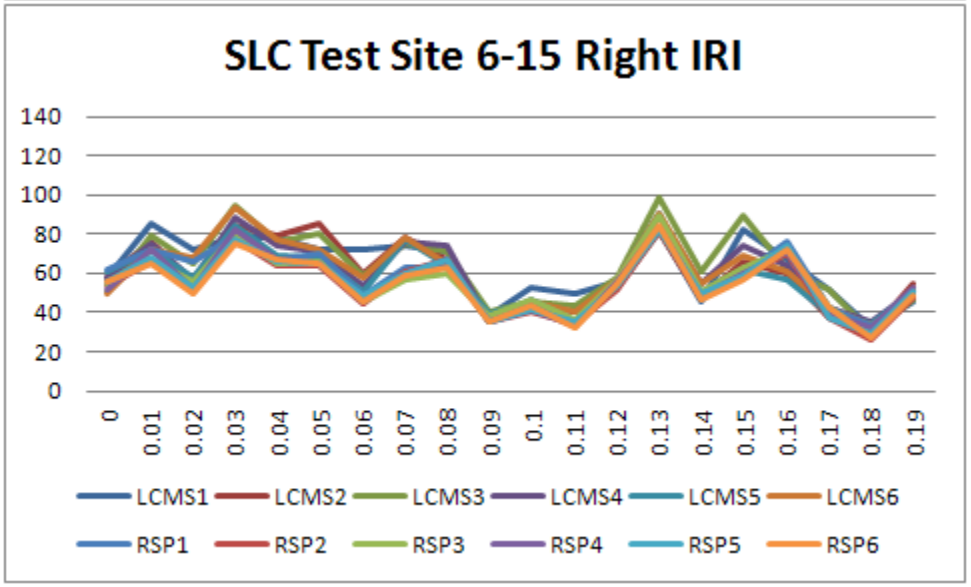




Pavemetrics

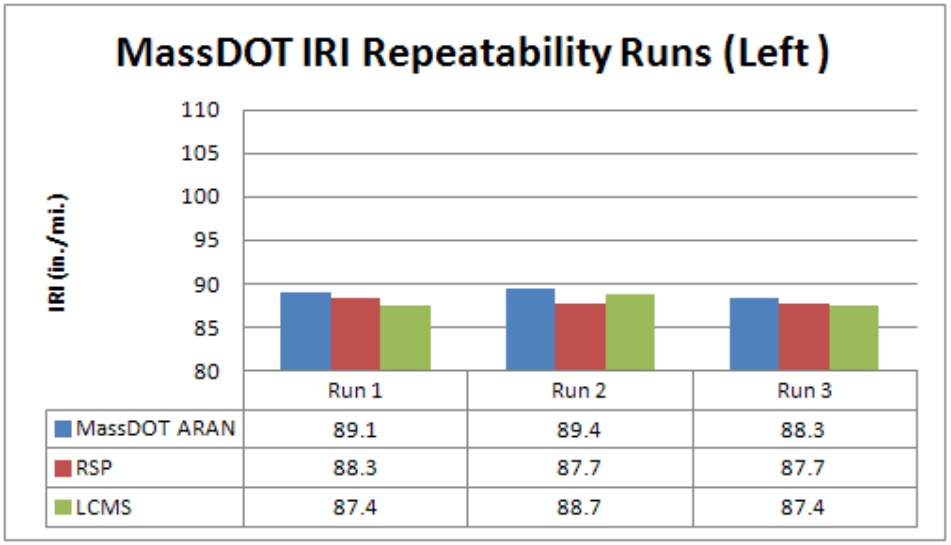
UTAH DOT – Test sites



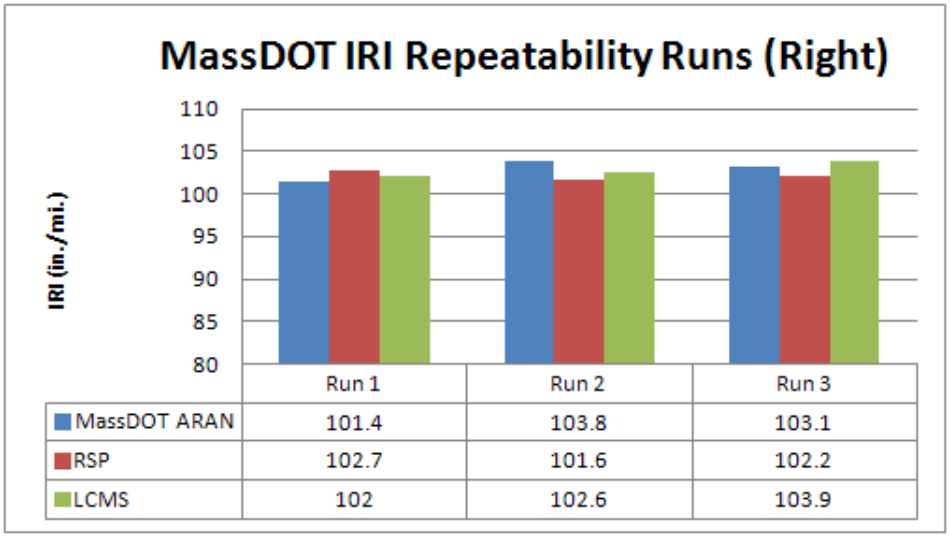


Pavemetrics

MassDOT



	Run 1	Run 2	Run 3
MassDOT ARAN	89.1	89.4	88.3
RSP	88.3	87.7	87.7
LCMS	87.4	88.7	87.4



	Run 1	Run 2	Run 3
MassDOT ARAN	101.4	103.8	103.1
RSP	102.7	101.6	102.2
LCMS	102	102.6	103.9

Pavemetrics

Does it work? LCMS vs Surpro

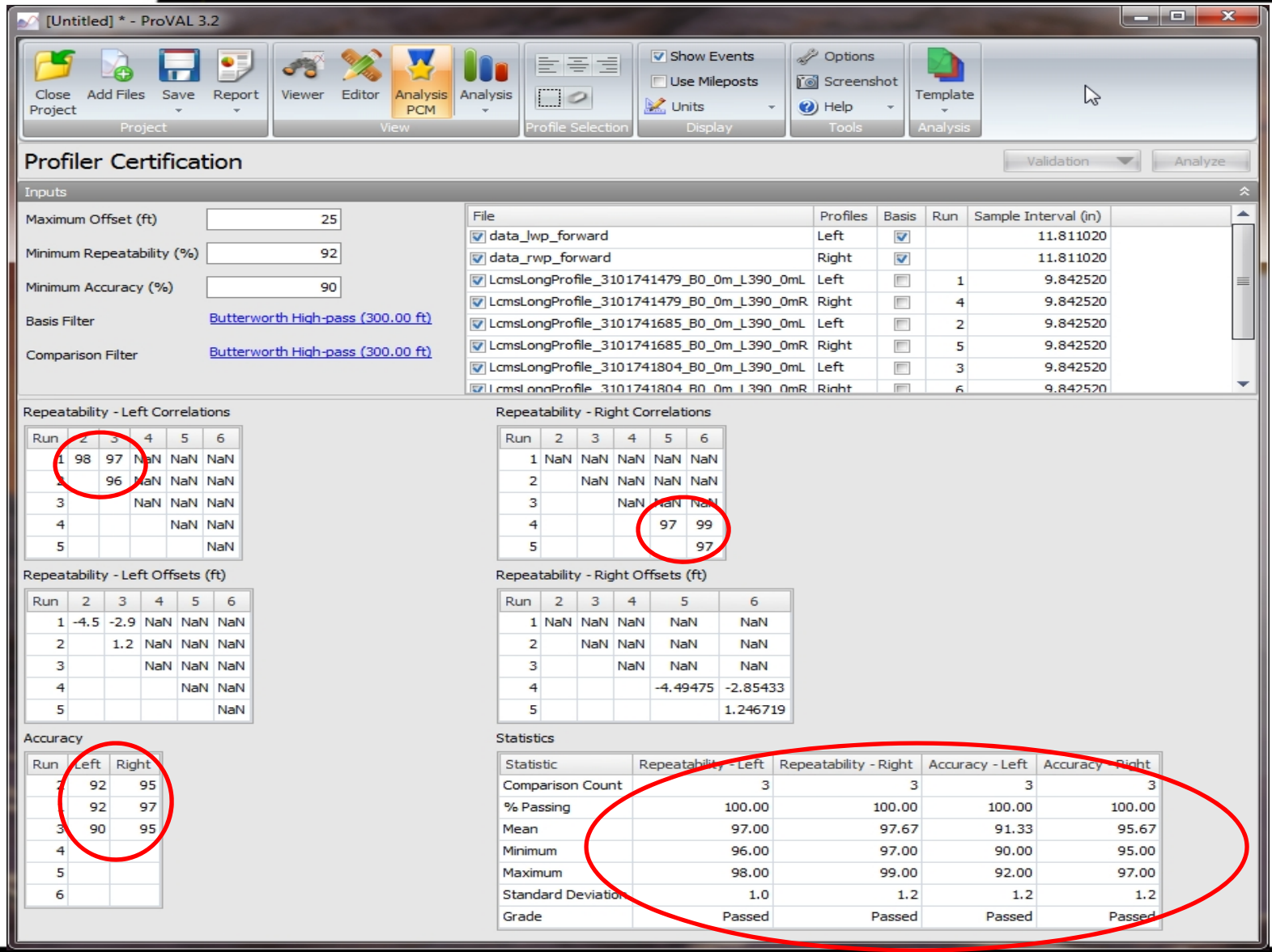
IRI values calculated for 4 LCMS runs on a 400m validation test track

Run	IRI Left (m/km)	IRI Right (m/km)
1	1.19	1.64
2	1.16	1.51
3	1.19	1.54
4	1.21	1.55
Mean	1.19	1.56
Standard deviation	0.02	0.06
Surpro	1.21	1.54

•IRI values are stable and close to the values obtained with the reference instrument (Surpro).

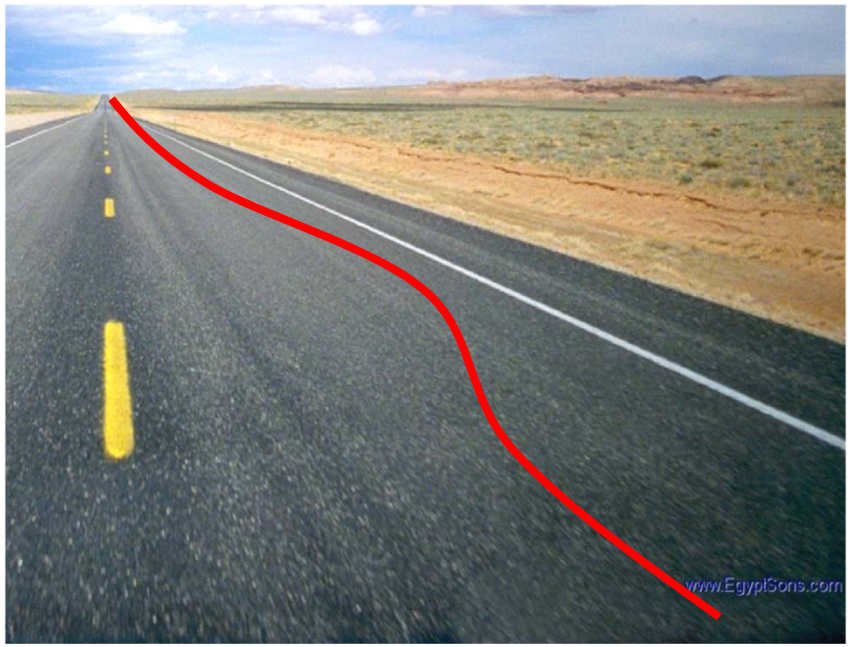
Pavemetrics

LCMS passes Profiler certication in PROVAL

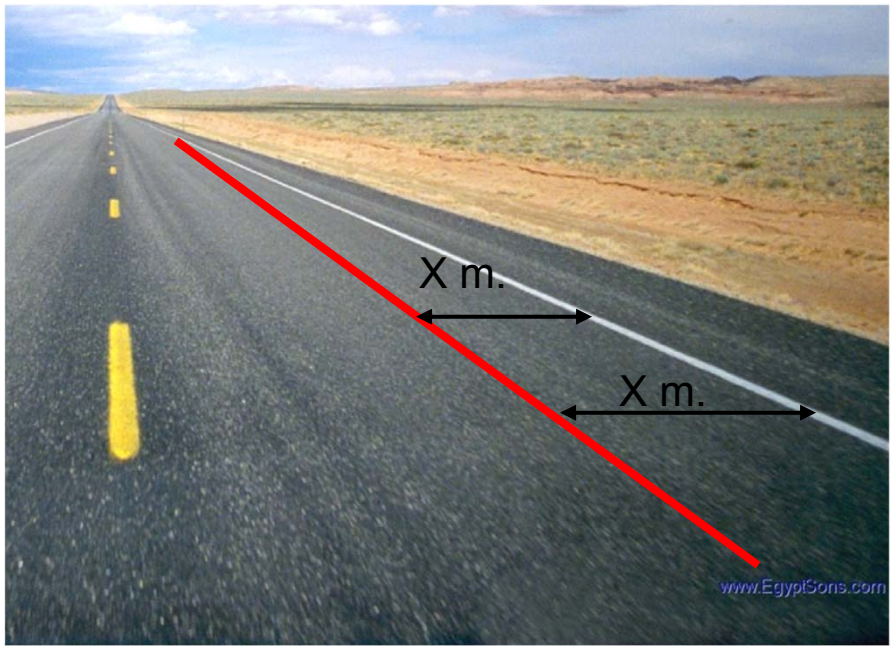


LCMS benefits

- LANE MARKINGS are used to correct profiles and compensate for driver wander.
- Simplifies certification procedures
- Eliminates the need to certify operators



Classic system: Results depend on the trajectory of the vehicle (subject to variation based on driver's ability)



LCMS-IRI system: Erratic trajectory of the vehicle will still result in straight elevation profiles

Pavemetrics

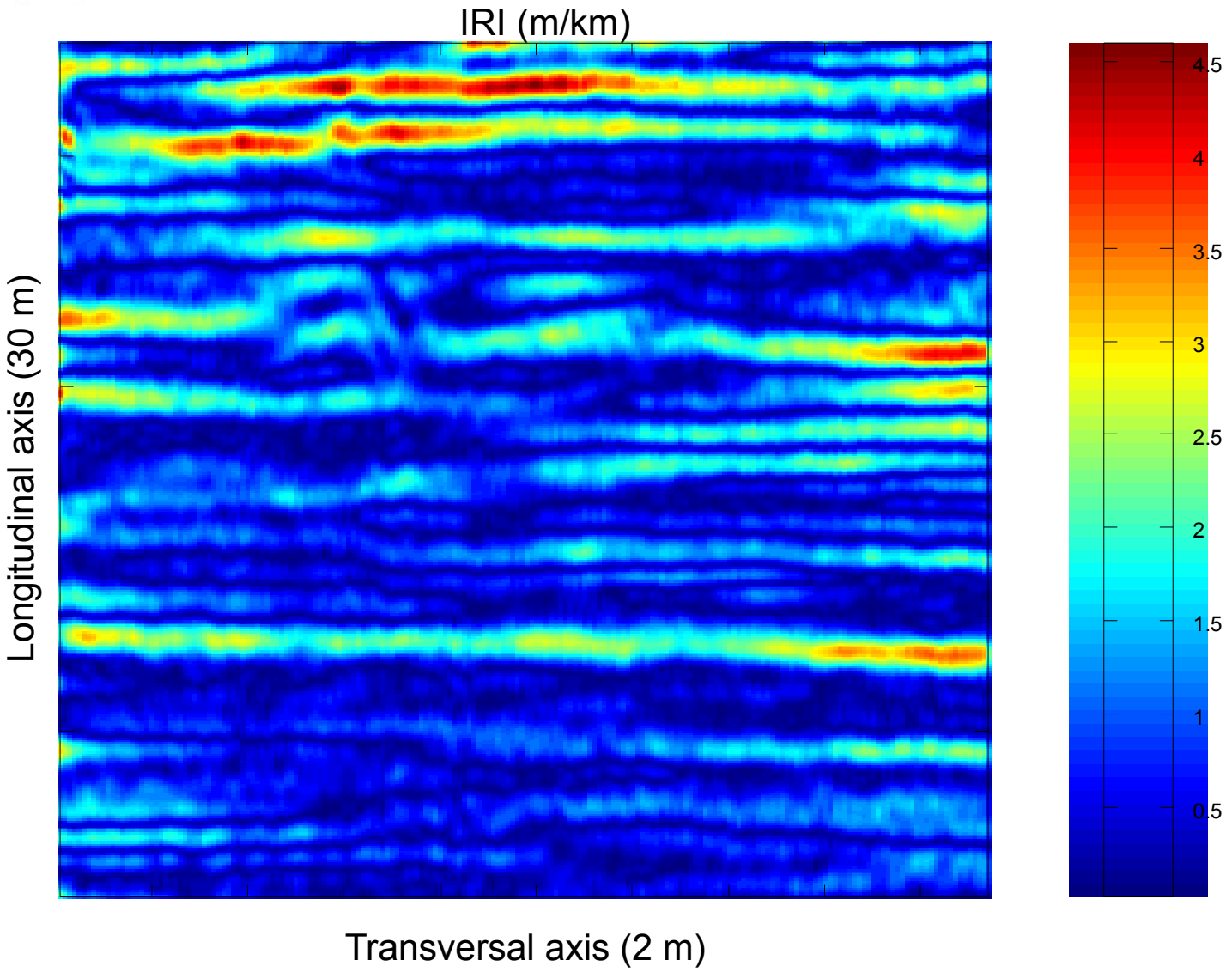
Results: lane tracking

- Driver was asked to zigzag on validation track #1 (400 m).
- Elevation profiles computed with and without lane tracking.

	With lane tracking		No lane tracking	
Run	IRI Left (m/km)	IRI Right (m/km)	IRI Left (m/km)	IRI Right (m/km)
1	1.33	1.50	1.16	1.43
Reference value	1.29	1.47	1.29	1.47
Difference	3.1%	2.0%	10.1%	2.7%

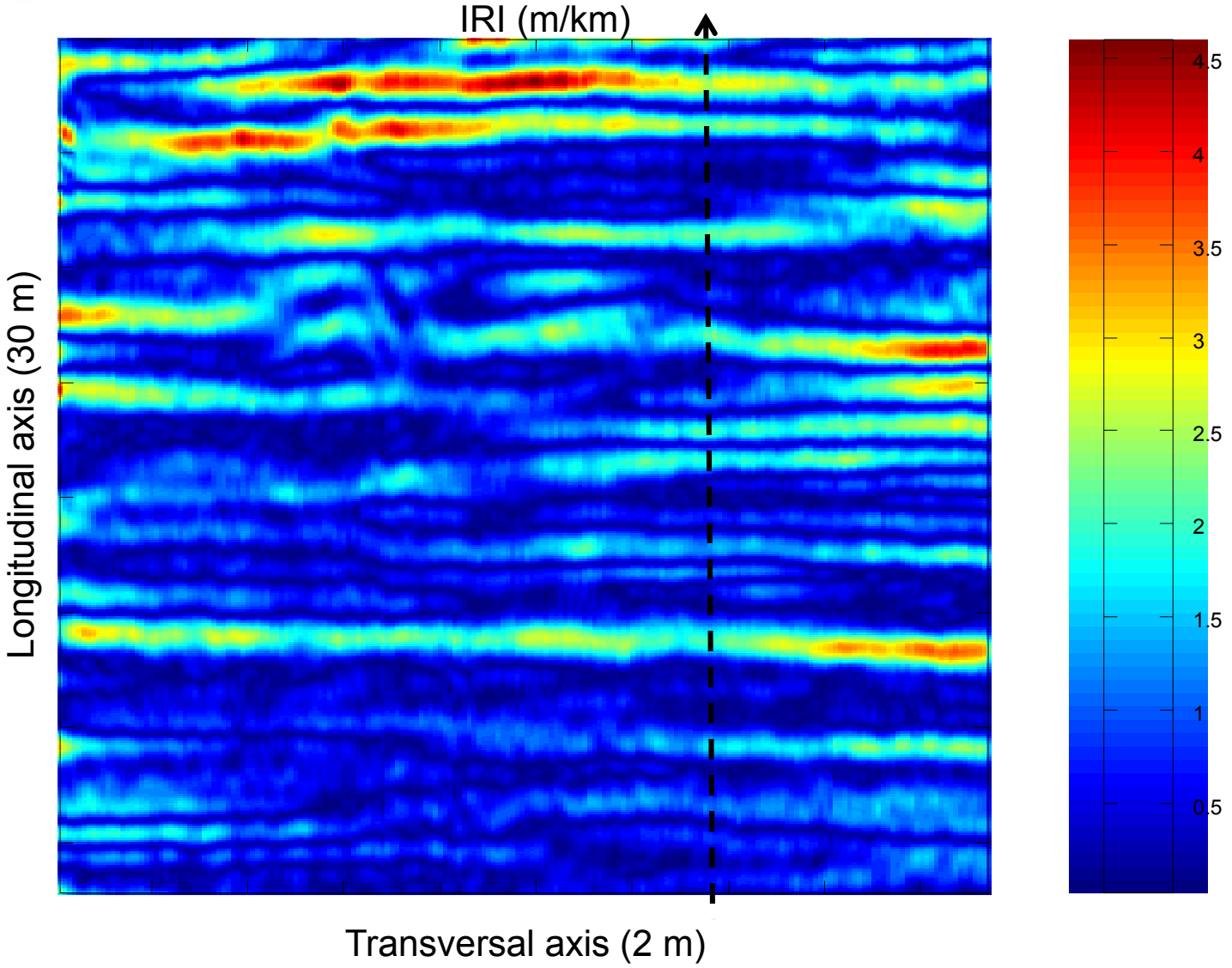
Pavemetrics

Results: IRI image (2 x 30m)



Pavemetrics

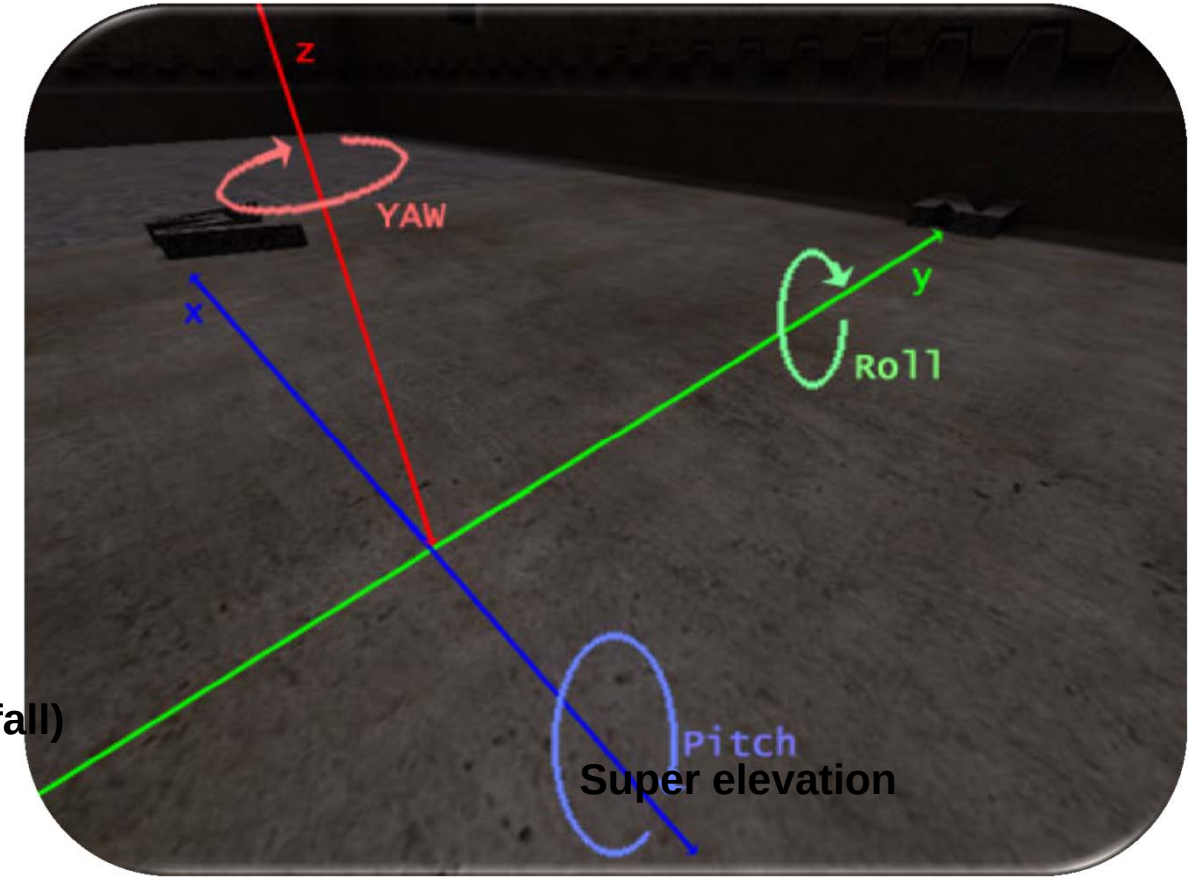
Results: IRI image (2 x 30m)



Road Geometry Measurement

Pavemetrics

Cross slope (Cross-fall)

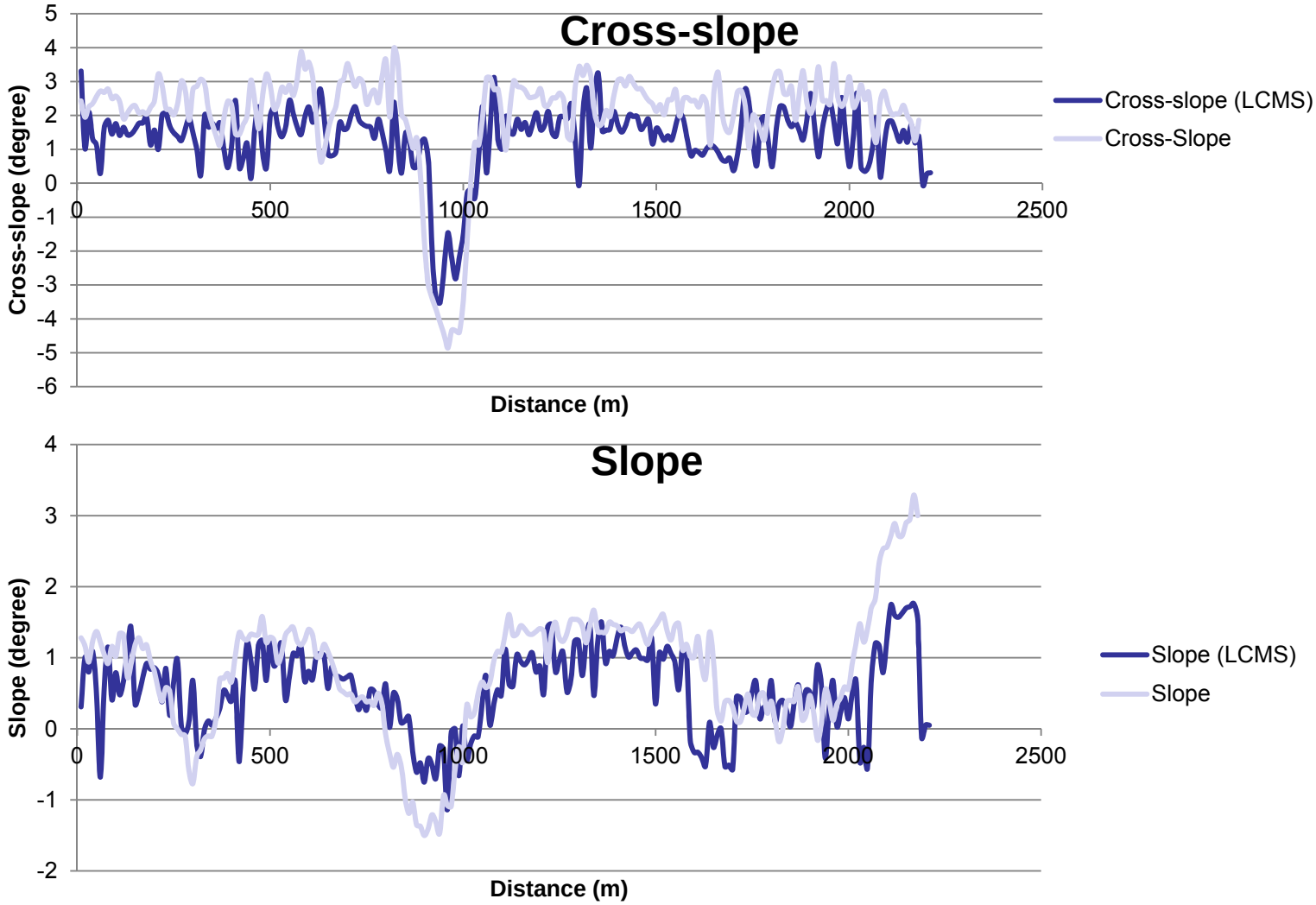


Super elevation

Horizontal Curvature

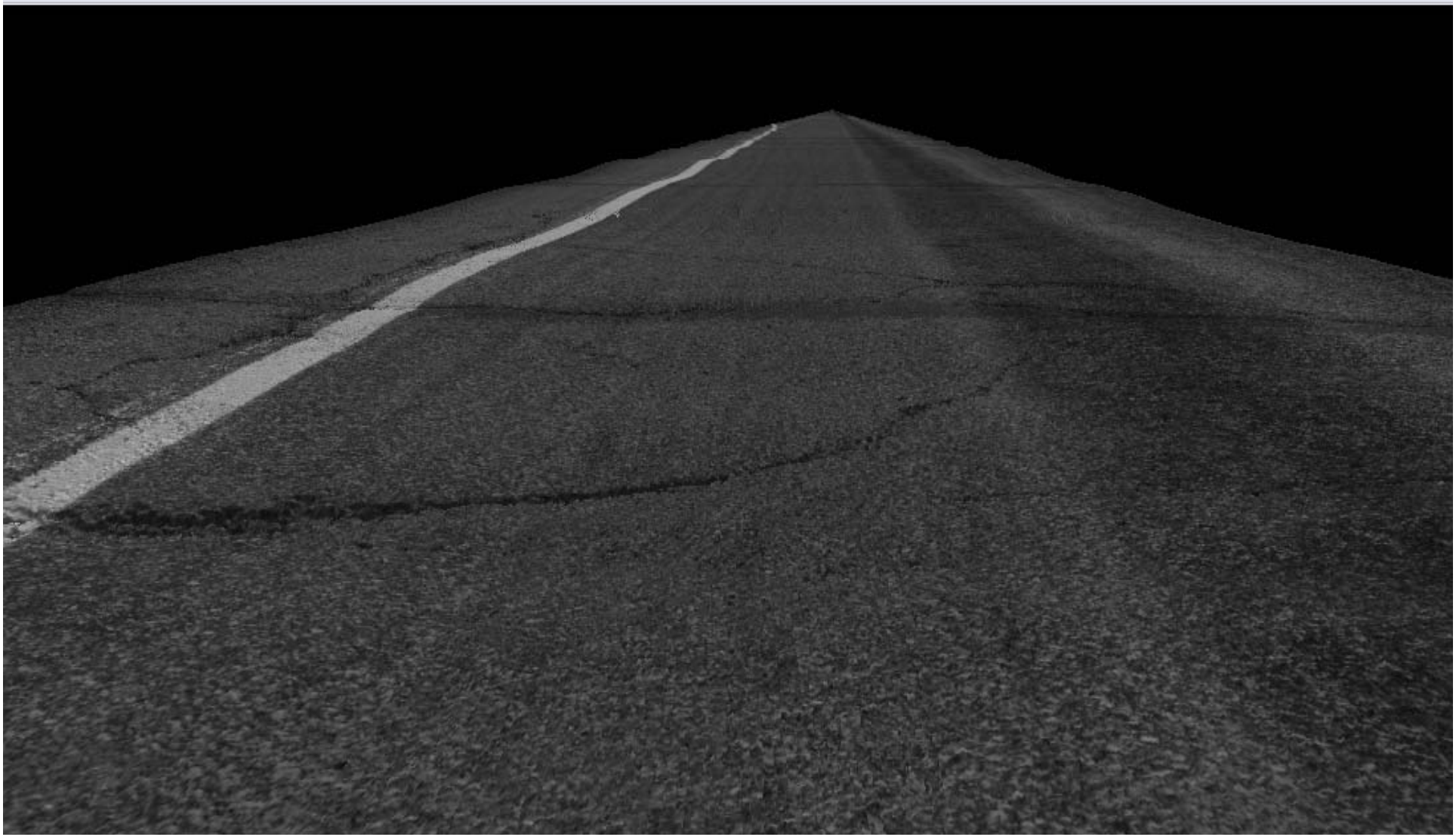
Pavemetrics

Road tests - Geometry



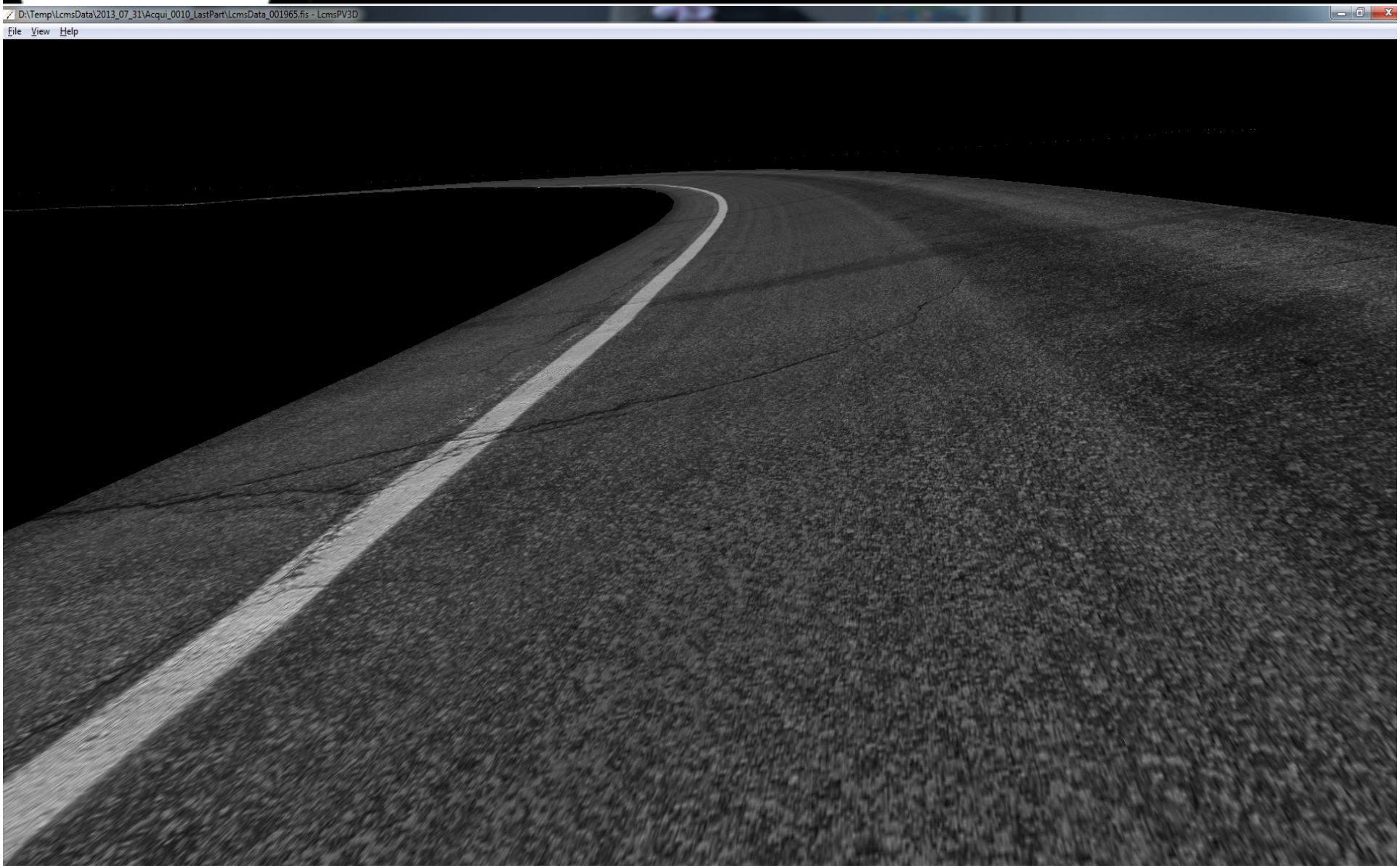
Pavemetrics

3D Road Profile Before Geometric Corrections



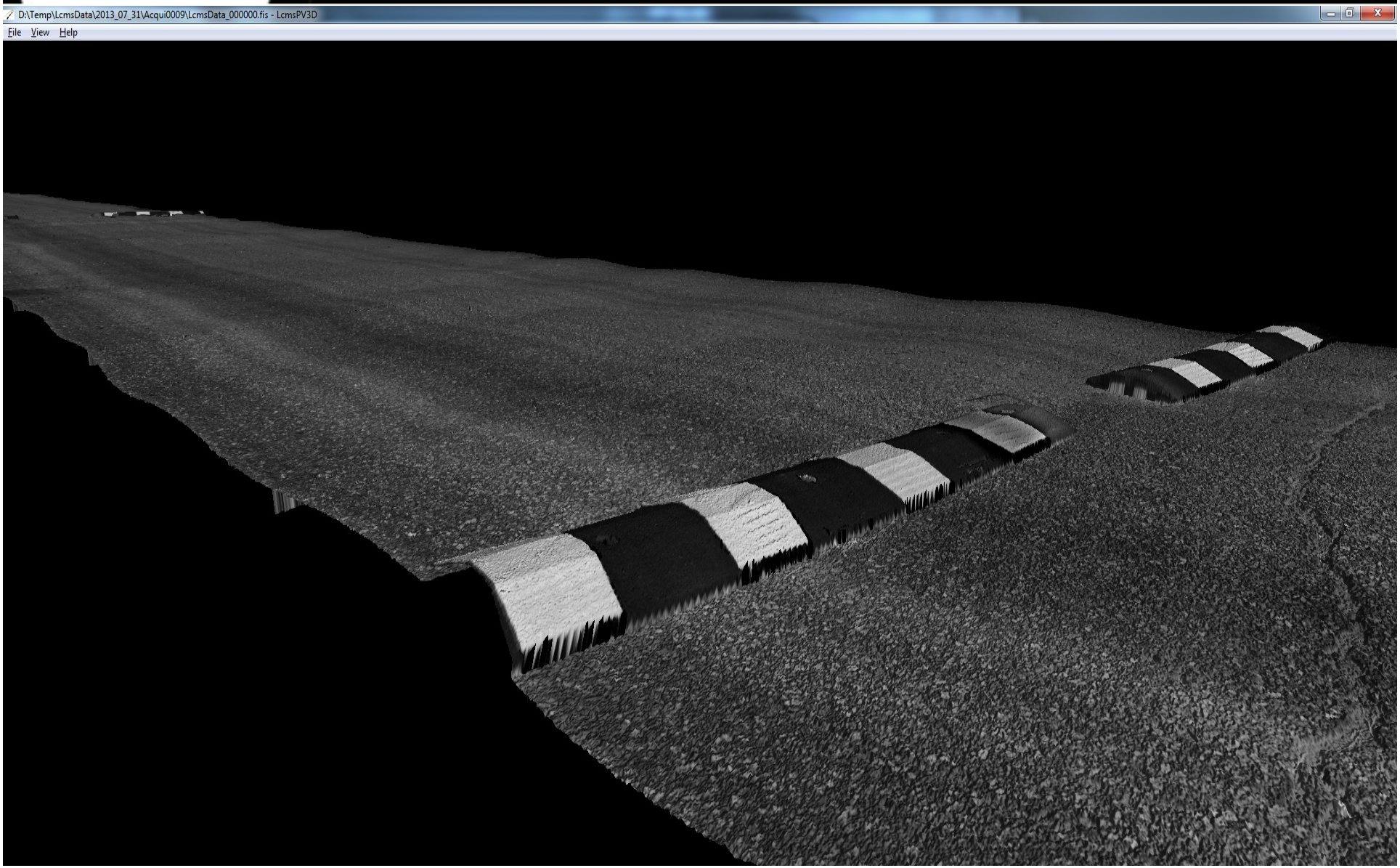
Pavemetrics

3D Road Profile After Geometric Corrections



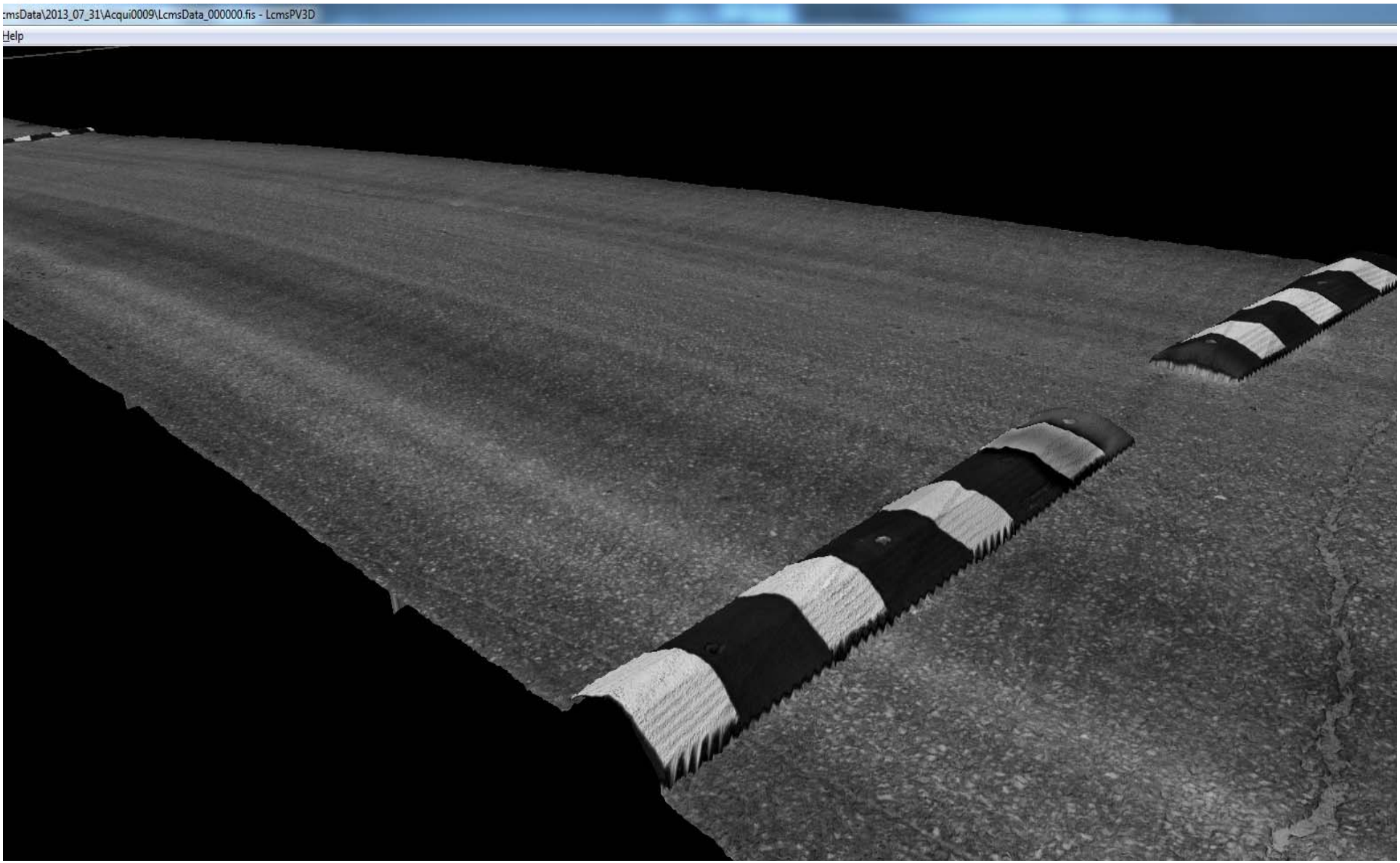
Pavemetrics

3D Road Profile Before Geometric Corrections



Pavemetrics

3D Road Profile After Geometric Corrections



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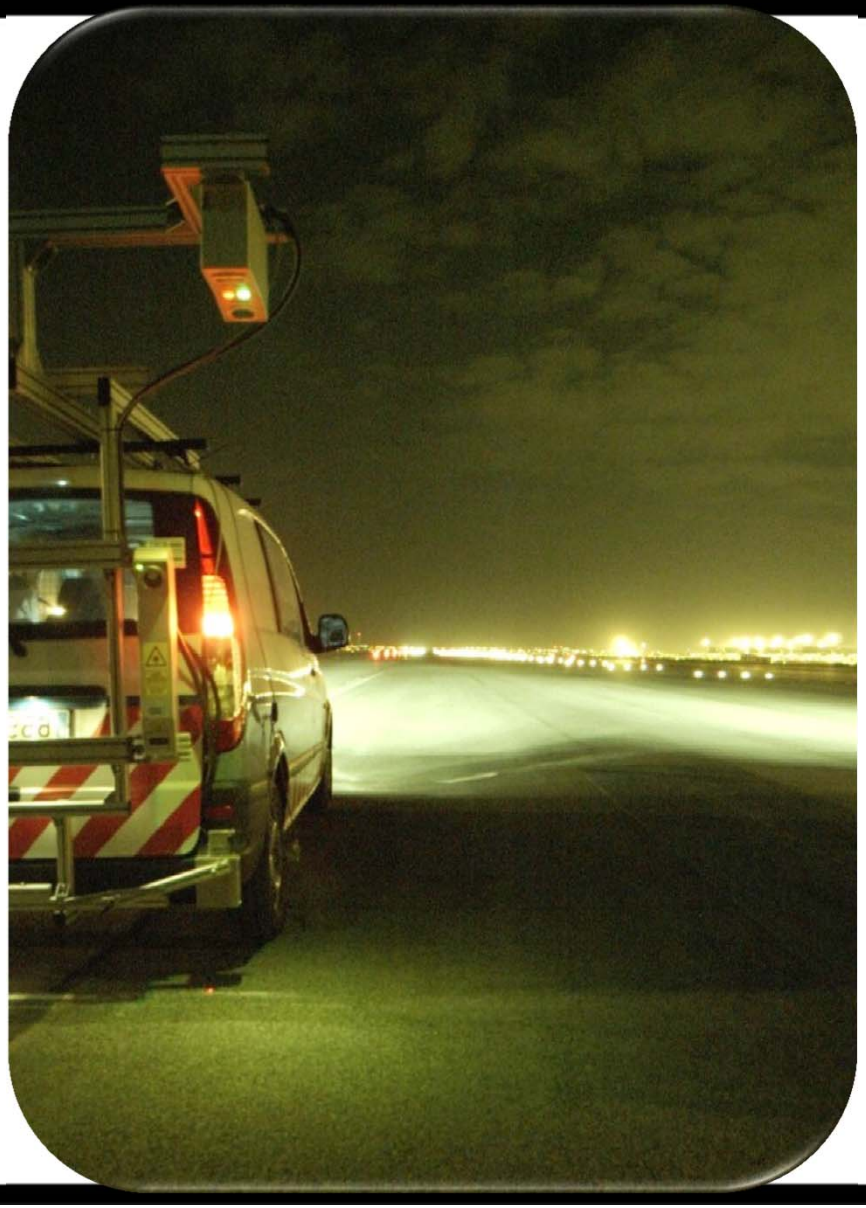
Any questions ?



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