

The logo features a large white circle on a black background. Inside the circle, the word "Pavemetrics" is written in a yellow sans-serif font. Below the text, there is a yellow curved line that ends in a small hook, with three short black dashed lines positioned underneath it.

Pavemetrics

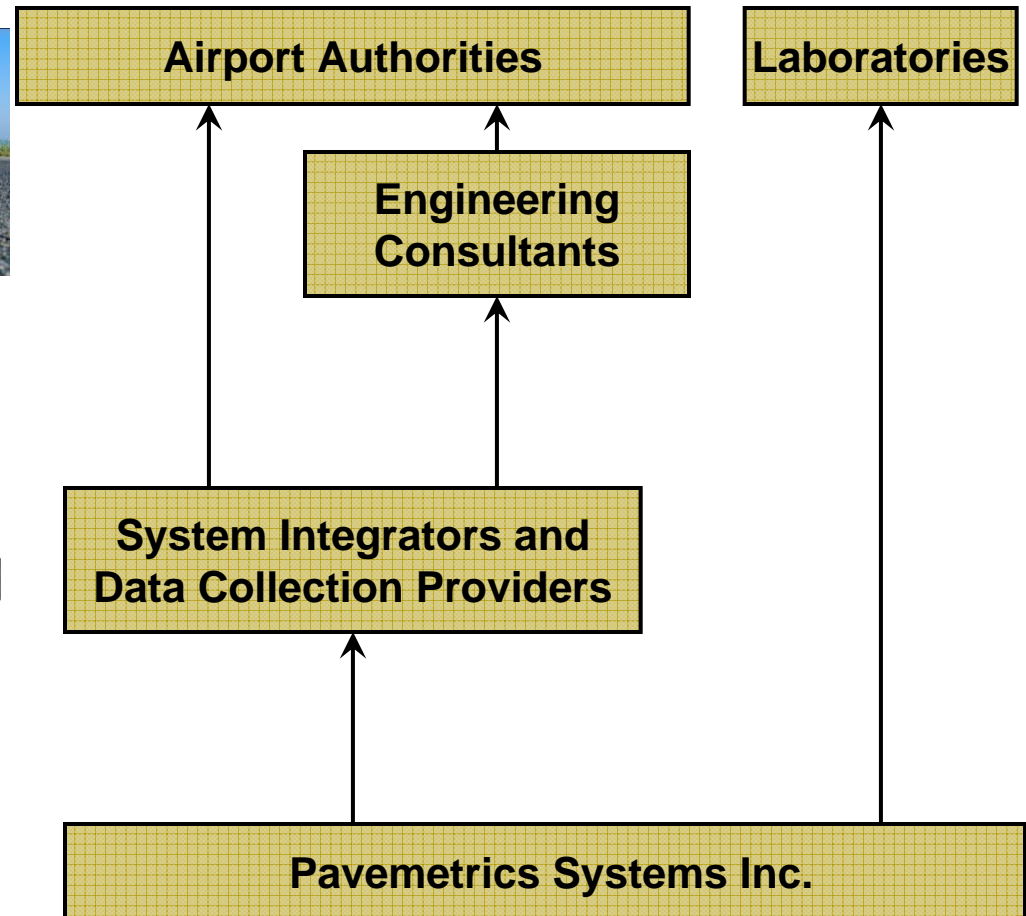
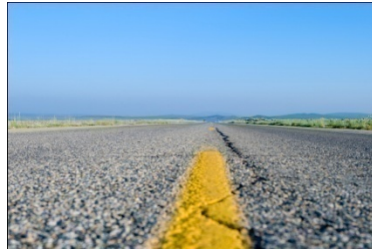
SWIFT 2011 - Laser Crack Measurement System (Barcelona Airport survey)

Vision Technology for Inspection of Transportation Infrastructures

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Countries using Pavemetrics systems for road inspection

- **80% of USA state DOTs**
- **Canada**
- **Australia**
- **New Zealand**
- **England**
- **France**
- **Italy**
- **Switzerland**
- **Denmark**
- **Spain**
- **Netherlands**
- **Korea**
- **China**
- **India**
- **Brazil**
- **South Africa**
- **Mexico**
- **Poland**
- **Koweit**
- **United Arab Emirates**
- **Ireland**
- **Nigeria**
- **Israel**
- **Chile**
- **Sweden**

World wide Users and Integrators

- Dynatest (Denmark)
- Fugro- Roadware (Canada)
- Trimble – Geo 3D (Canada)
- Mandli (USA)
- ICC (USA)
- Vectra (France)
- LCPC (France)
- Colas (France)
- Transport Research Lab (UK)
- WDM (UK)
- Yotta (UK)
- SNC Lavalin (Canada)
- Romdas (New Zealand)
- Euroconsult (Spain)
- AEPO (Spain)
- RWW (Netherlands)
- TipTop (China)
- Faropt (China)
- Ramboll (Sweden)
- Ontario Ministry of Transportation
- KICT (Korea)
- Kohat (Korea)
- Trimble – Geo 3D
- Semic (Mexico)
- Infralab (Switzerland)
- Sineco (Italy)
- Stantec (USA)
- Infrastructure Management Group (Australia)
- ARRB (Australia)
- Saskatchewan Highways (Canada)
- Manitoba Highways (Canada)
- Quebec Ministry of Transport (Canada)
- University Georgia Tech.
- University of Alabama
- University of Manitoba
- Porto Rico DOT
- City of Los Angeles
- City of New York
- City of Tucson
- **Abu Dhabi Airport**

TimeLine and sensors history

R&D project with the MTQ to develop a laser rutting system

Roadware is the first integrator to embrace the LRMS technology

A technological revolution: a prototype of a 3D crack detection system is developed and tested on the road (**LCMS 140Hz**)

Acquisition rate of the **LCMS** is decupled to 1400Hz. Development of the algorithms.

The MTQ tests the **LCMS** 1400Hz on a survey level: 15 000 km of roads are collected.

The **LCMS** 11,200Hz version is tested in Holland for the detection of ravelling in porous asphalt.

1995...

2000

2002

2004

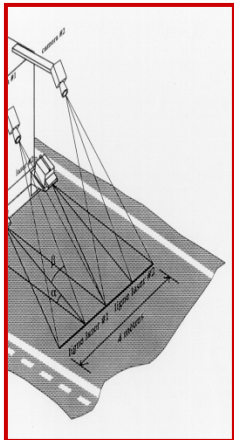
2006

2008

2009

2010

2011



MTQ operates the first LRSM. It collects 4m transverse profiles at 25Hz



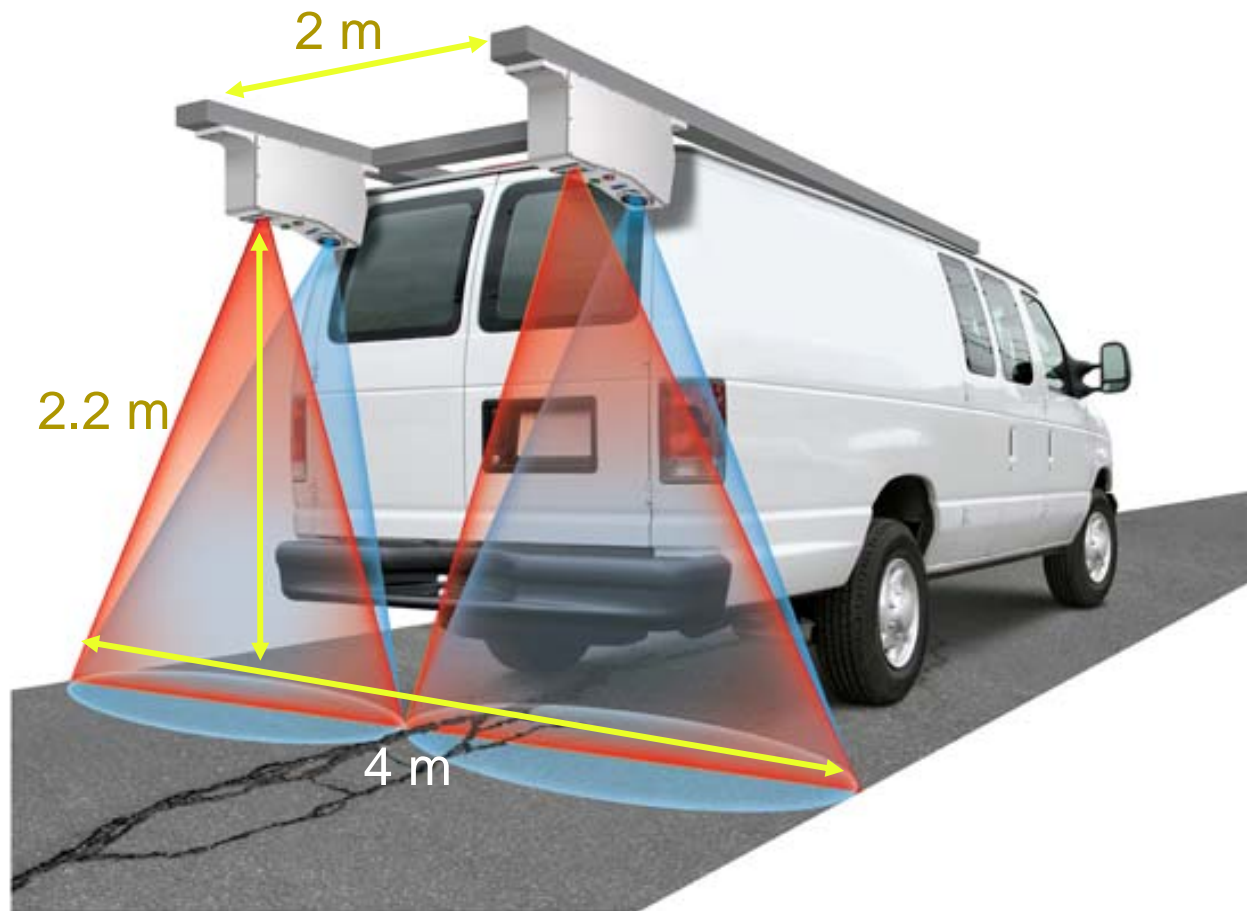
LRMS is now faster : High Speed version now captures 3D profiles at 150Hz



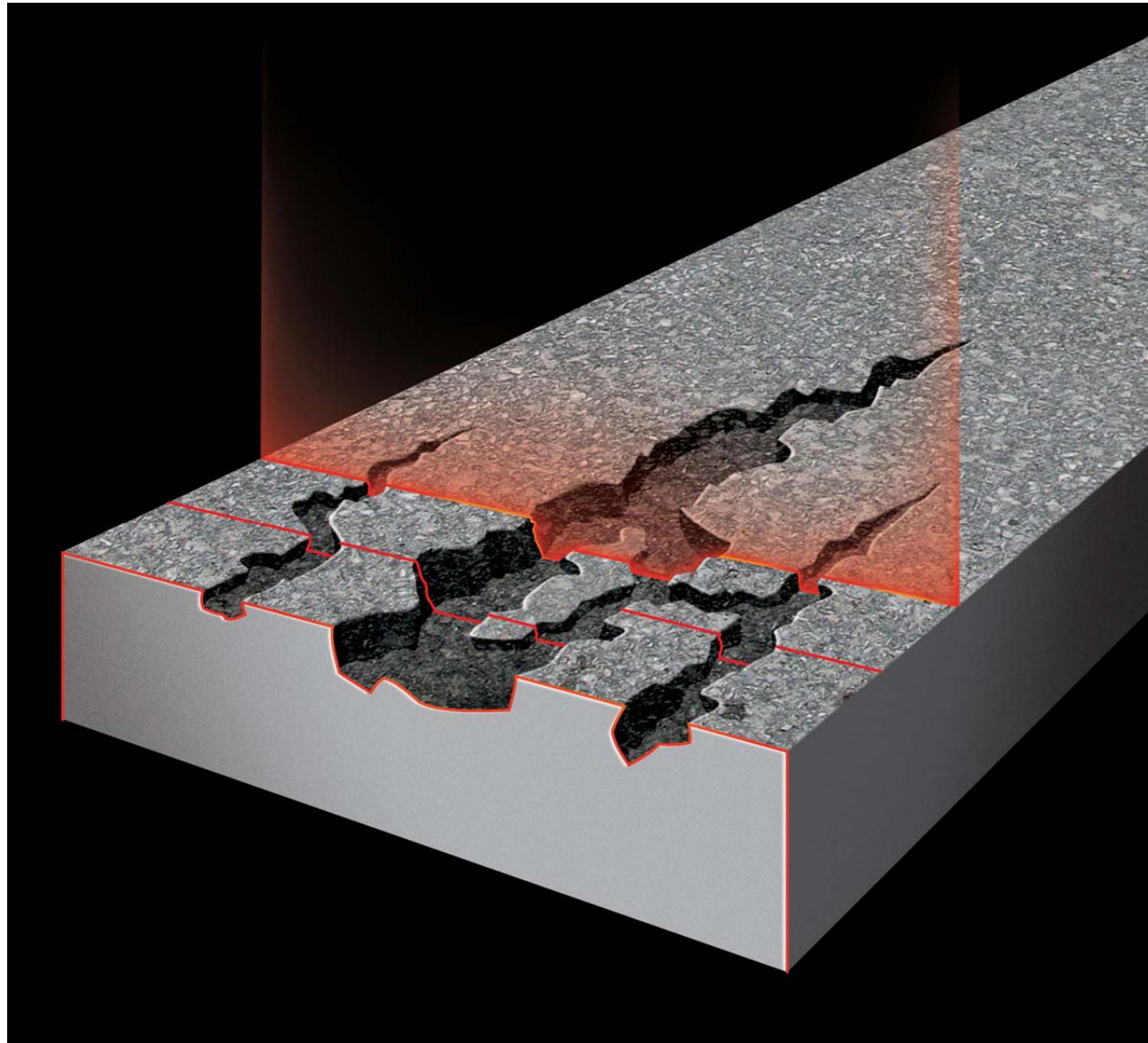
LRIS is introduced. 1mm road images with crack enhancement is now possible!



LCMS 5600Hz is commercialized. Let the latest generation our 3D road sensor surprise you!

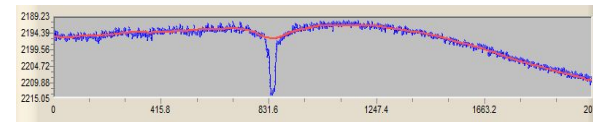
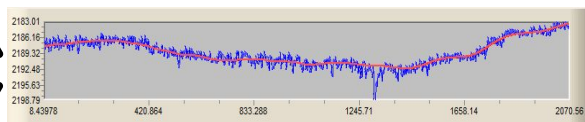


Laser profiling (principle)



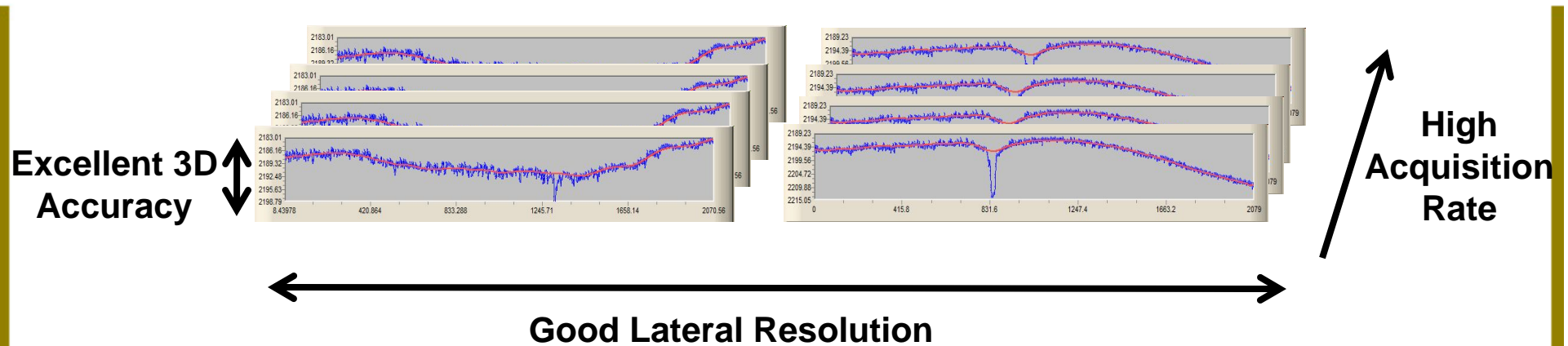
What makes a 3D sensor very good for crack measurement?

Excellent 3D
Accuracy



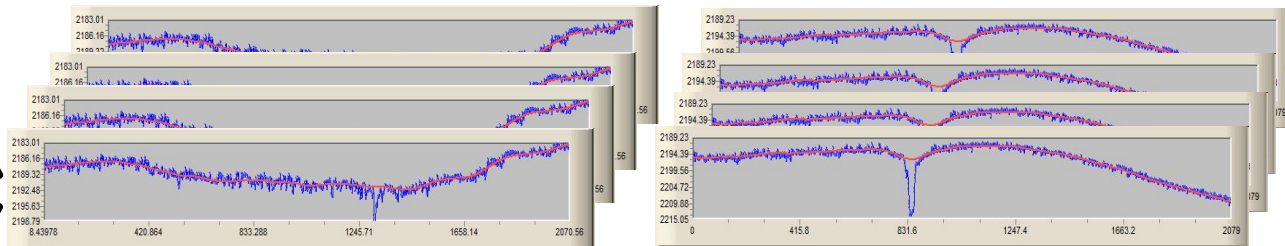
Good Lateral Resolution

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



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

**Excellent 3D
Accuracy**



Good Lateral Resolution

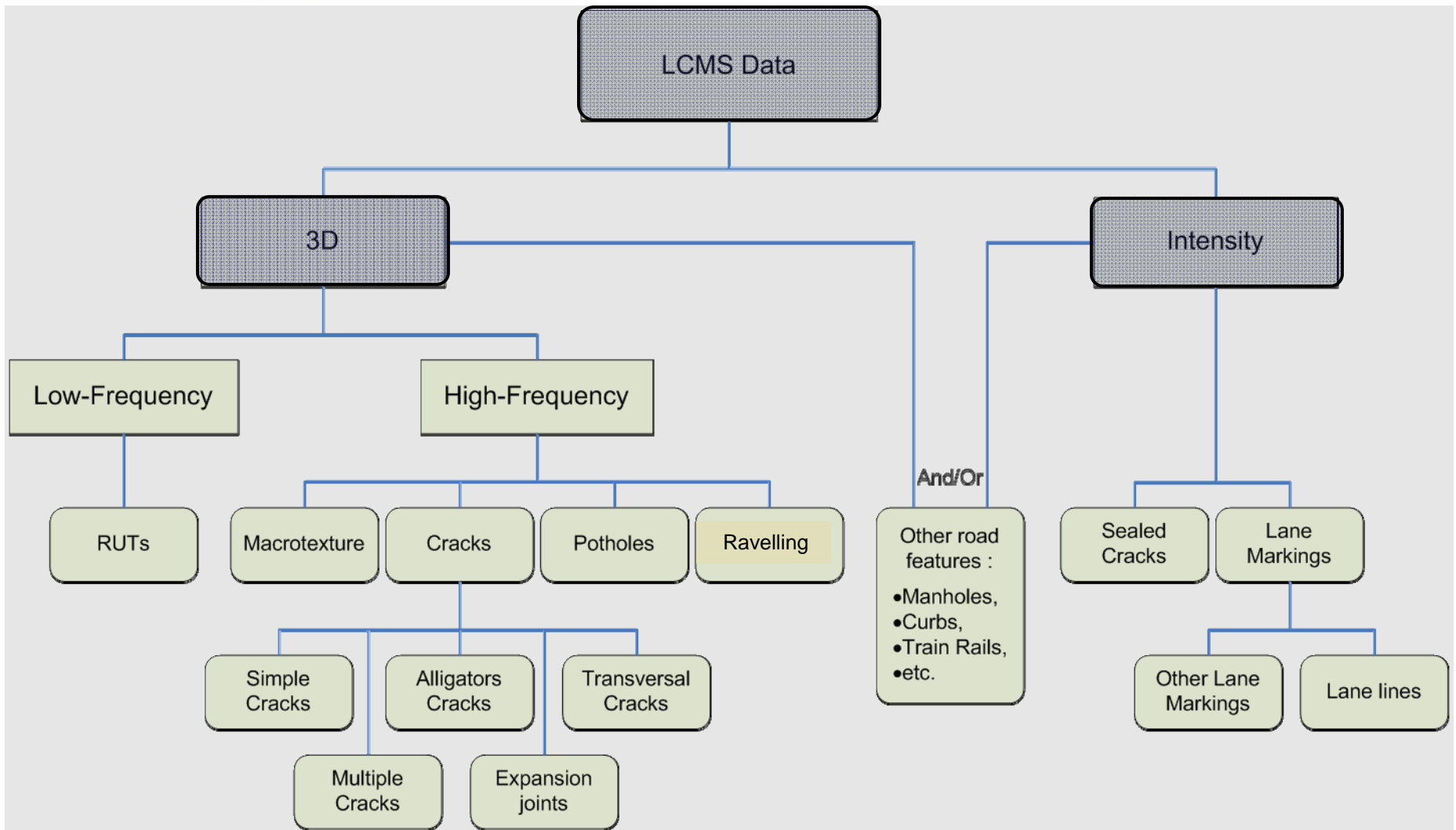
**High
Acquisition
Rate**



LCMS Specifications

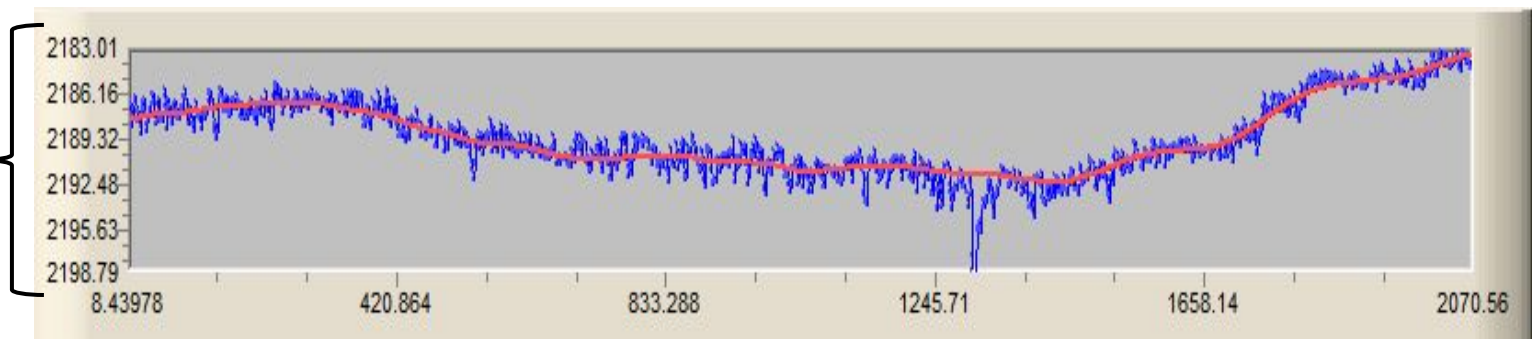
Acquisition Rate	11,200 profiles/s
Range Accuracy	0.5mm
Lateral Resolution	1mm (FOV = 4m)

LCMS Data Processing Tree



Single Road Profile (2 meter)

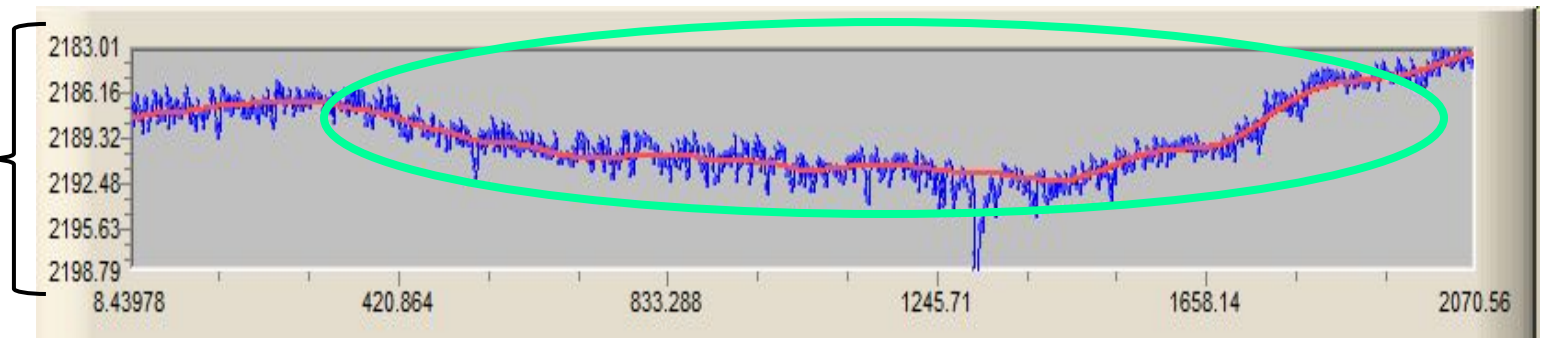
Distance
between Sensor
and ground
(in mm)



Single Road Profile (2 meter)

Rut

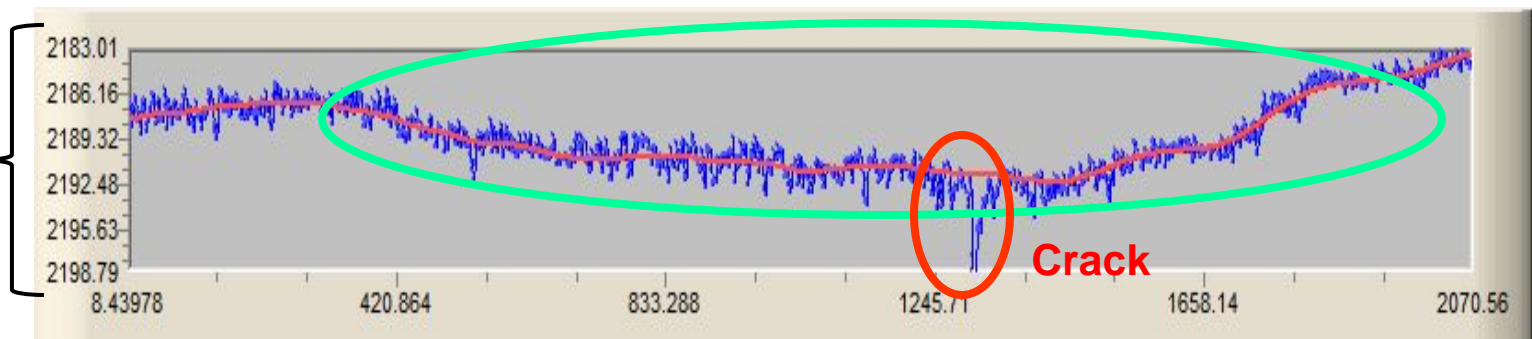
Distance
between Sensor
and ground
(in mm)



Single Road Profile (2 meter)

Rut

Distance
between Sensor
and ground
(in mm)

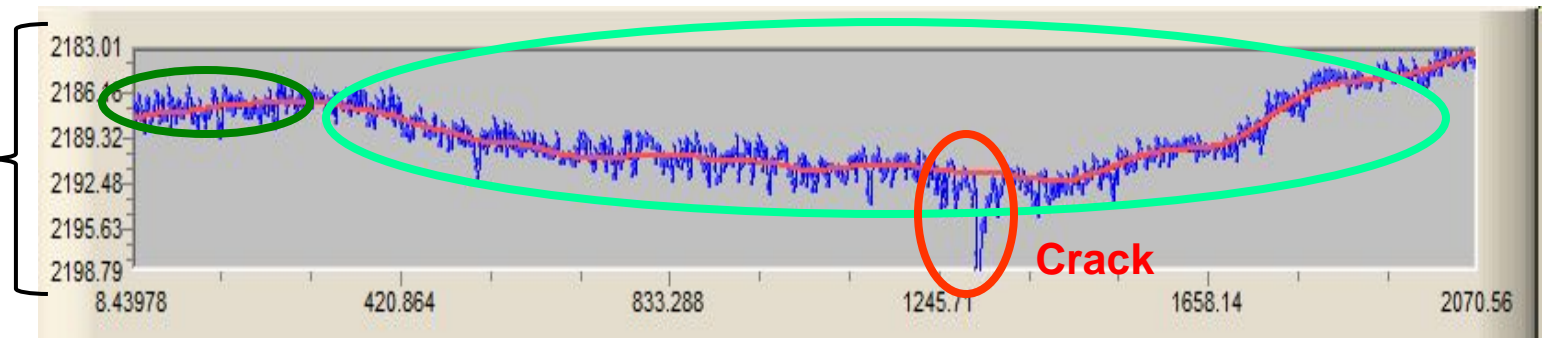


Single Road Profile (2 meter)

Macro-texture

Rut

Distance
between Sensor
and ground
(in mm)

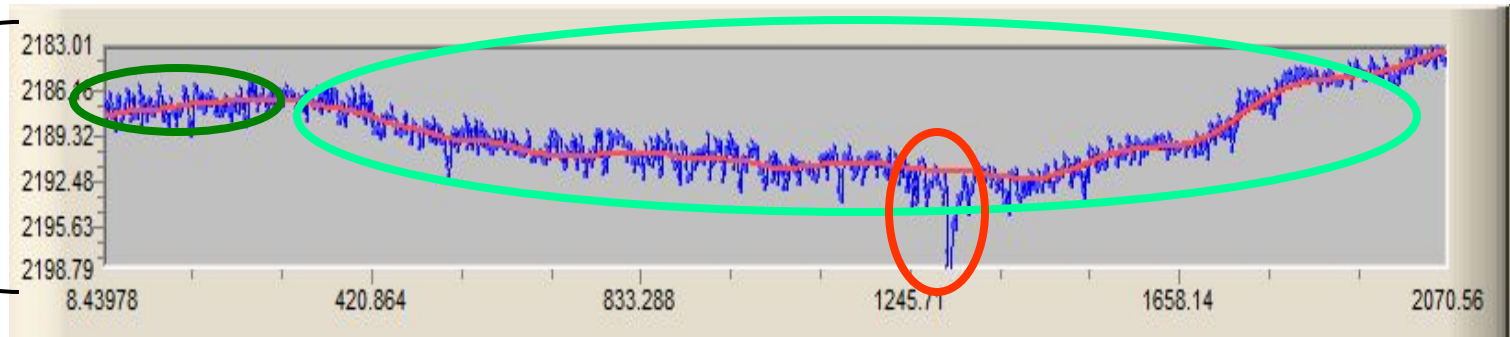


Single Road Profile (2 meter)

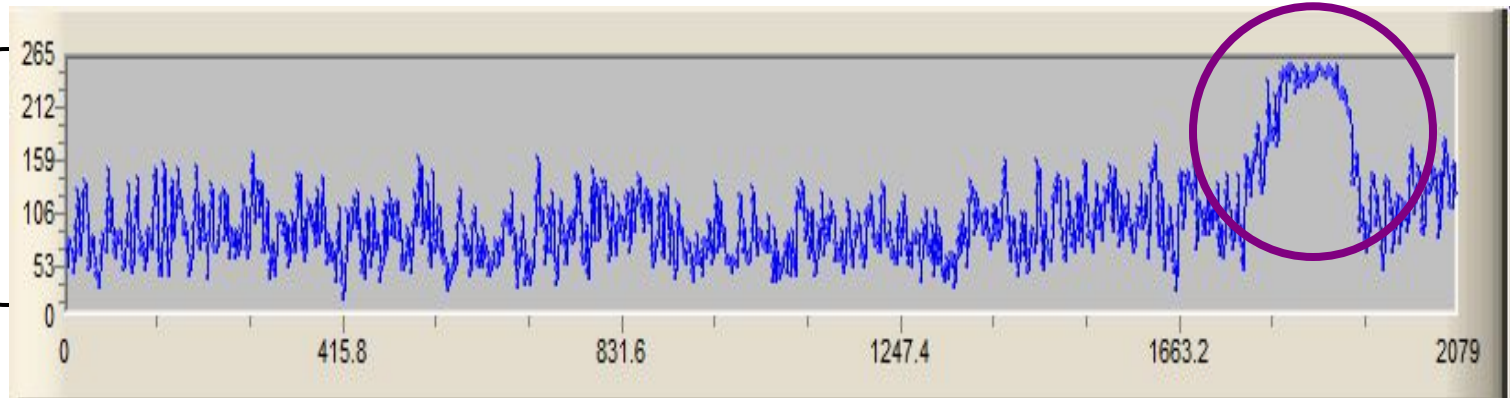
Macro-texture

Rut

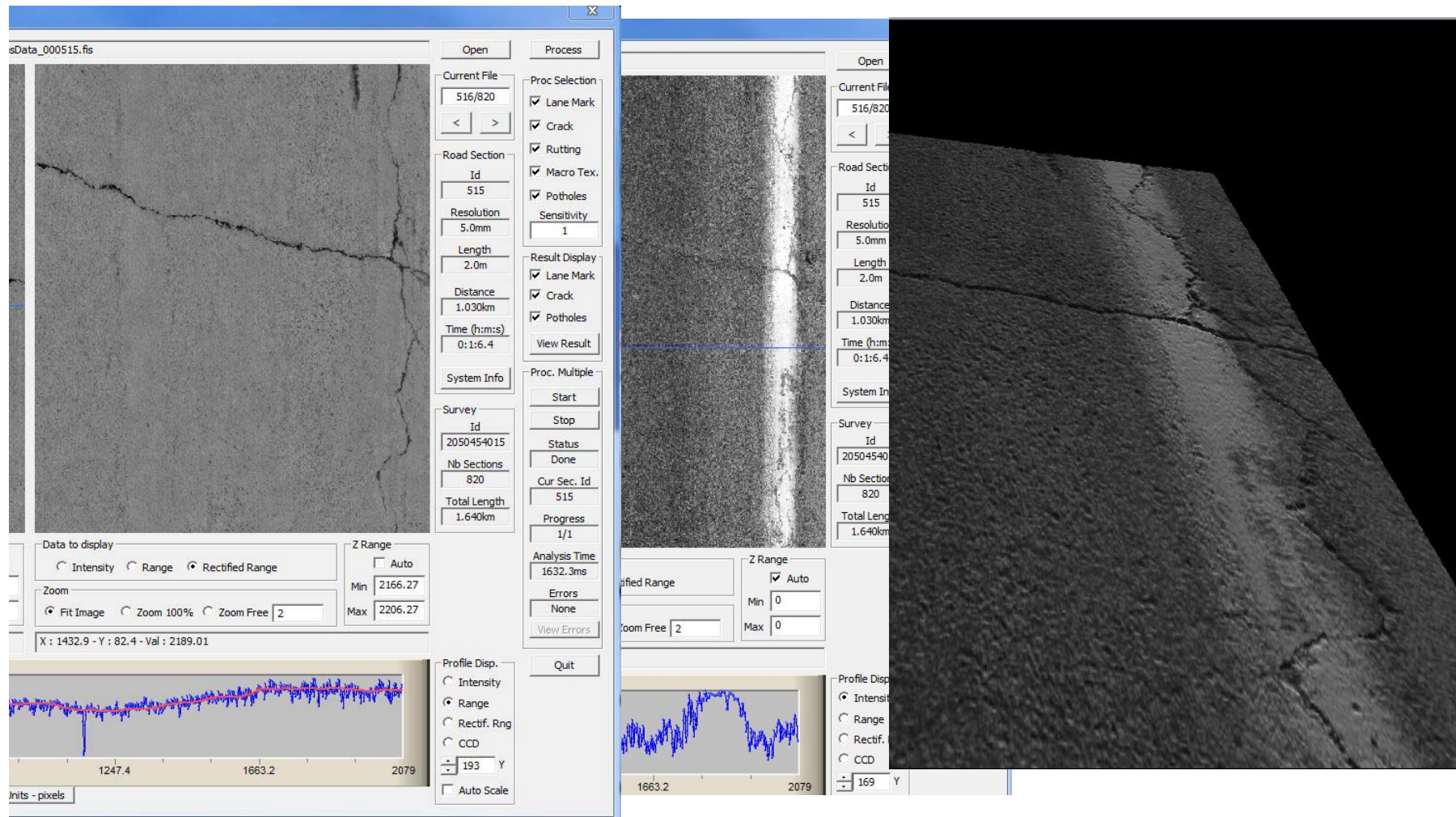
Distance
between Sensor
and ground
(in mm)



Laser intensity
(black = 0,
white = 255)

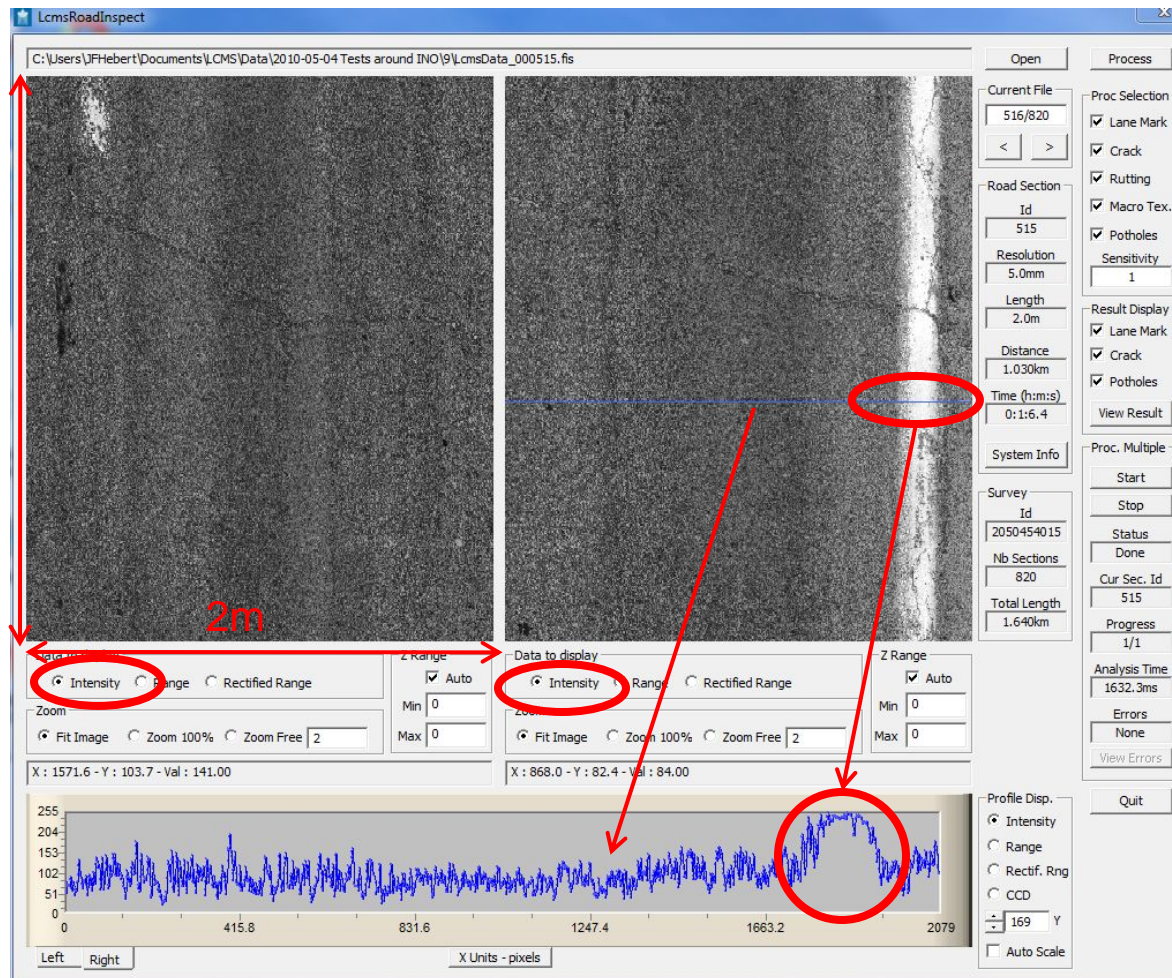


Right Lane
Marking



Road Section: Intensity Data

400 road profiles captured every 5 mm = 2m road section



Definition:

A Road Section is a set of profiles merged together.

Can be viewed in:

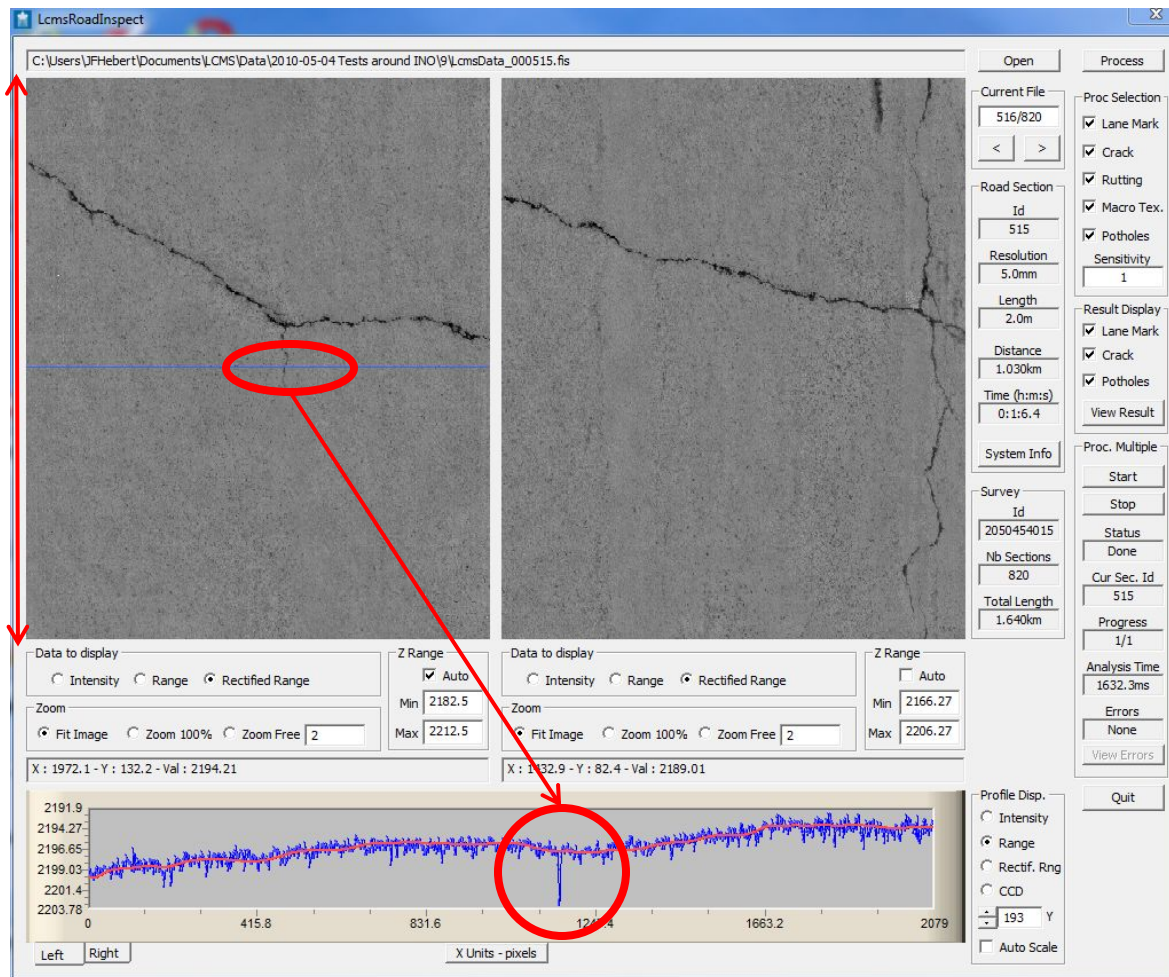
- Intensity
- Range

Intensity:

- Depends on the reflective properties of the surface.

Road Section: Range Data

400 road profiles captured every 5 mm = 2m road section



Range:

- Gives the distance to the ground.

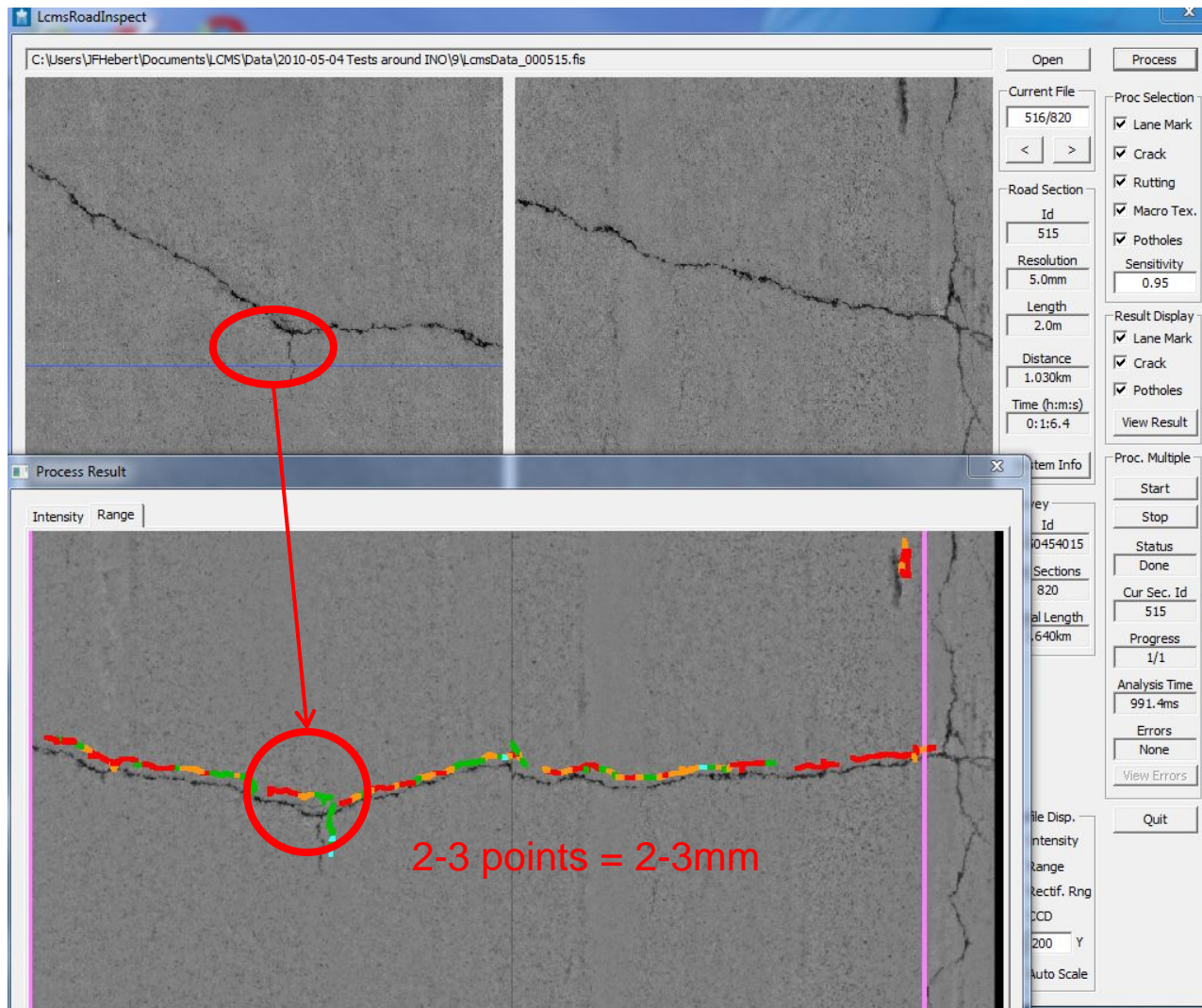
Mapping to 2D Viewer:

- Darker points = further away
- Gray points = on-surface
- White points = closer

Cracks:

- Notch in the profile
- Appear darker in range image

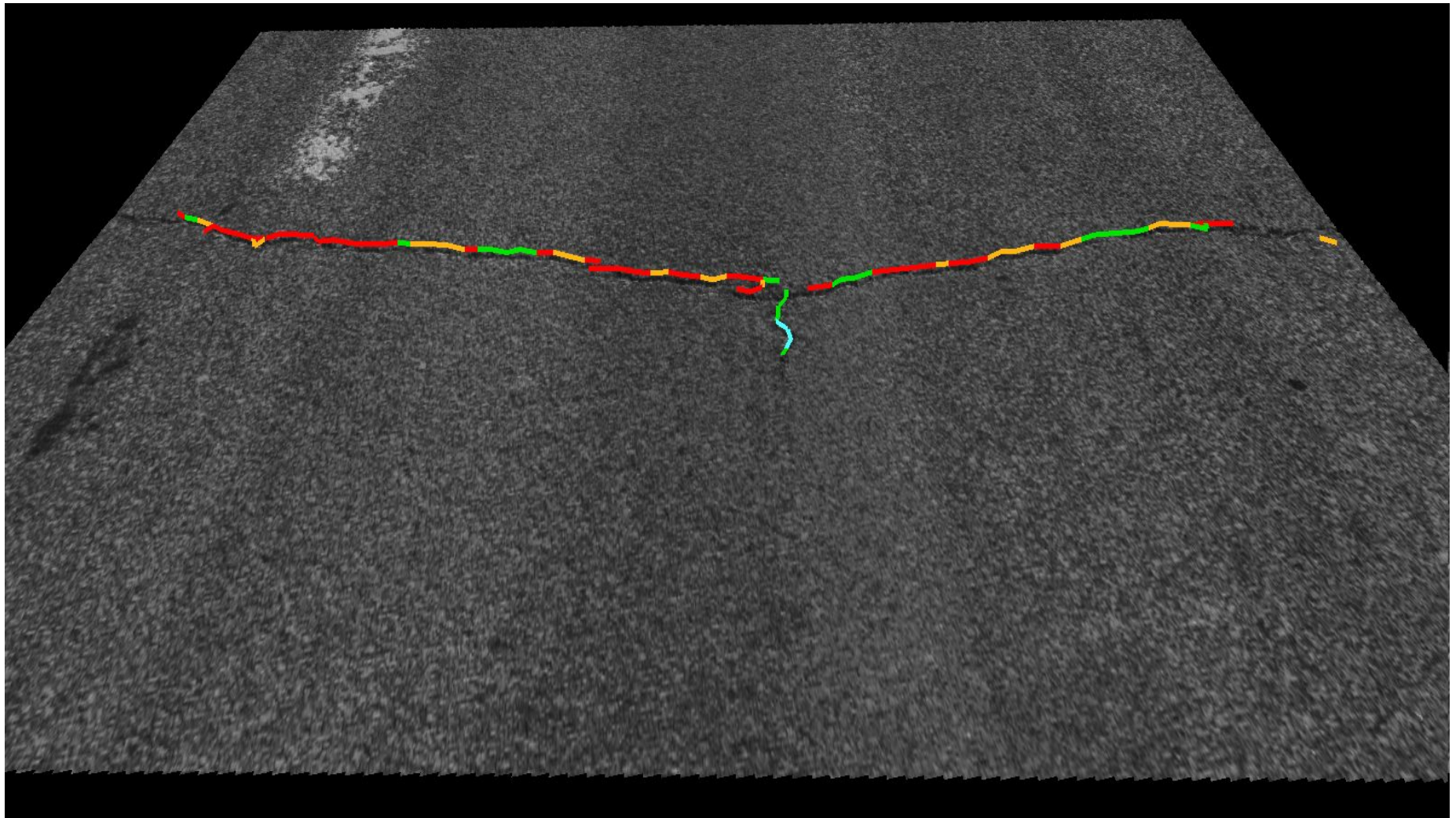
Crack detection example



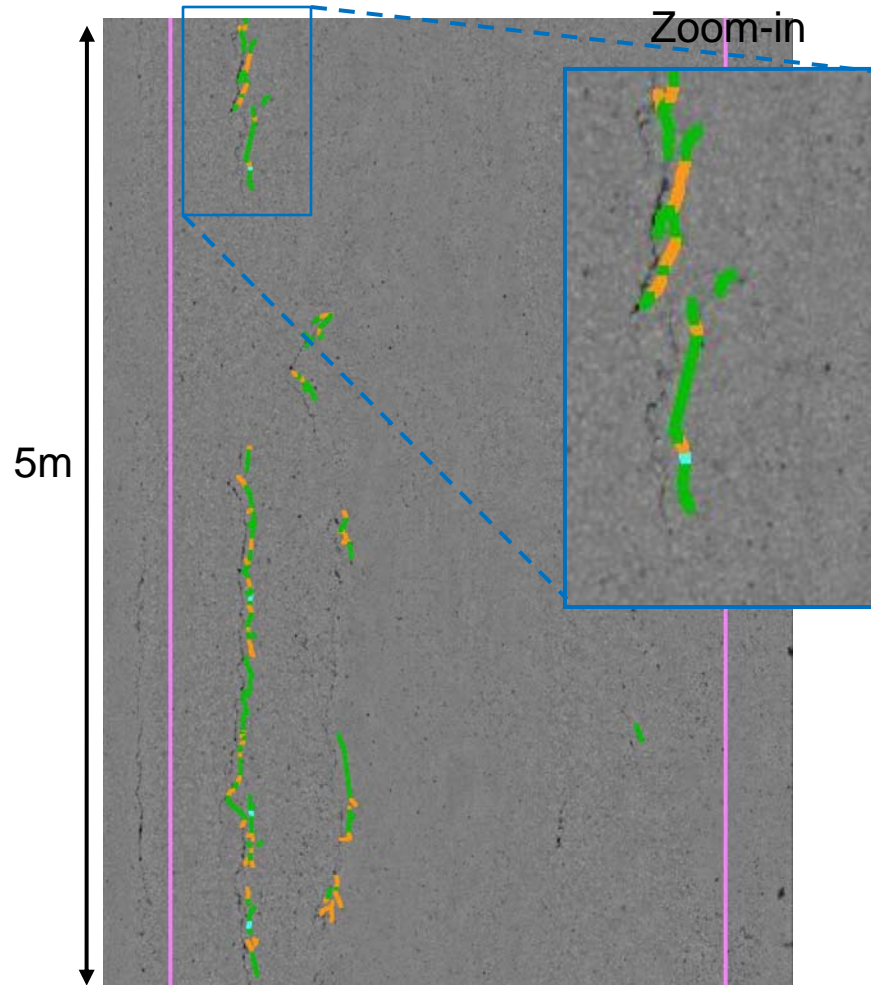
Range + Intensity = 3D !



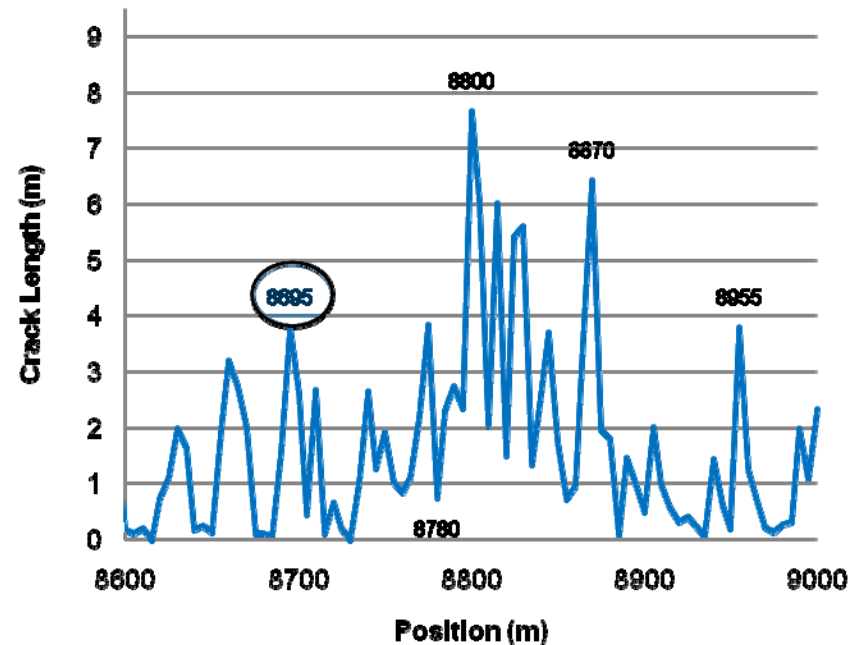
Automatic Crack Detection Length, Type, Severity



Crack example: 8695m (Osaka data file 1739.jpg)

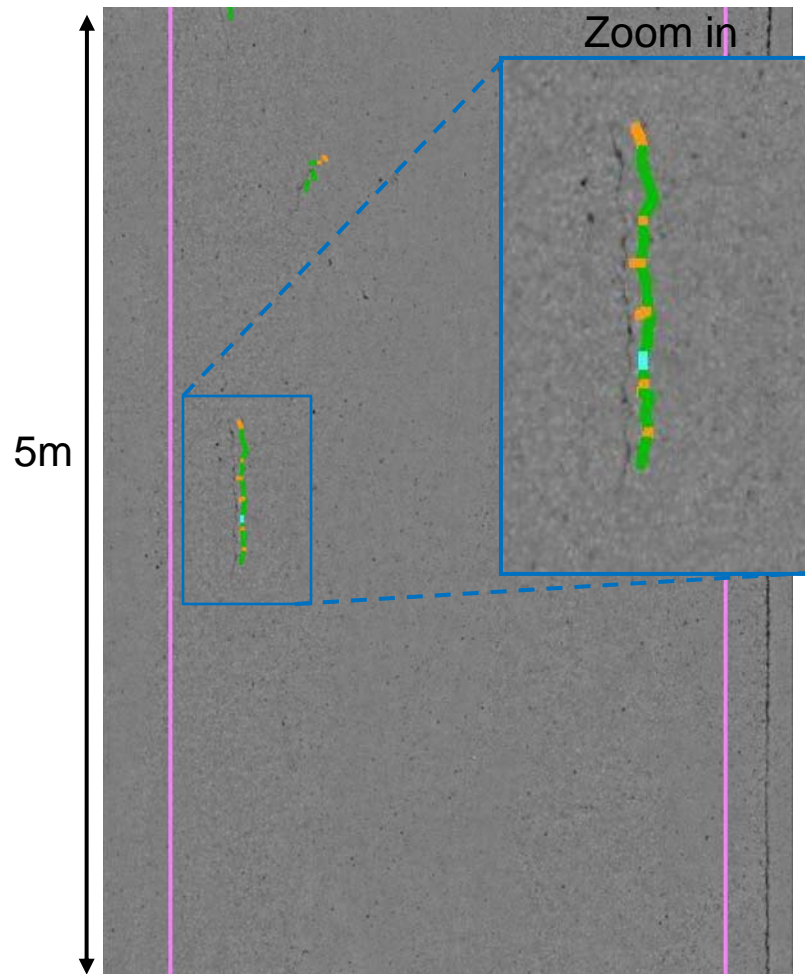


Crack length (per road section) between 8.6km and 9.0 km for Osaka Data
(files 1720.jpg-1800.jpg)

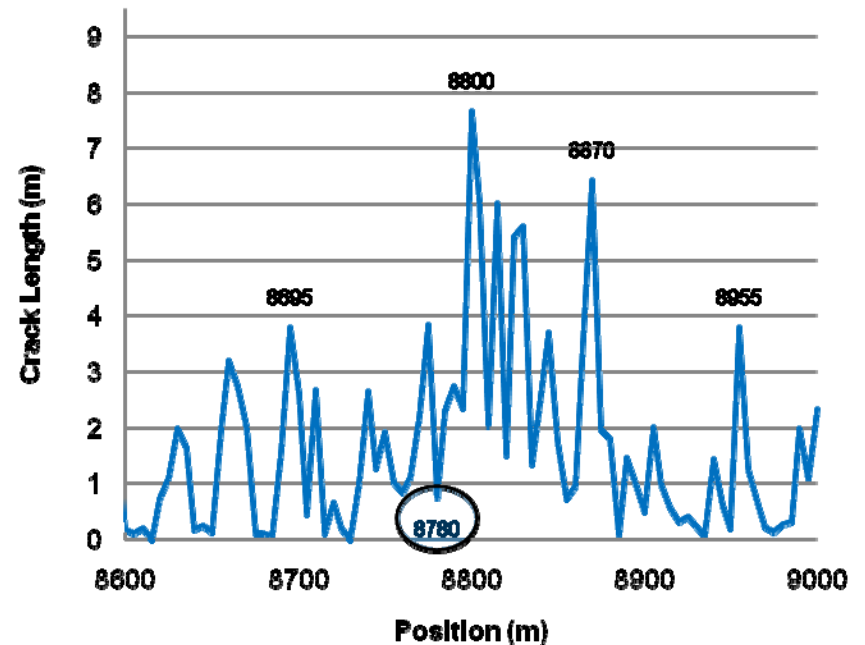


Crack example: 8780m

(Osaka data file 1756.jpg)

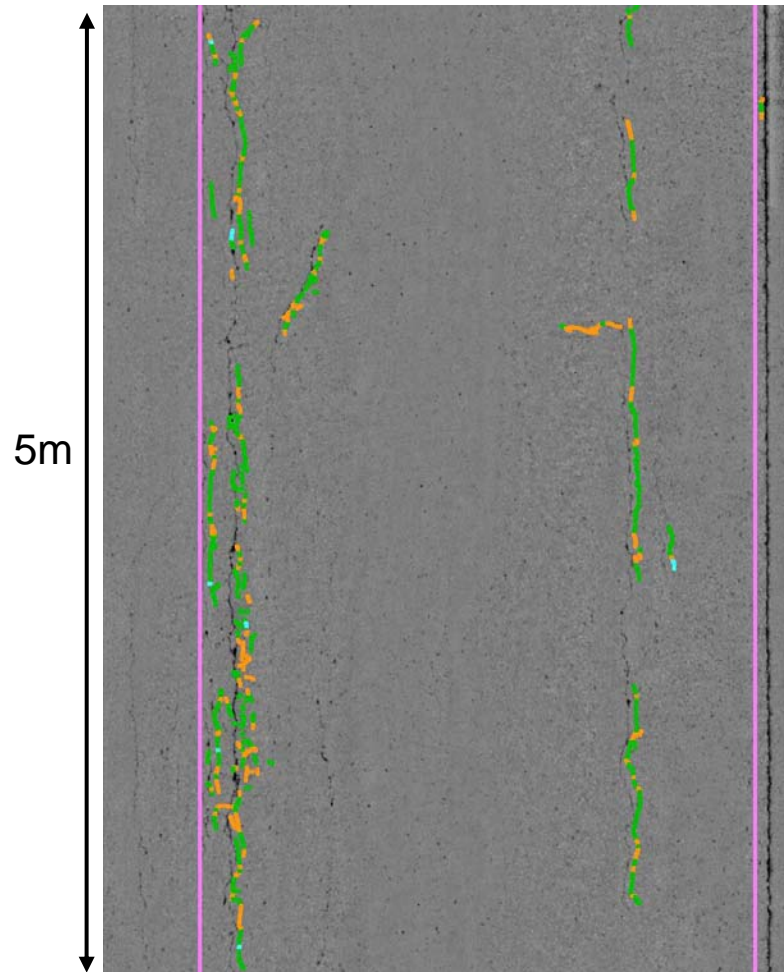


Crack length (per road section) between 8.6km and 9.0 km for Osaka Data
(files 1720.jpg-1800.jpg)



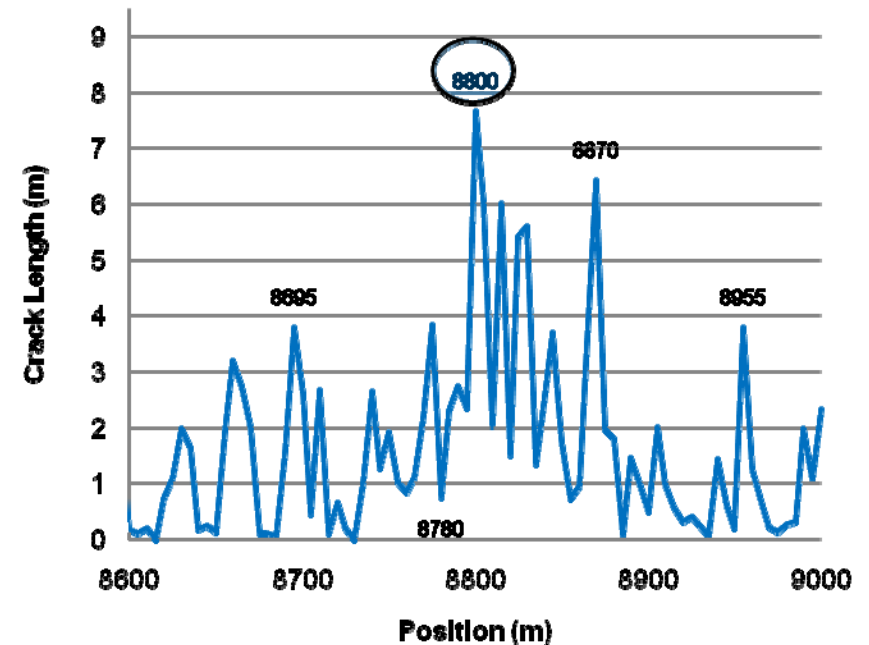
Crack example: 8800m

(Osaka data file 1760.jpg)



Crack length (per road section) between 8.6km and 9.0 km for Osaka Data

(files 1720.jpg-1800.jpg)



Pavemetrics

MTQ - Network level testing Summer 2008





MTQ – LCMS Network level validation tests

- 990 000 images of 10m sections were visually evaluated
 - In all 9 900 km of road network was evaluated
 - Visual results were seperated into 4 classes:

Good

OK

Bad

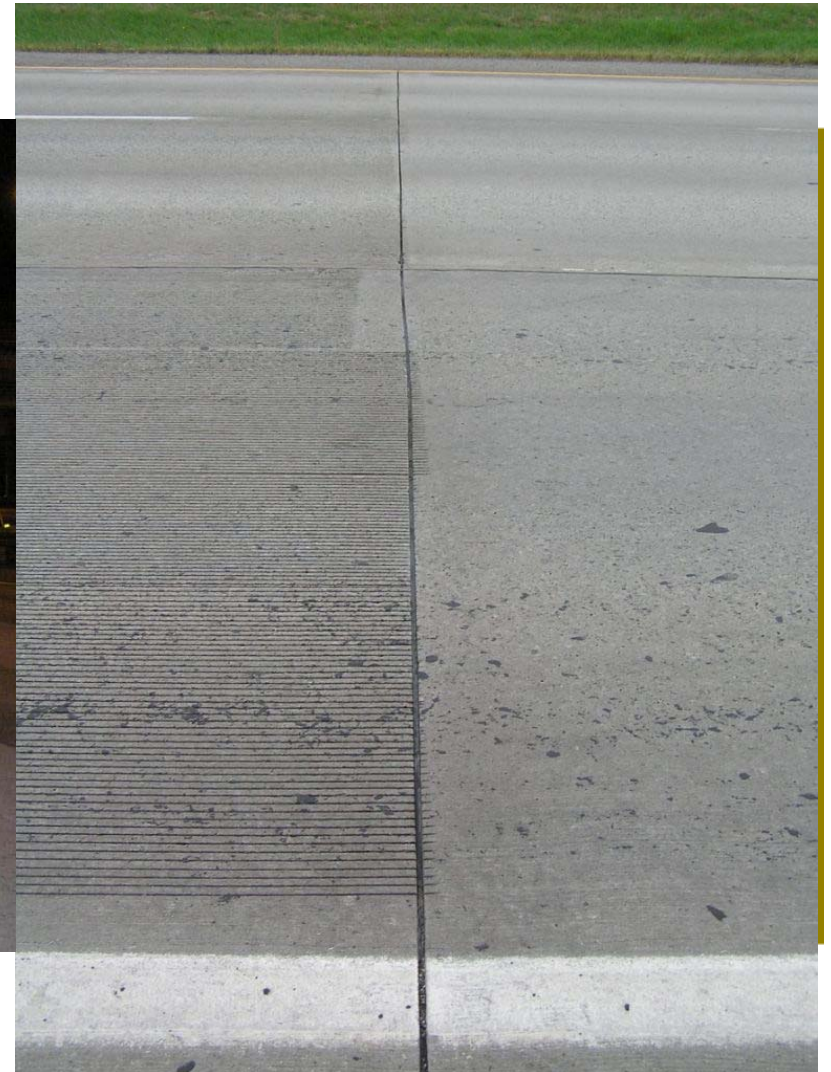
NA = other

Results – network level visual evaluation

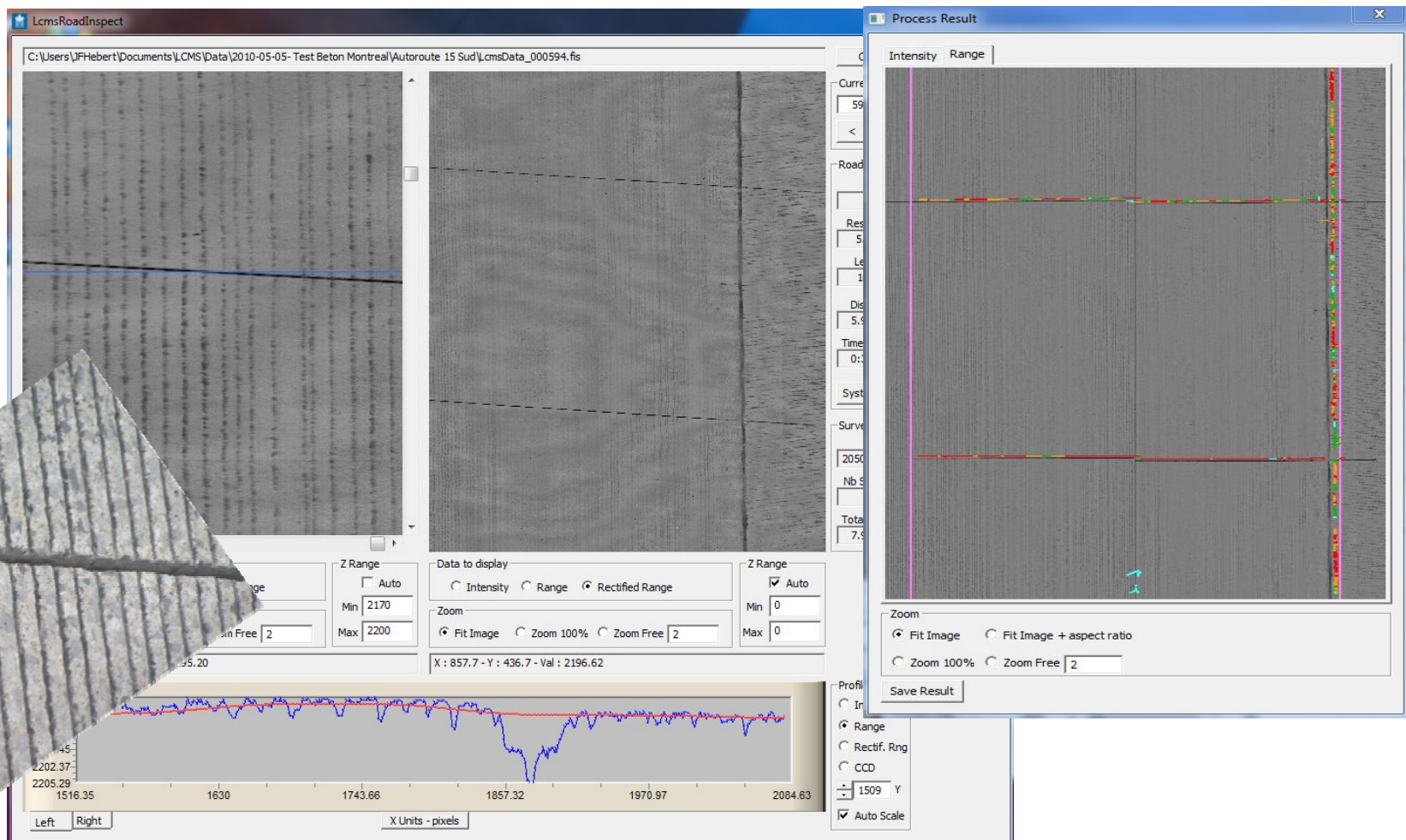
District #	Total (sections)	Results (manual classification)							
		Number of images (10m sections)				Proportion (%)			
		Good	Average	Bad	NA	Good	Average	Bad	NA
84	35288	34144	310	144	690	96,8	0,9	0,4	2,0
85	4243	4101	53	51	38	96,7	1,2	1,2	0,9
86	147903	144040	516	1520	1827	97,4	0,3	1,0	1,2
87	149926	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

Pavemetrics

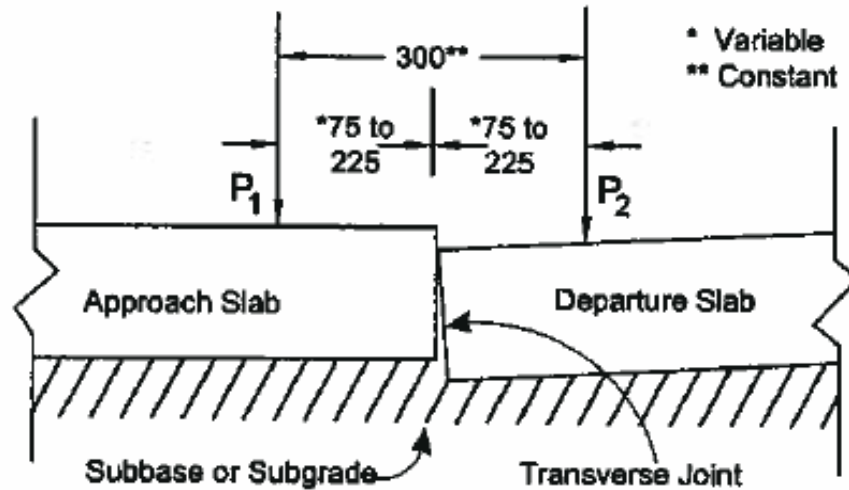
Concrete roads



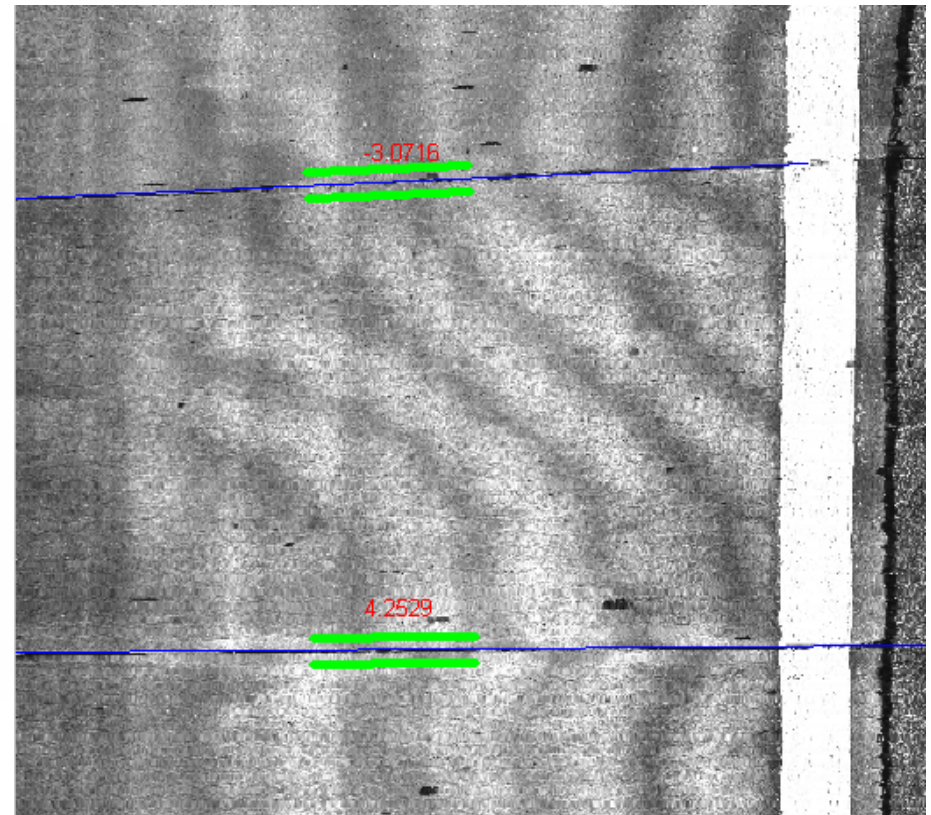
Joints, tinning and faulting



Joint detection and faulting



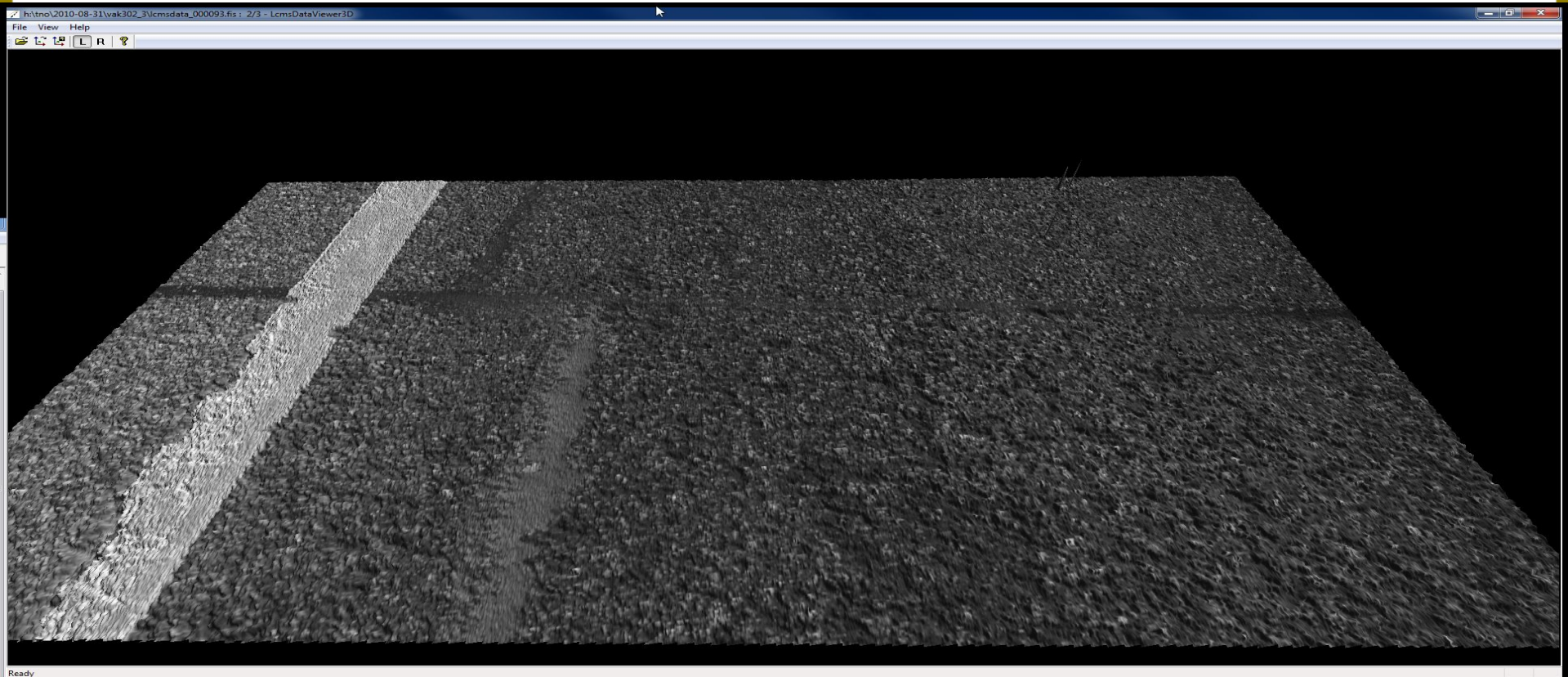
Note: All dimensions shown in millimeters unless otherwise noted.



Raveling Index (RI)

- Raveling spots (loss of aggregate) are identified from the 3D range images.
- The volume of the missing aggregate spots are measured per surface area.

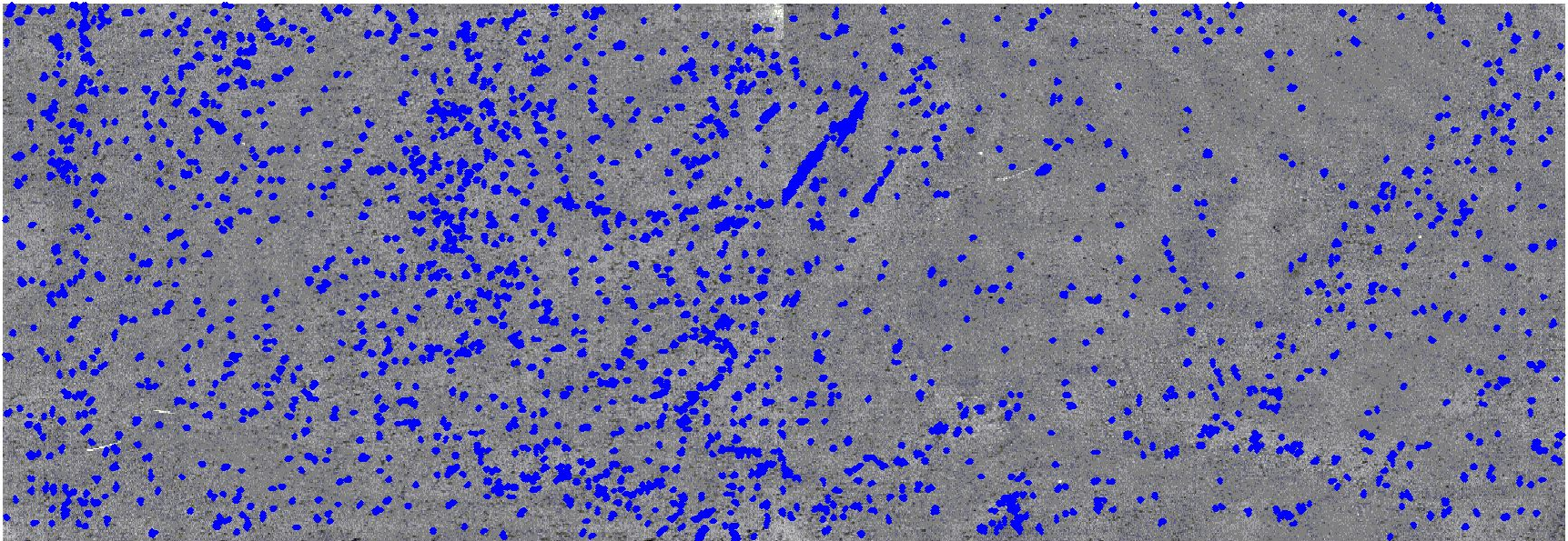
$$RI = V_{ravelling} / A_{Total}$$



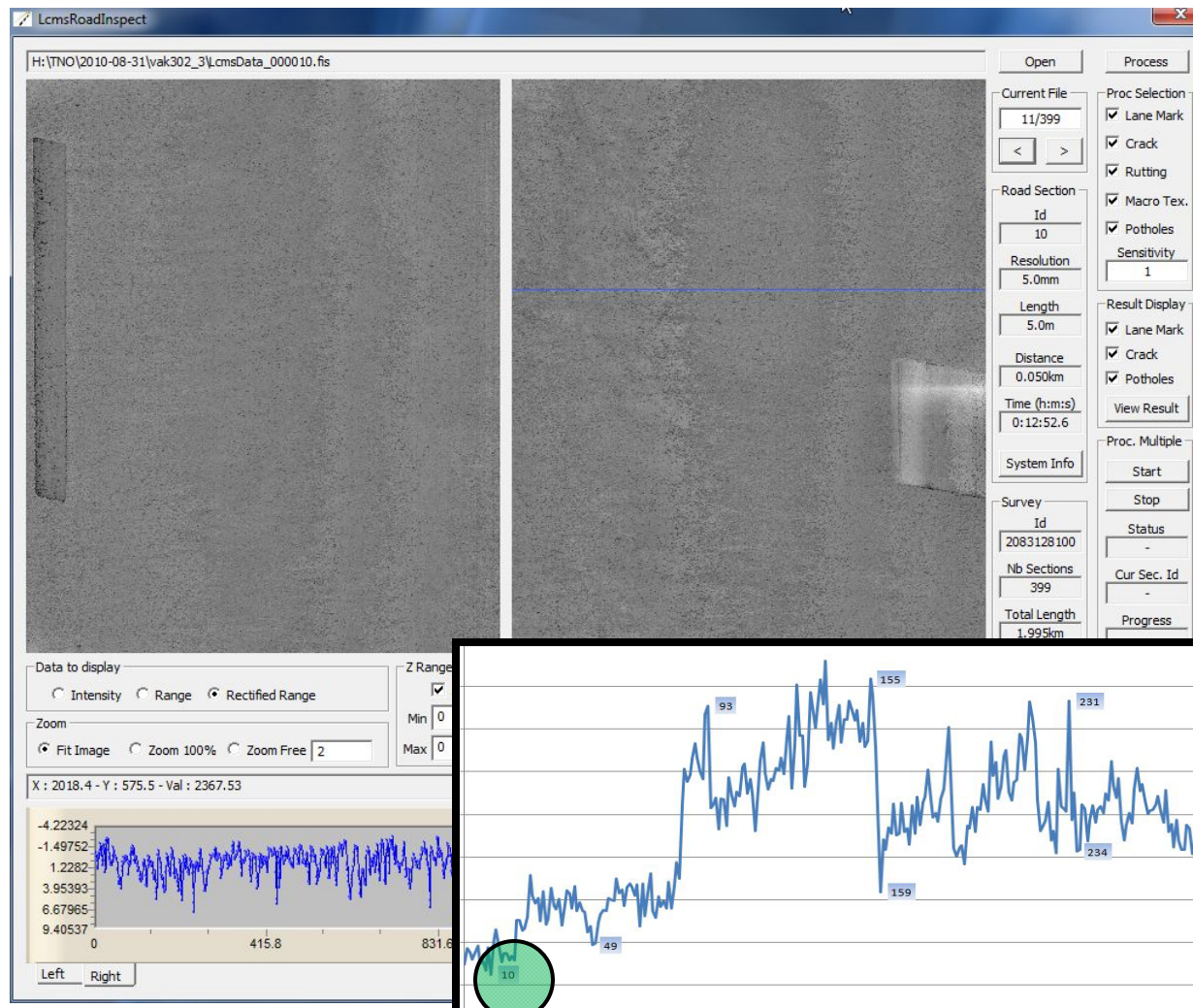
Aggregate loss detection



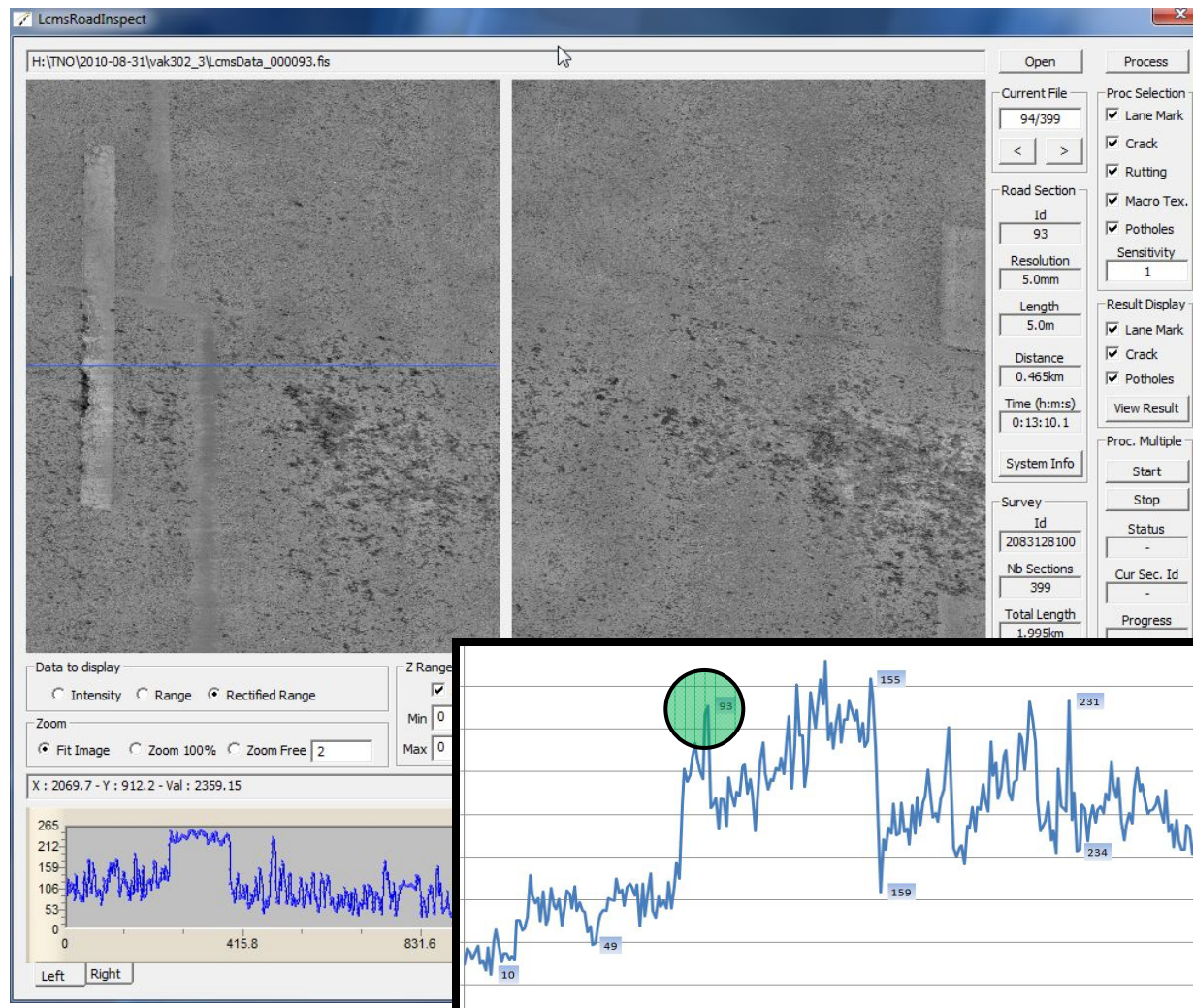
Aggregate loss detection



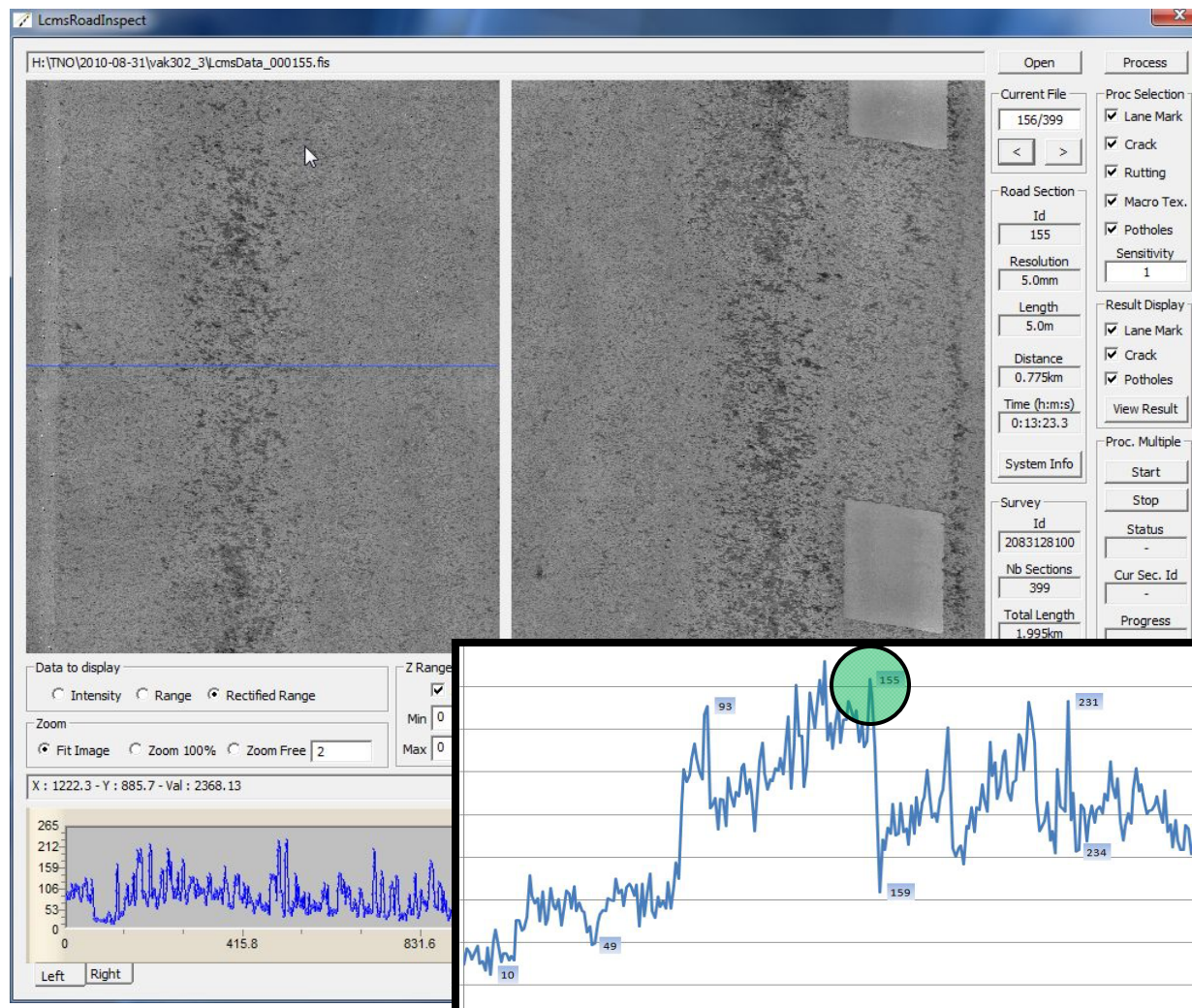
RI – Road test – Porous Asphalt in the Netherlands



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



Road Section #155 : Raveling patch



The screenshot displays the LcmsRoadInspect software interface. The main window is divided into two panels showing grayscale images of a road surface. The left panel shows a road surface with a blue horizontal line. The right panel shows a road surface with a white rectangular patch. Below the images is a data display panel with the following controls:

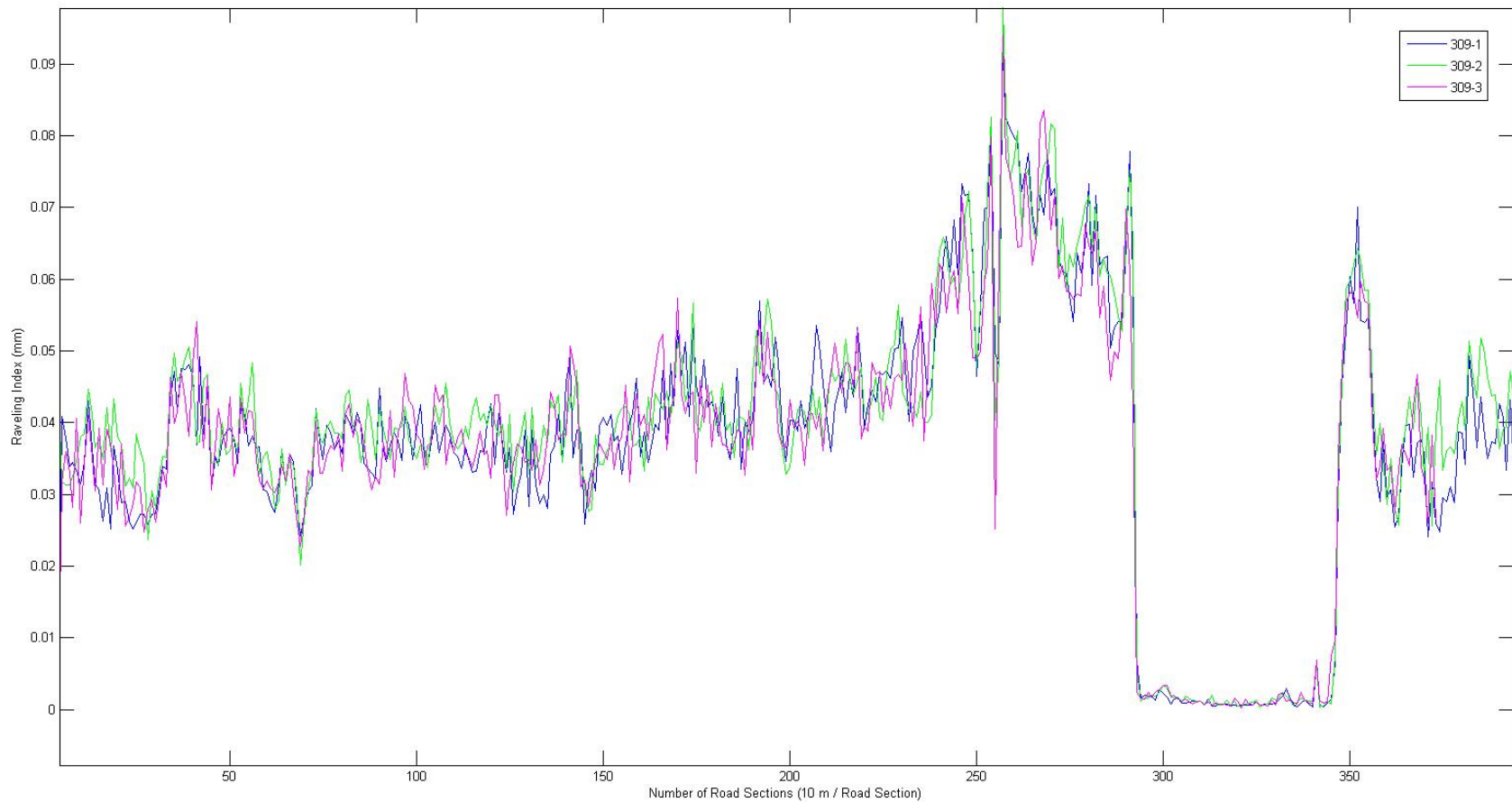
- Data to display:** Radio buttons for Intensity, Range, and Rectified Range (selected).
- Zoom:** Radio buttons for Fit Image, Zoom 100%, and Zoom Free (selected). A zoom value of 2 is entered.
- Coordinates:** X : 323.6 - Y : 57.1 - Val : 2373.41
- Graph:** A line graph showing the profile of the road surface. The Y-axis ranges from 0 to 265. The X-axis ranges from 0 to 831.6. The graph shows a blue line representing the profile, with a green circle highlighting a specific point.

On the right side of the interface is a control panel with the following sections:

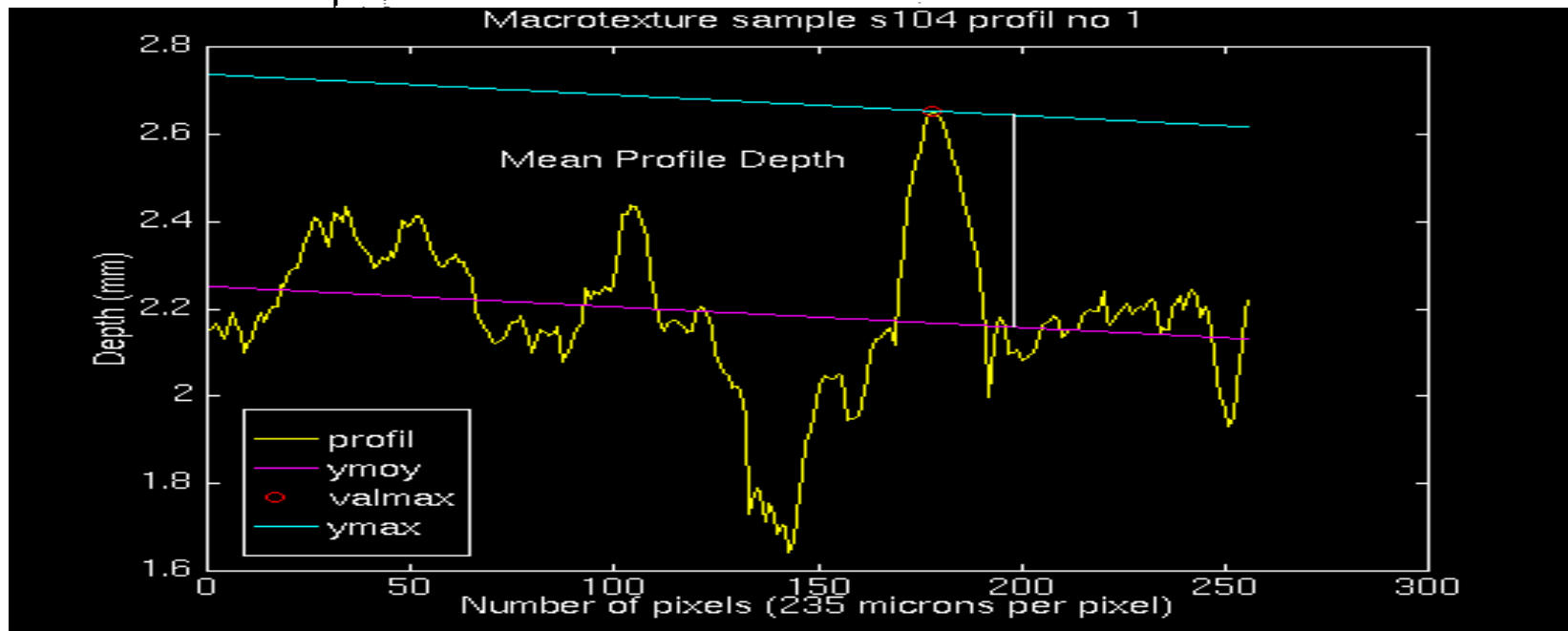
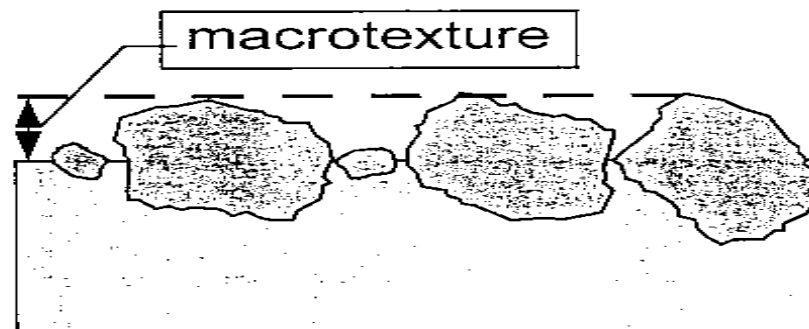
- Open / Process:** Buttons for opening and processing files.
- Current File:** A text box showing the file path: H:\TNO\2010-08-31\vak302_3\cmsData_000159.fls.
- Road Section:** A table with columns for Id, Resolution, Length, Distance, Time (h:m:s), and System Info. The data is as follows:

Id	Resolution	Length	Distance	Time (h:m:s)	System Info
159	5.0mm	5.0m	0.795km	0:13:24.1	
- Proc. Selection:** Checkboxes for Lane Mark, Crack, Rutting, Macro Tex., and Potholes (all selected). A Sensitivity value of 1 is shown.
- Result Display:** Checkboxes for Lane Mark, Crack, and Potholes (all selected). A View Result button is present.
- Proc. Multiple:** Buttons for Start, Stop, Status, Cur Sec. Id, and Progress.

Ravelling Index - Repeatability (Porous asphalt Netherlands)

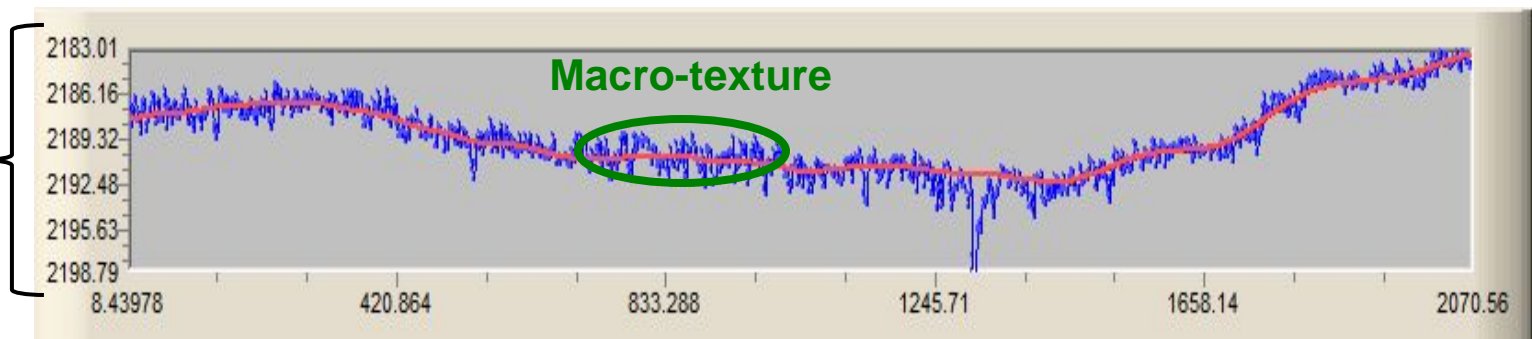


Macrotexture (MPD - ASTM E1845-01)



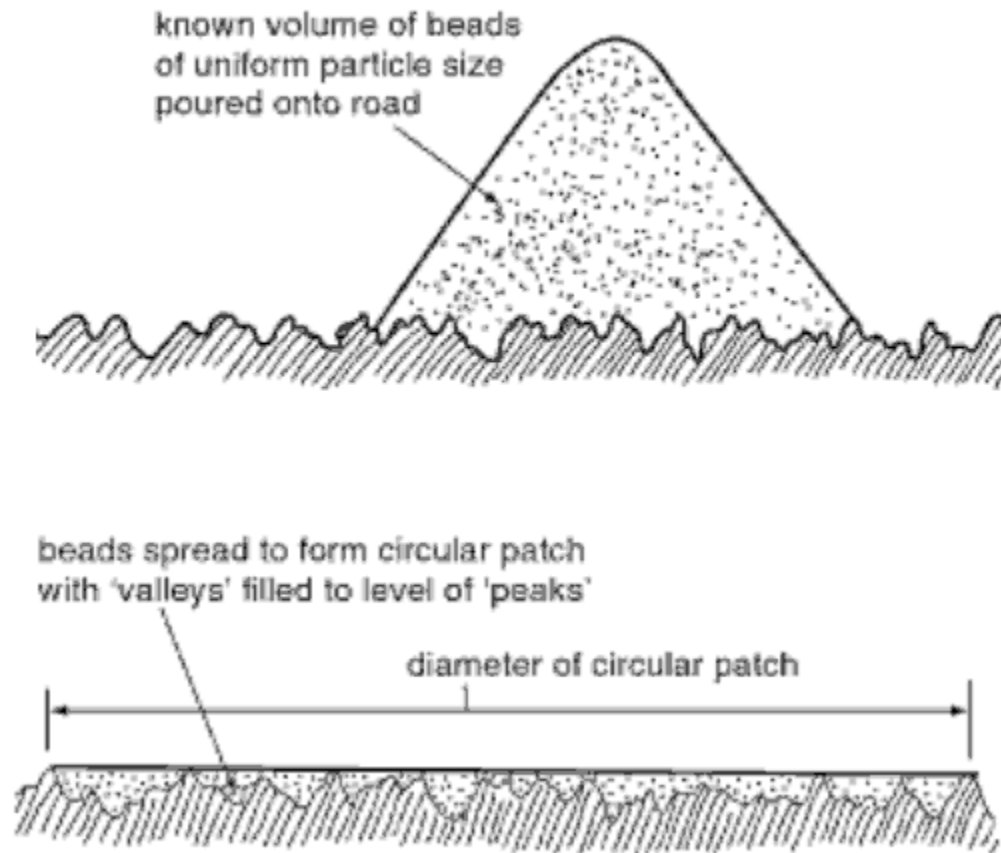
Single Road Profile (2 meter)

Distance
between Sensor
and ground
(in mm)



Macrotexture

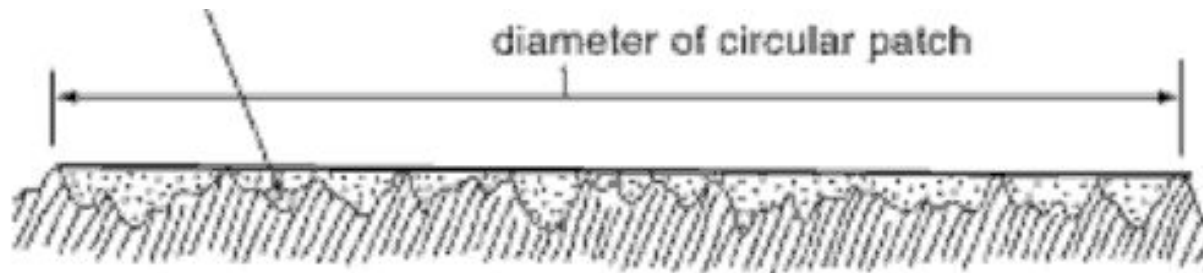
Sand patch method



Macrotexture – RPI

Digital Sand Patch Method

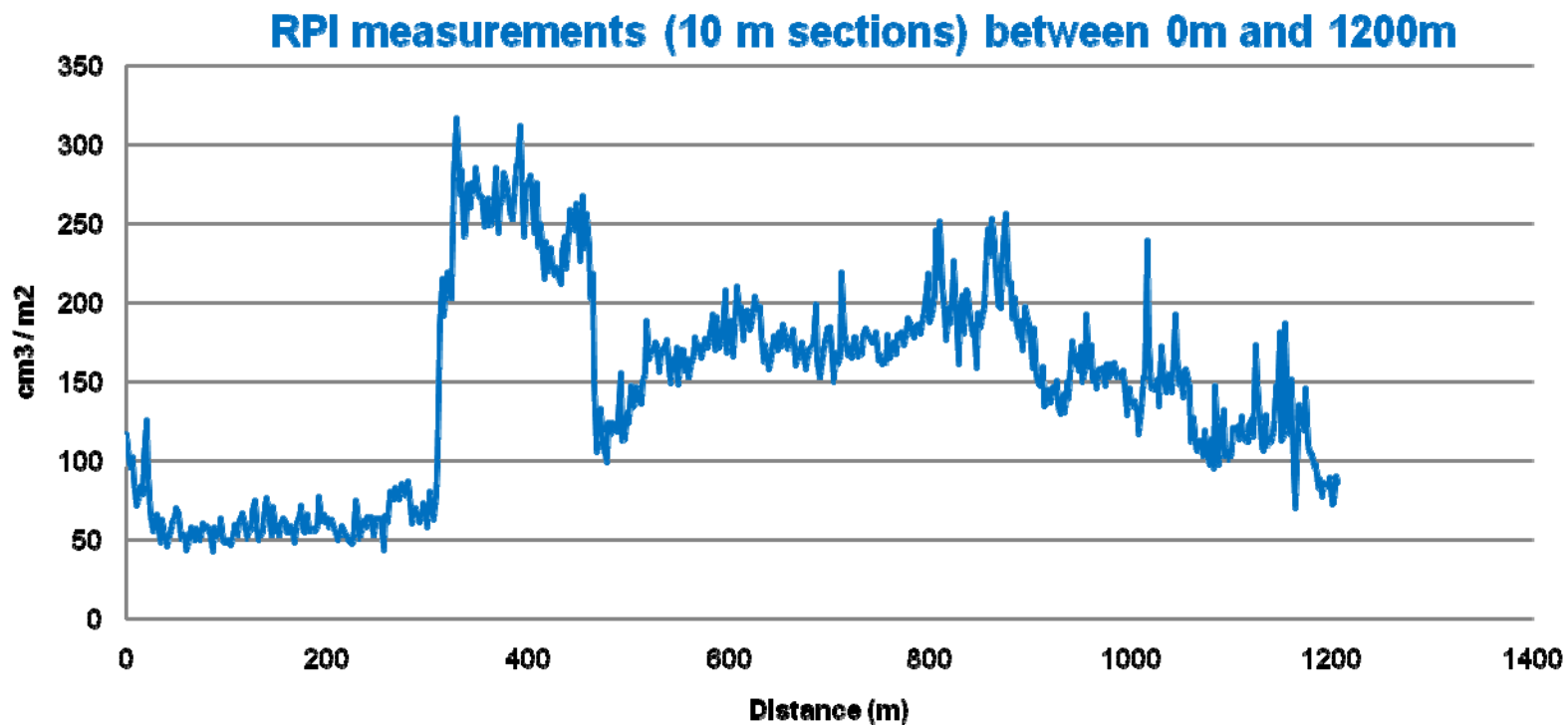
RPI - Road Porosity Index = (Volume under the surface – Ravelling - Cracks) divided by a surface area



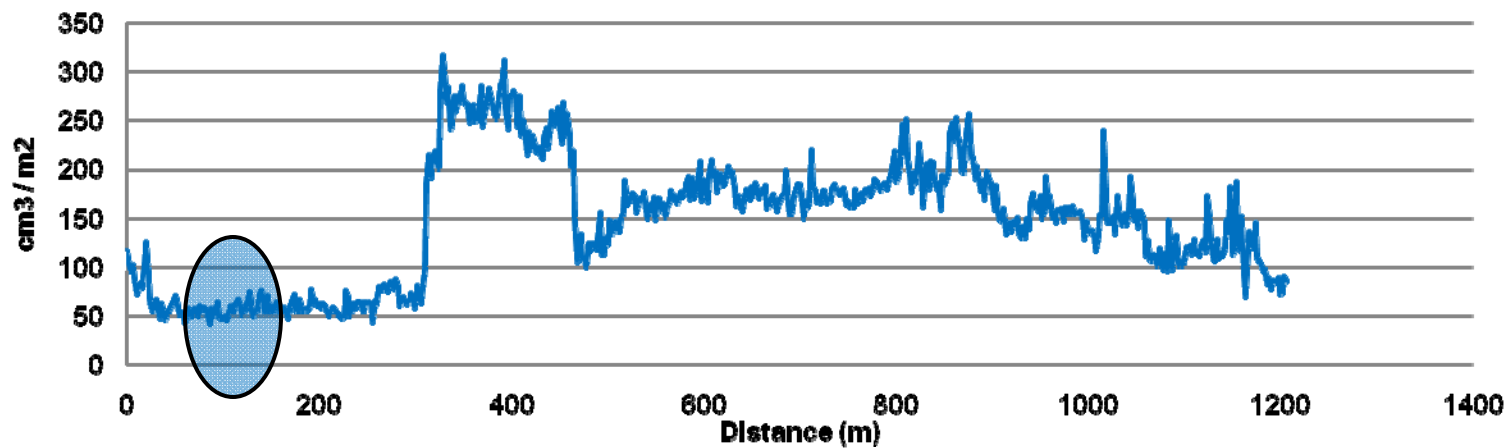
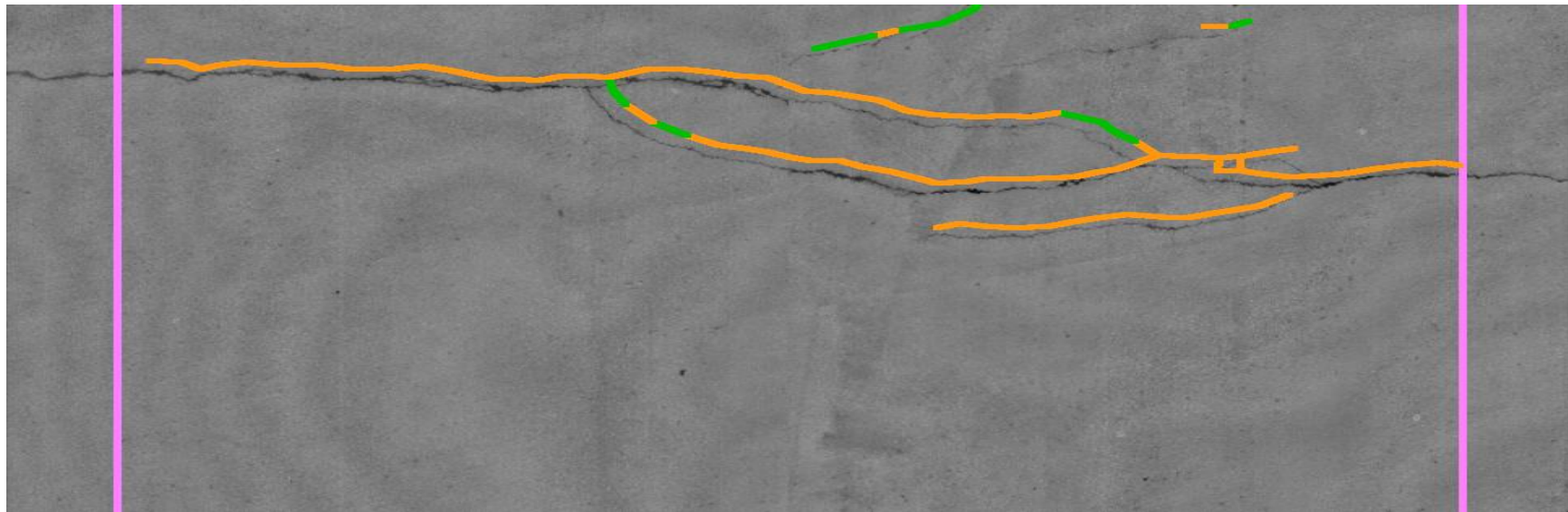
$$RPI = \frac{Vol_{air\ void} - Vol_{ravelling} - Vol_{cracks}}{Area_{Total}}$$

RPI – Road Test (Québec)

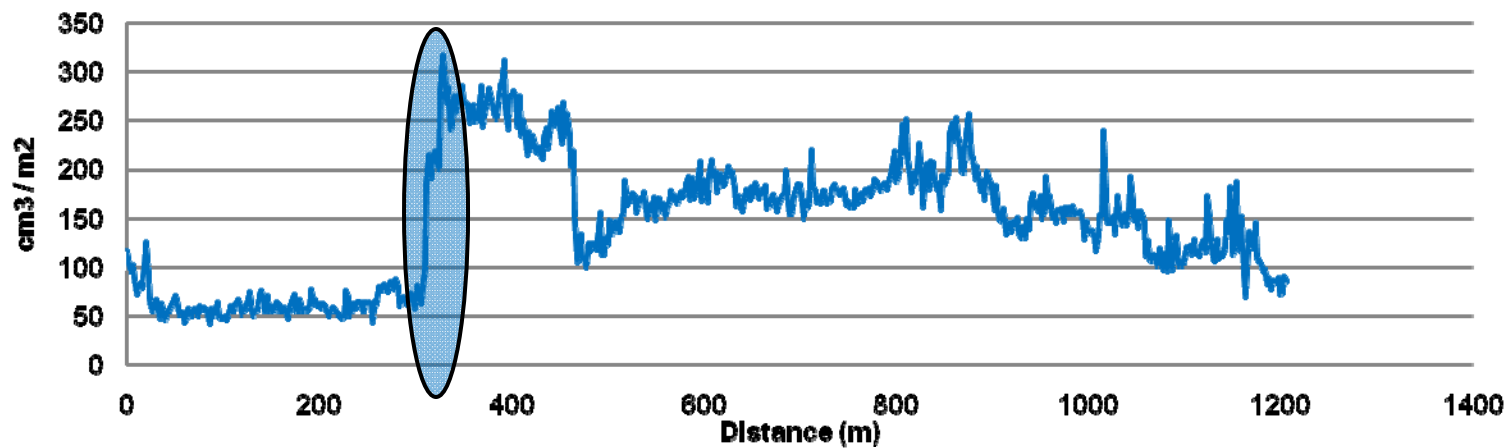
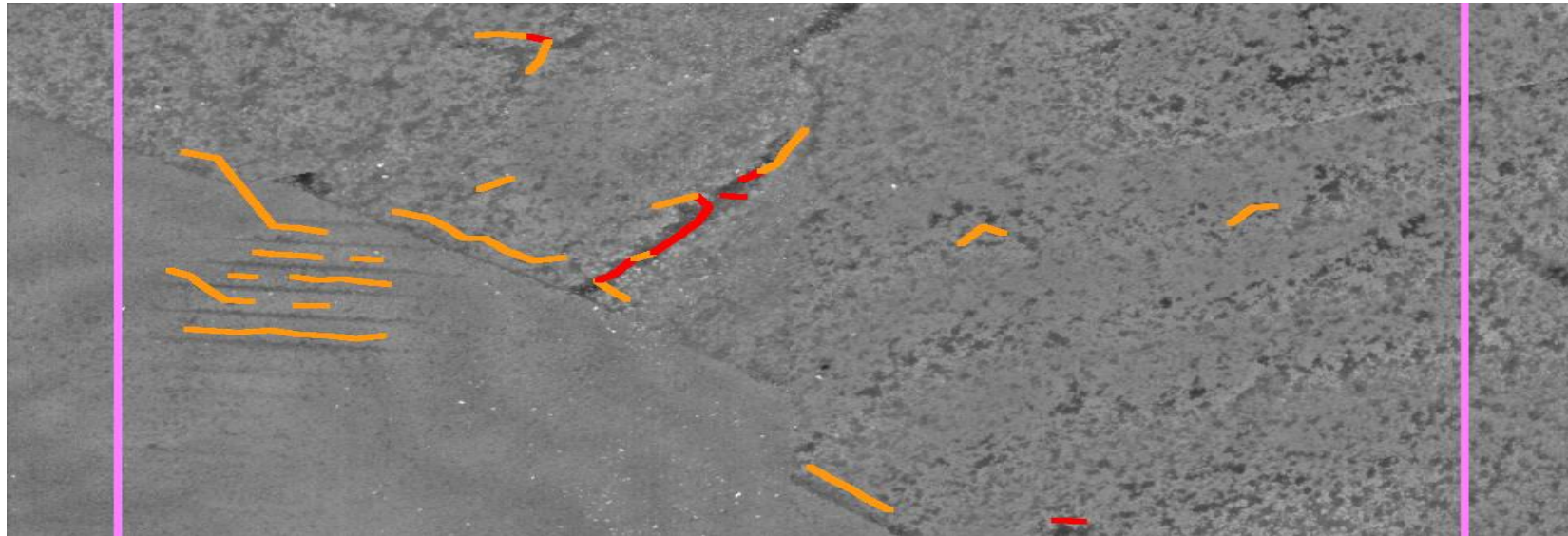
- This test section is interesting because it involves different types of pavement surfaces: Smooth, Very rough and Rough.



Smooth texture

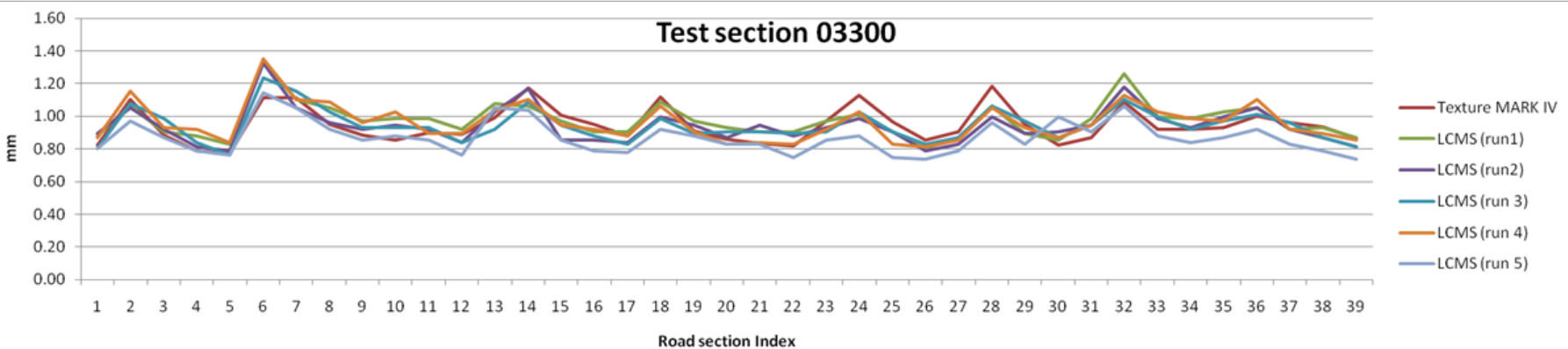
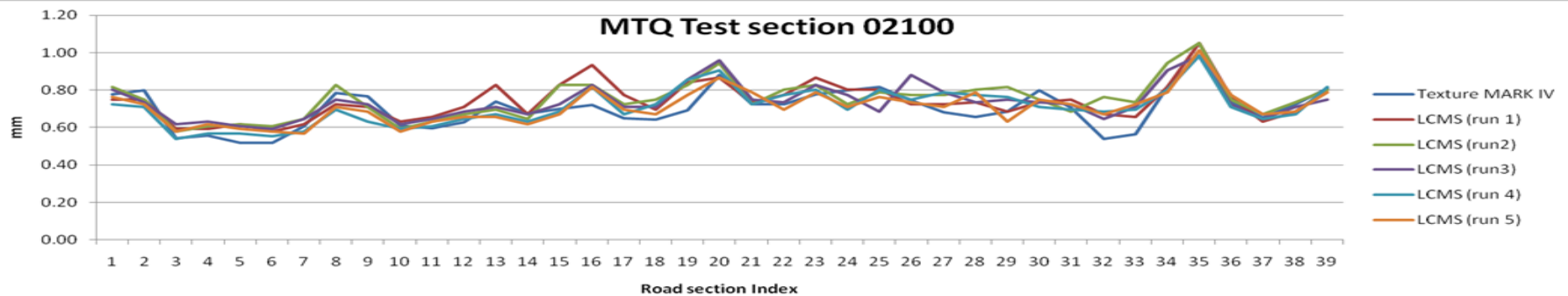
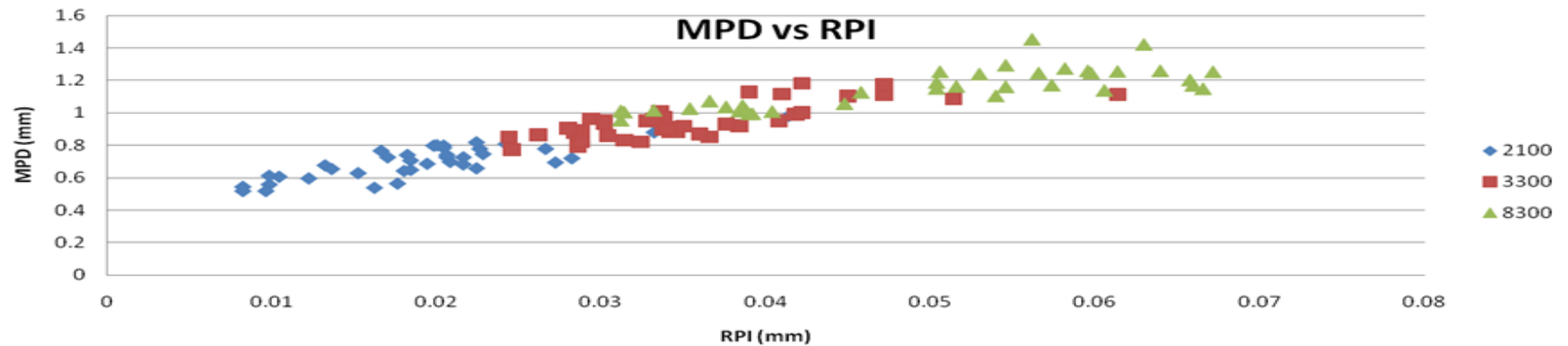


Smooth to Very Rough



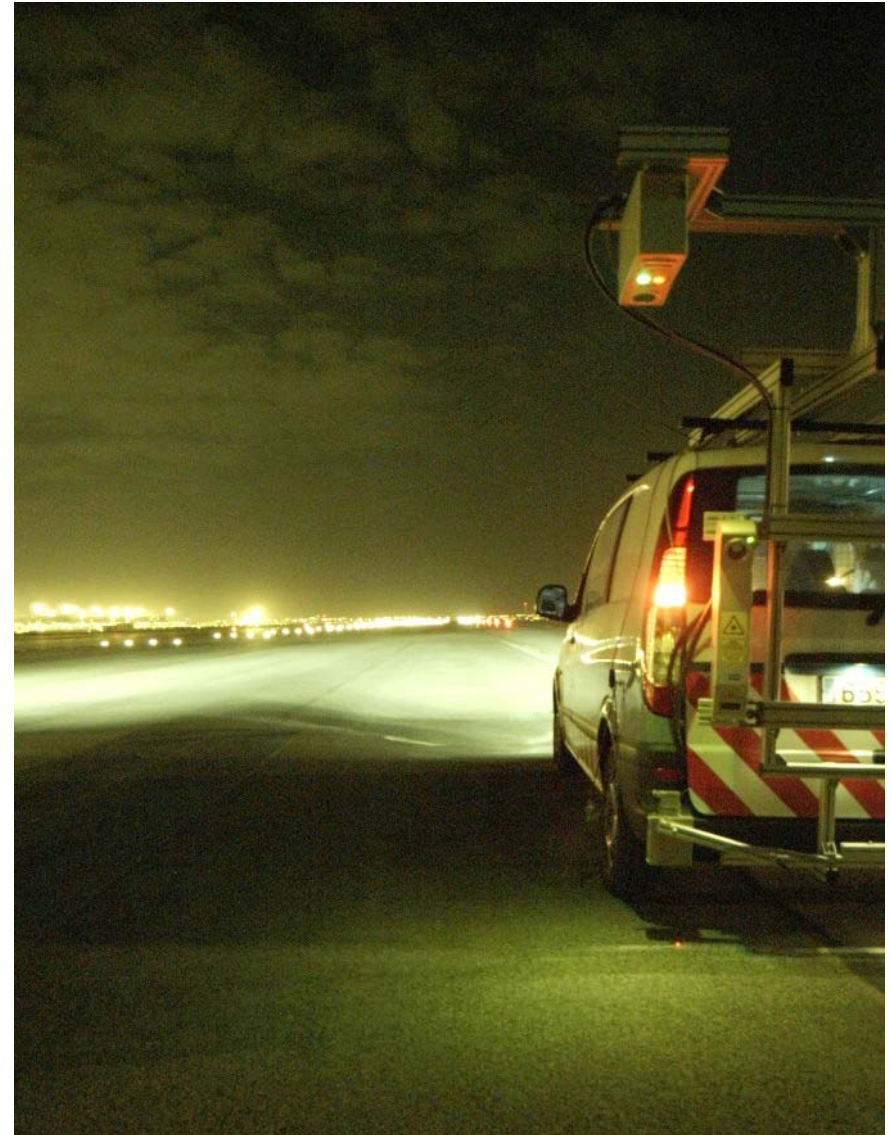
Rough Texture

Smooth Texture



Roads vs Airports

- Lane markings
- Rubber
- Joints (sealed, unsealed)
- Rapid variations in textures
- Multiple lane passes
- Stitching required

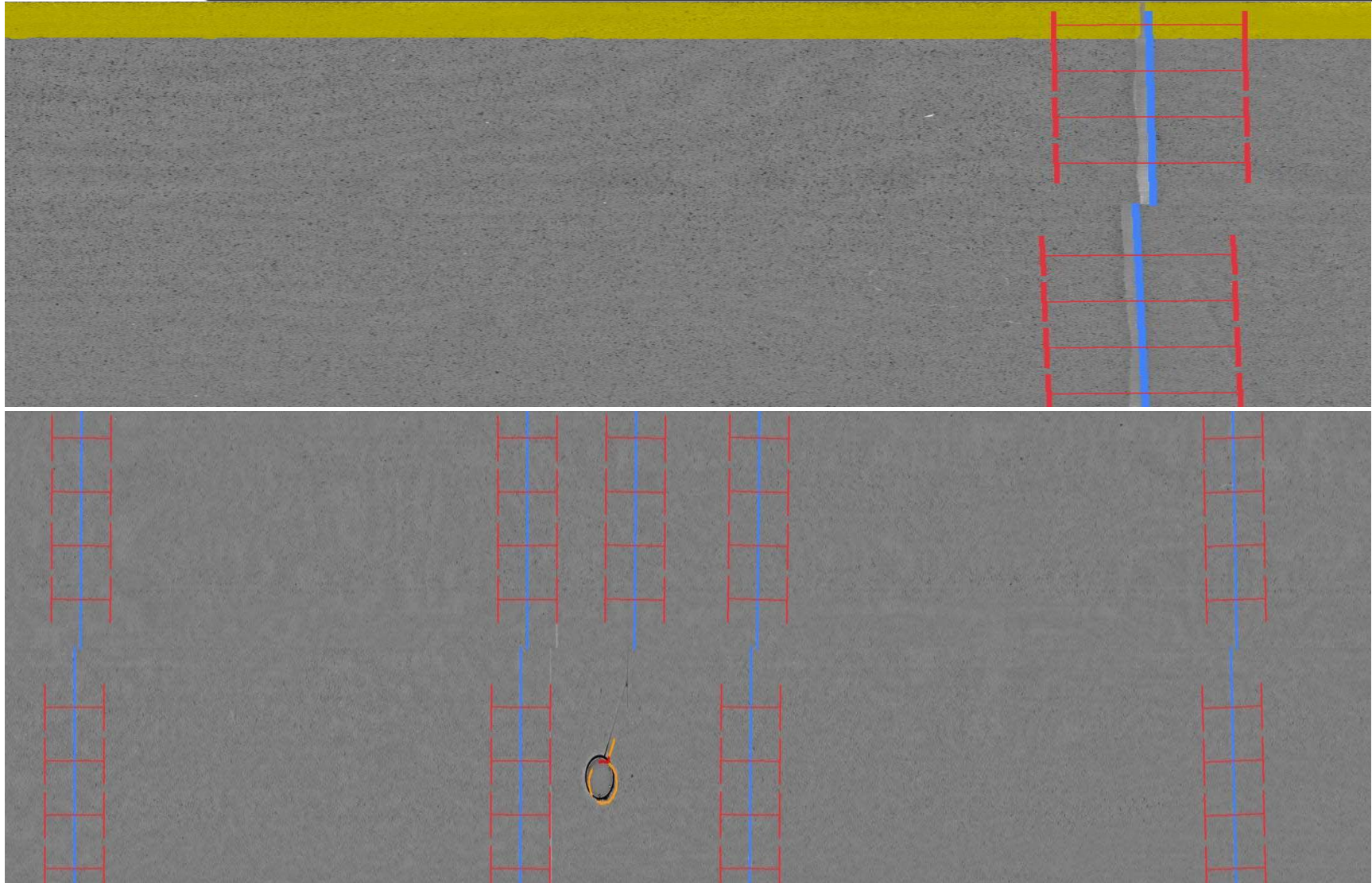




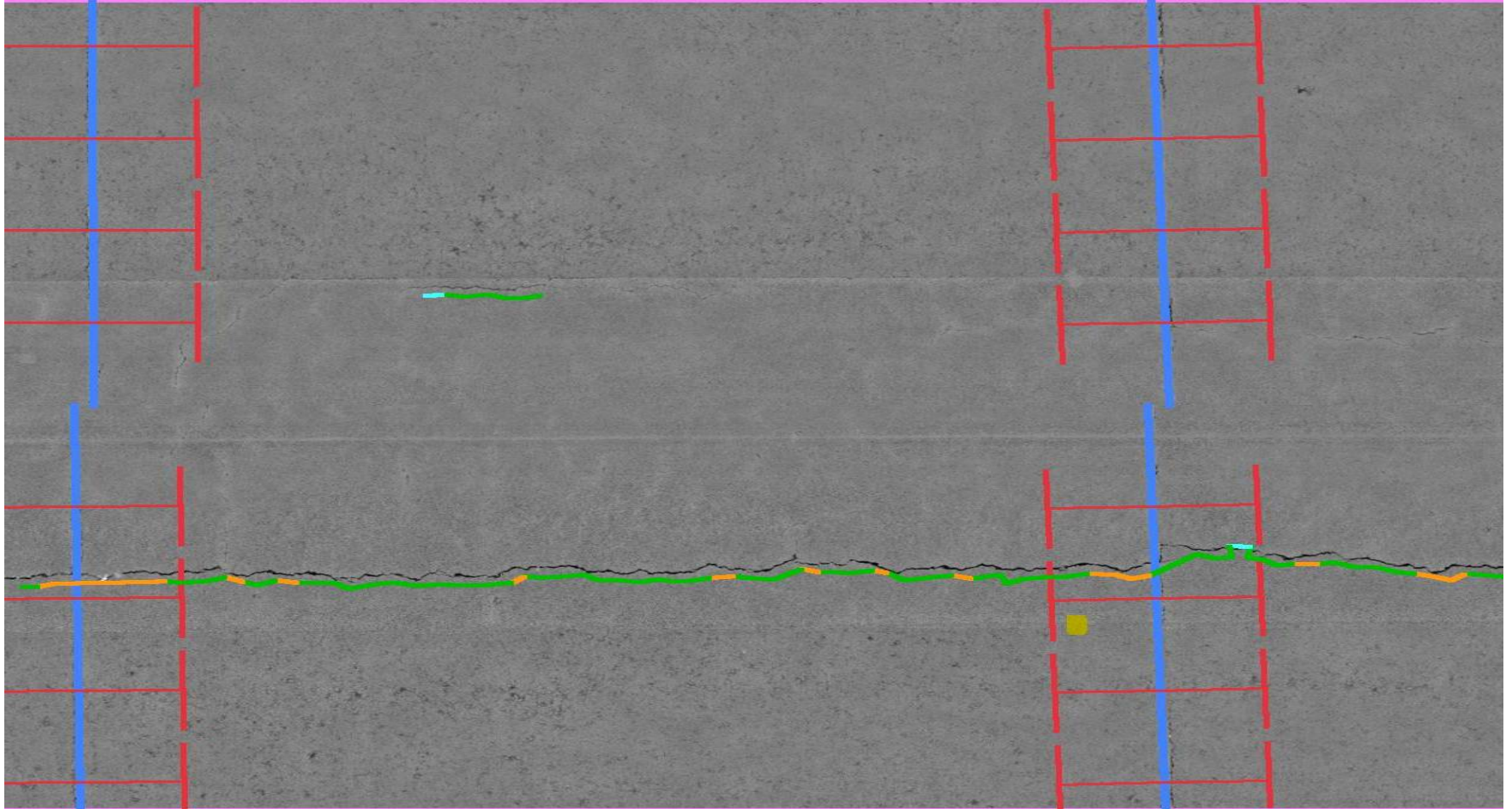
Lane Markings



Joints (sealed and unsealed)

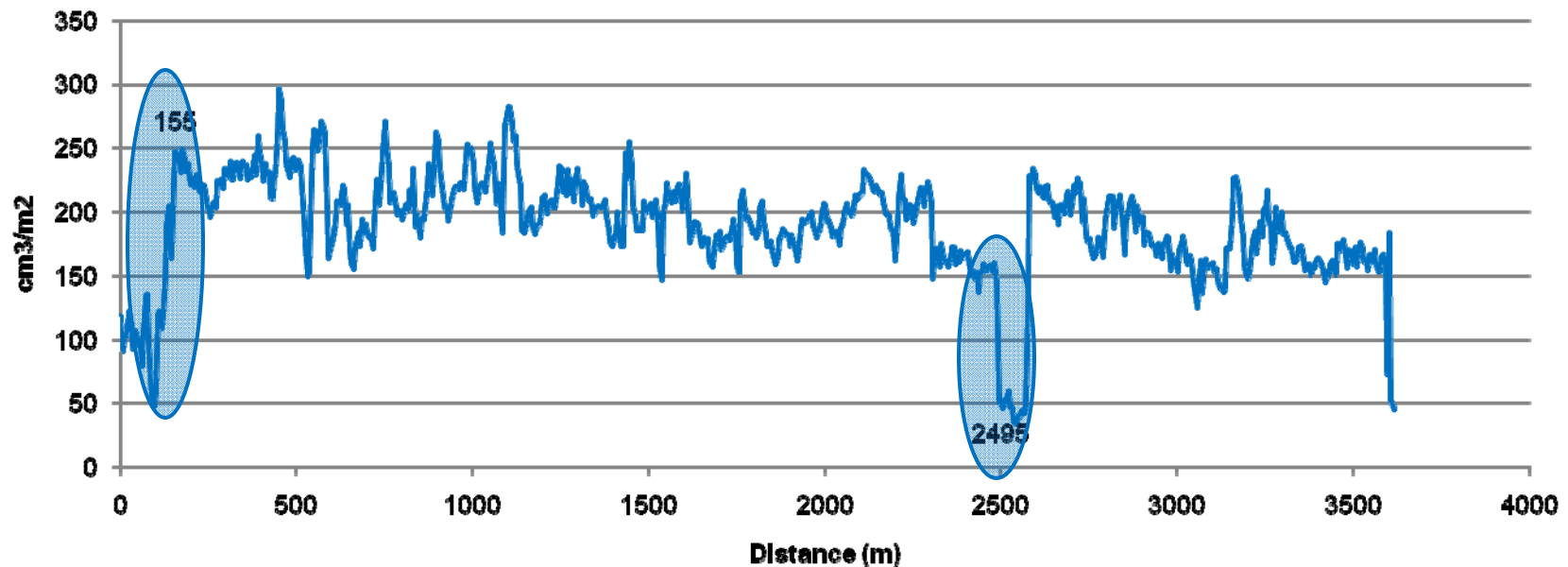


Joints and Cracks

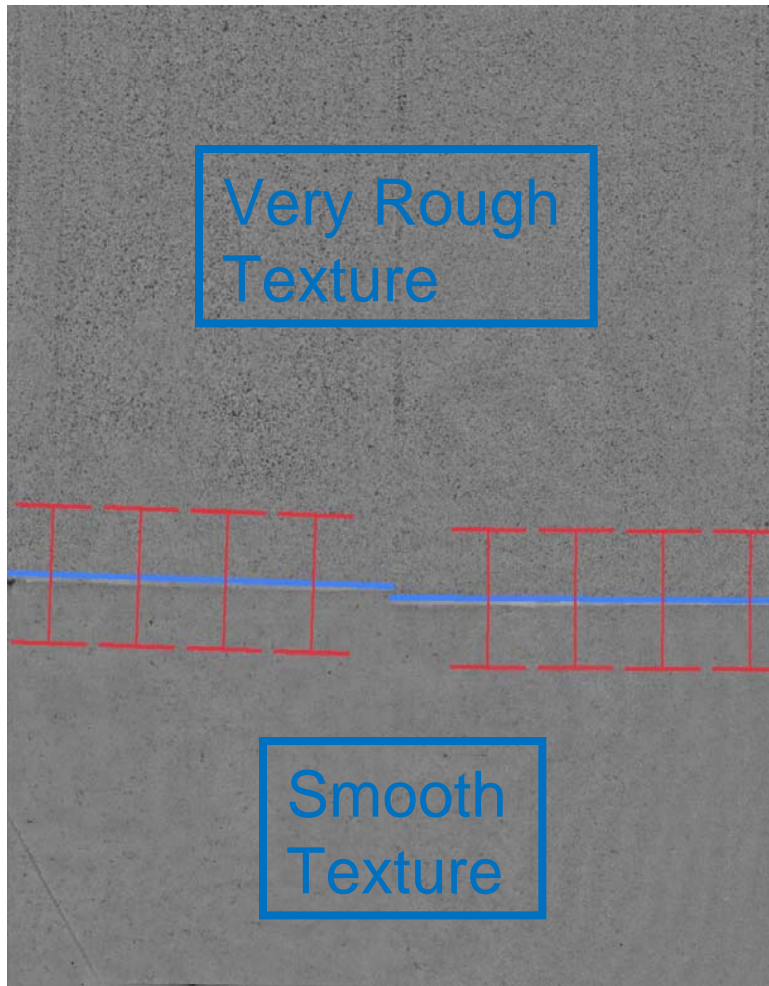


- RPI is a good indicator for texture transition.
- Abrupt asphalt texture transition at **155m**, from Smooth to Very Rough.
- Another asphalt texture transition at **2495m** (Rough to Smooth)

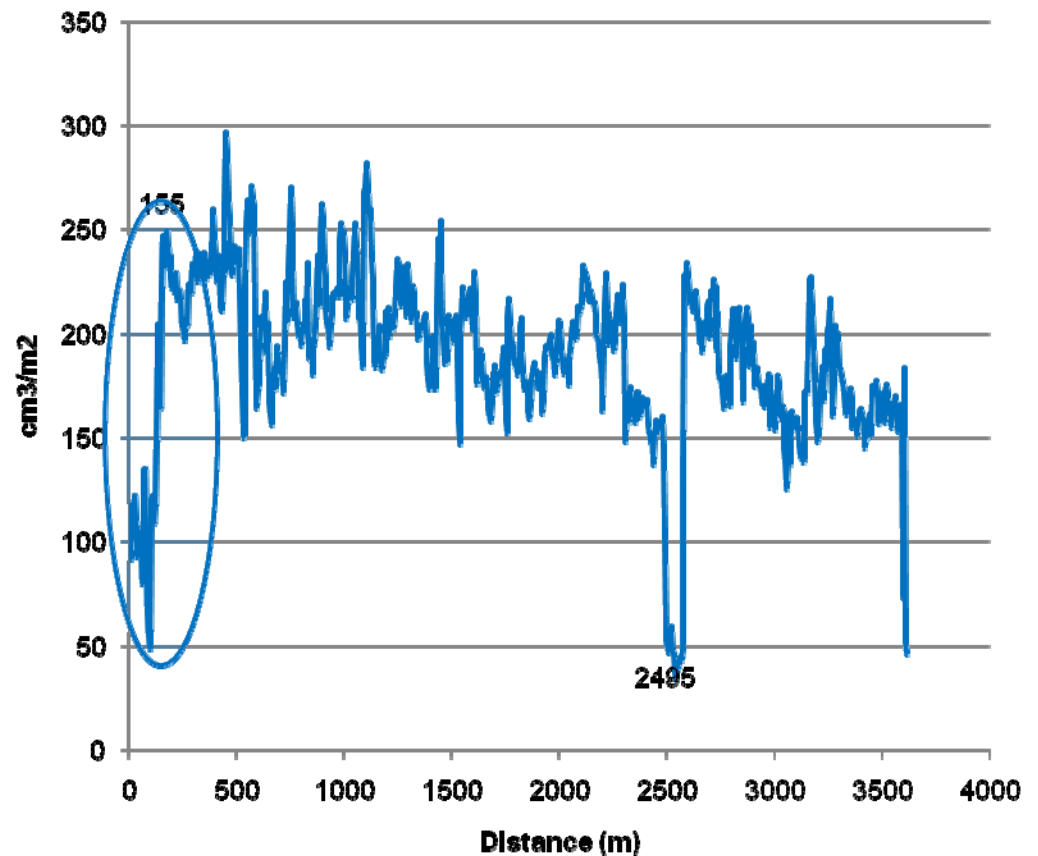
RPI per 5m road section for Lane #5



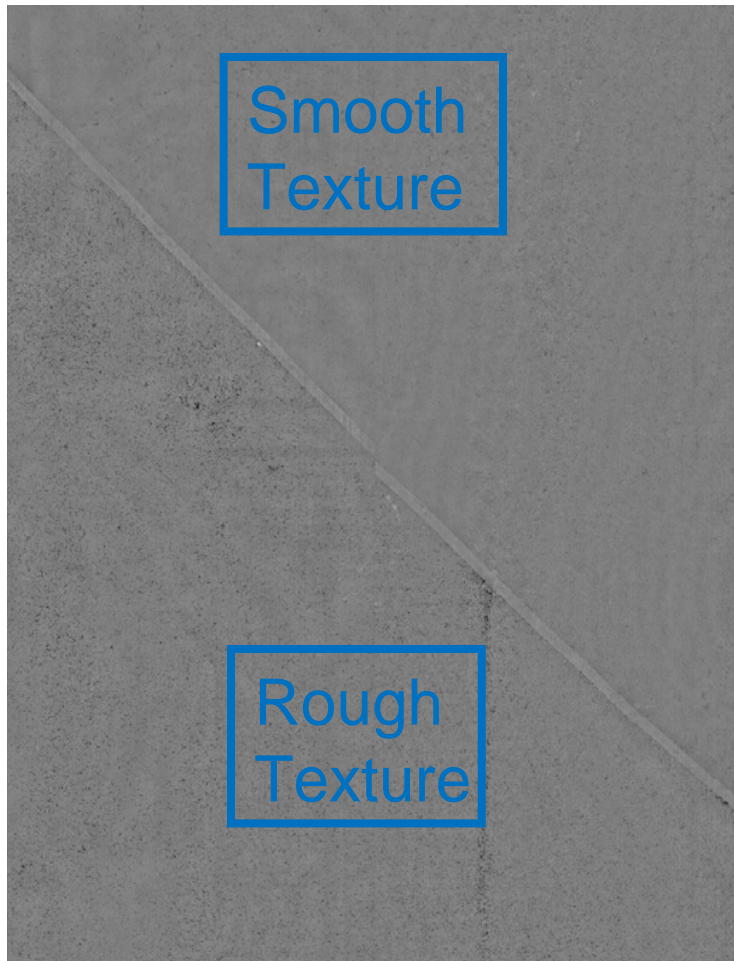
Texture transition from Smooth to Very Rough



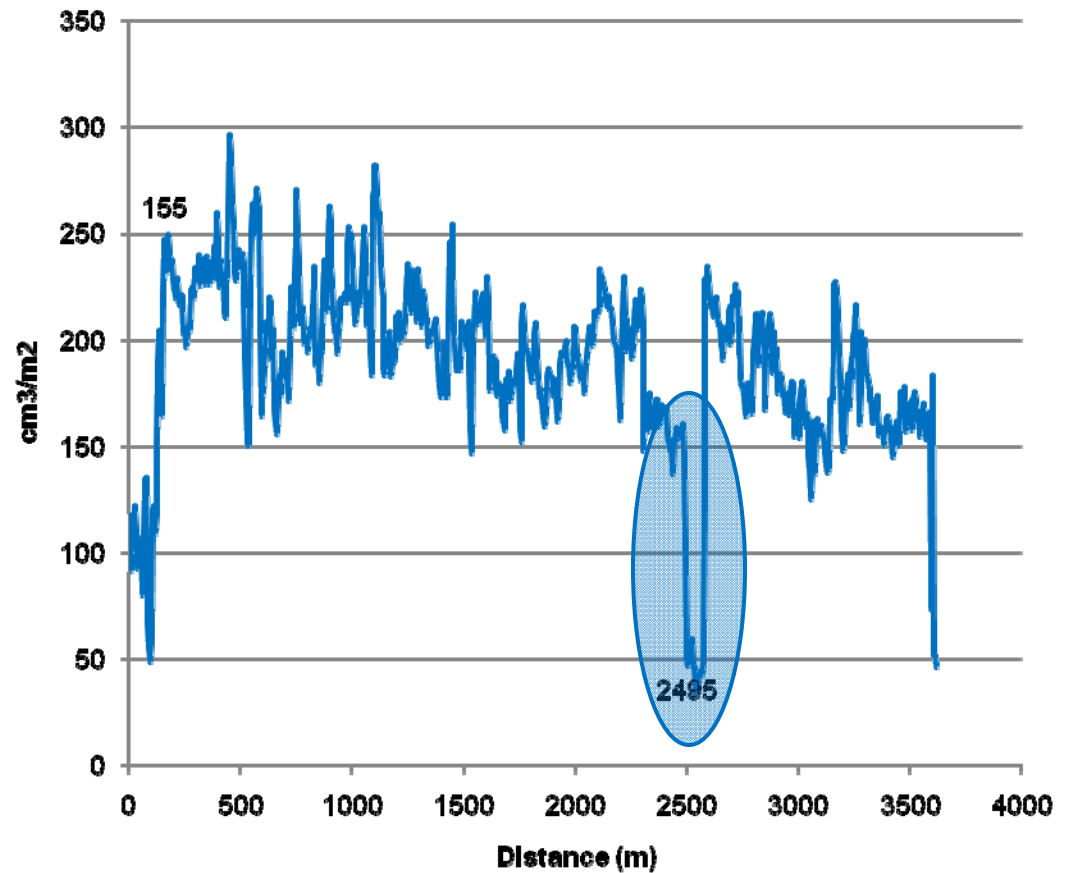
RPI per 5m road section for Lane #5



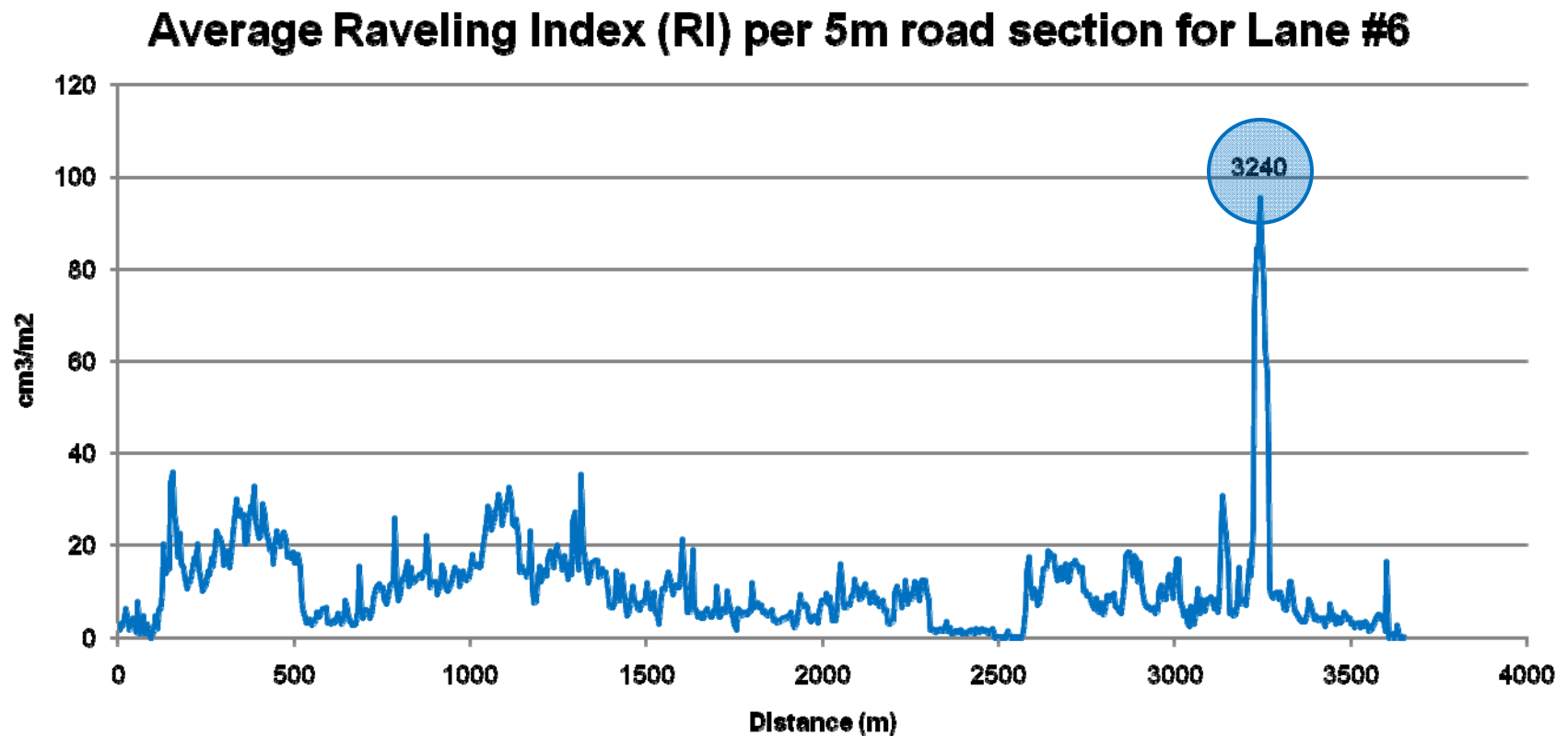
Texture transition from Rough to Smooth



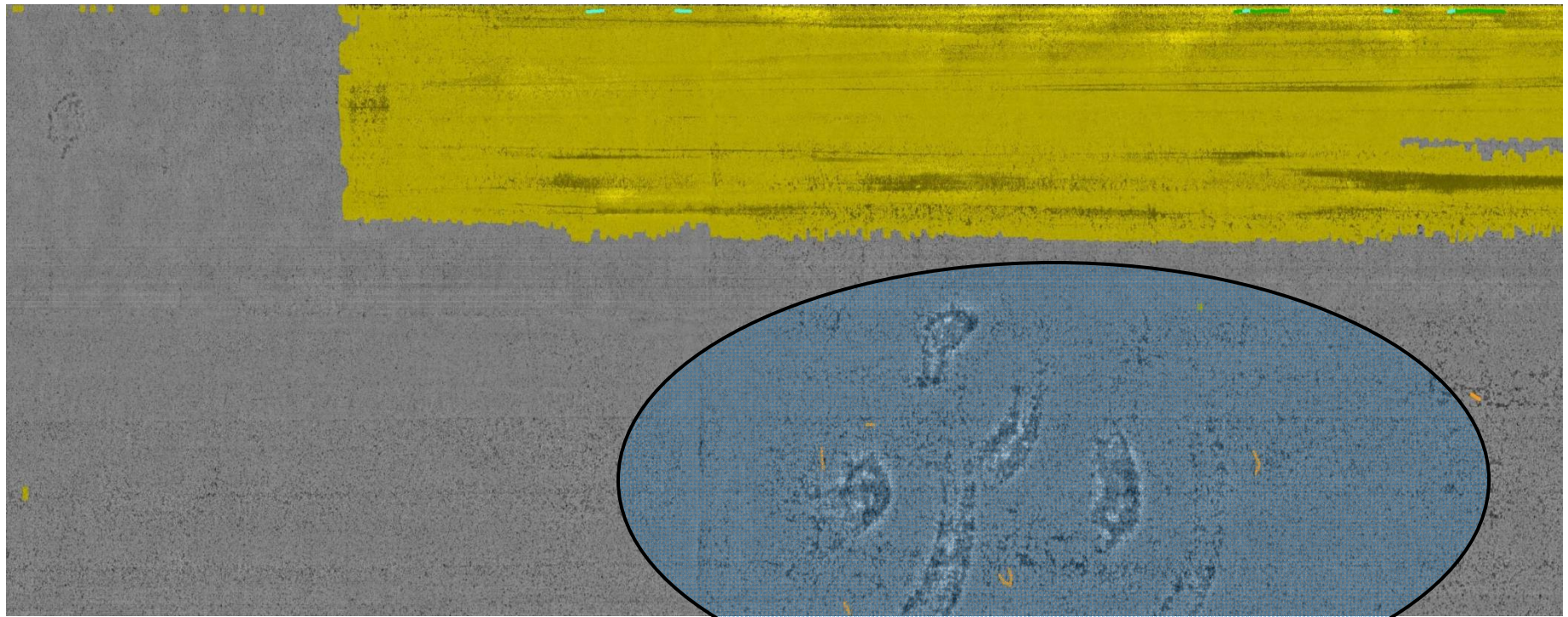
RPI per 5m road section for Lane #5



- Raveling index (RI) for Lane #6 shows a problem at distance 3240m

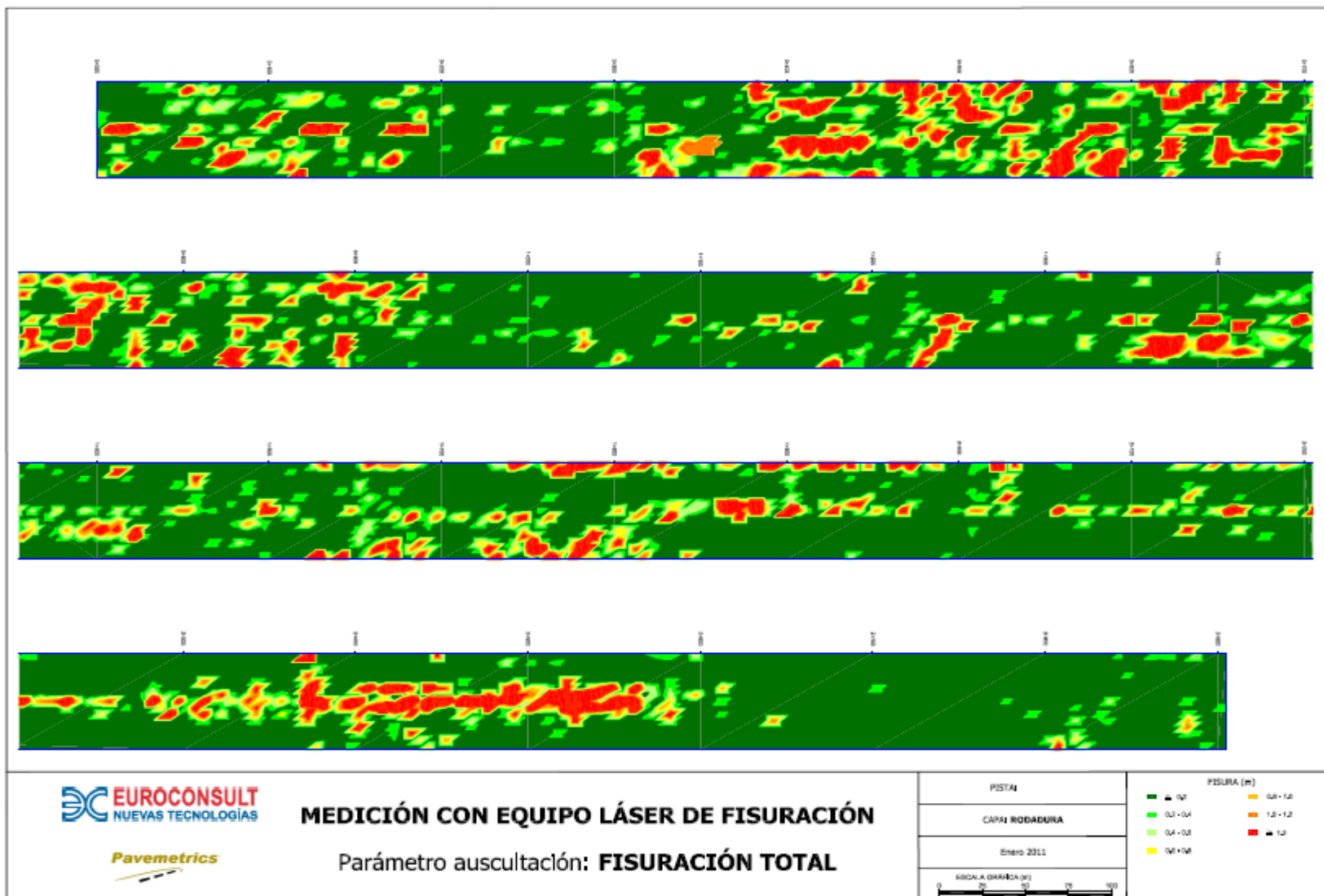


3D Range Images (3230m to 3250m)

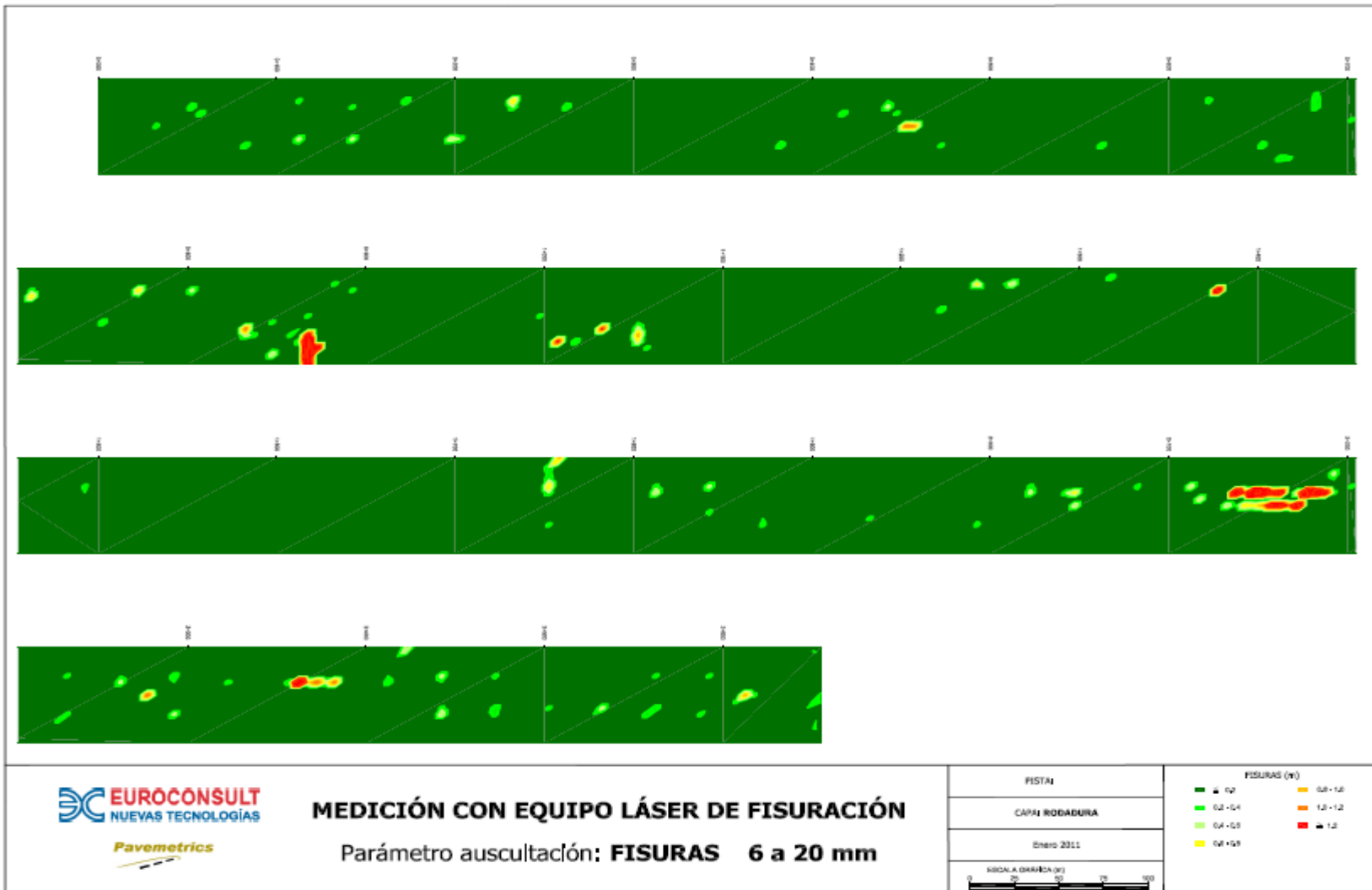


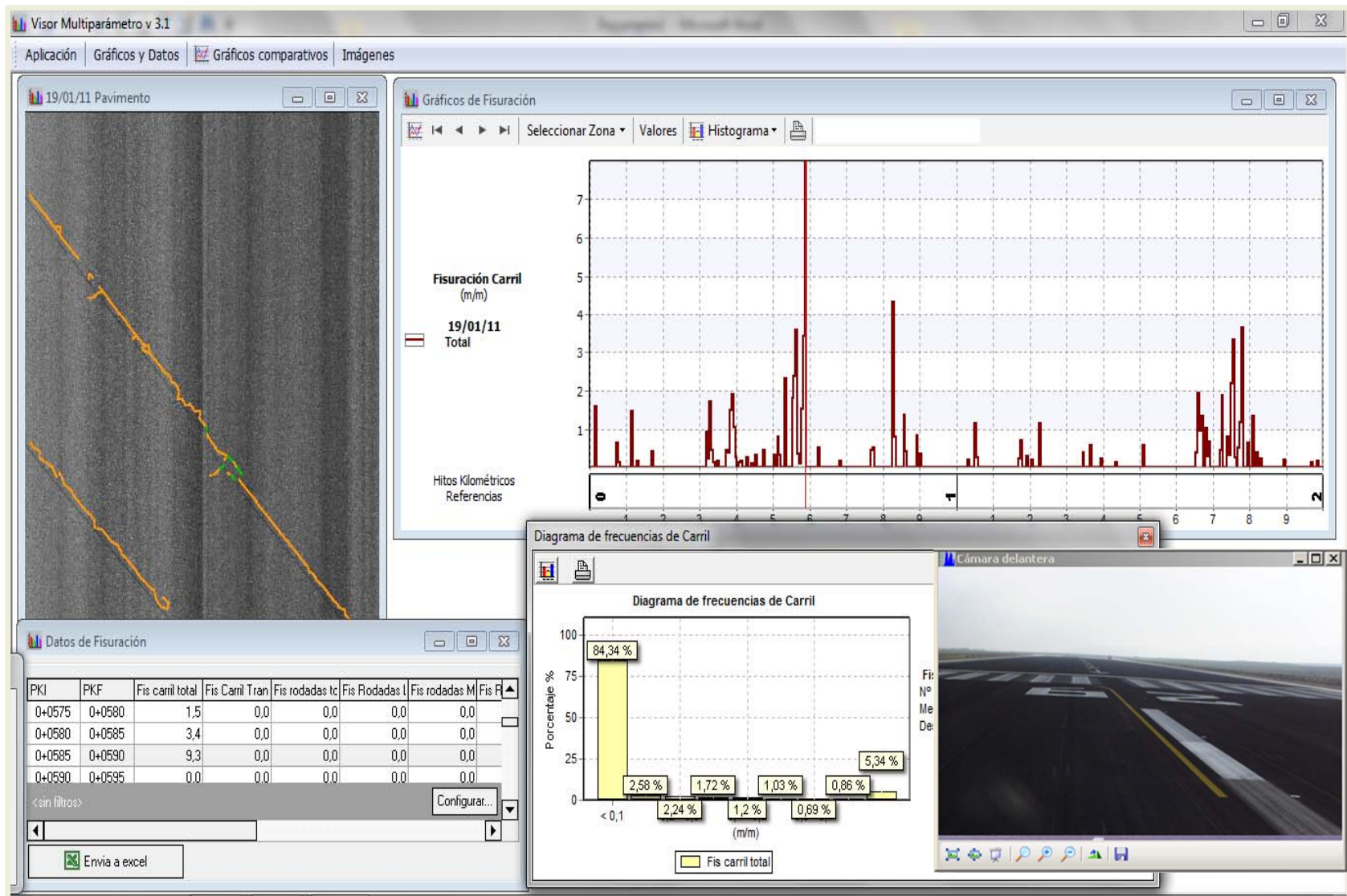
Severe raveled section

Barcelona – Cracking



Barcelona – Cracking (6mm+)





Any Questions ?



Thank you.

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