

AUTOMATED RAVELING INSPECTION AND MAINTENANCE PLANNING ON POROUS ASPHALT IN THE NETHERLANDS

FIRM15 - Brussels

TNO innovation
for life

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Ministry of Infrastructure and the
Environment

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INTRODUCTION

- › Willem van Aalst, TNO
 - › System engineer & project manager (infra inspection)
- › **Automated raveling inspection and maintenance planning on porous asphalt in the Netherlands**



Project(s) performed under authority of:

- › The Dutch Highway Agency, Ministry of Infrastructure and the Environment

CHALLENGES

- › Porous Asphalt (ZOAB):
 - › Dutch highways: > 85% ZOAB
 - › ZOAB 0/16: > 70%
- › Raveling:
 - › Loss of aggregates
 - › Dominant failure mechanism (>90%)
- › Alternative for visual inspections:
 - › Objective, Safe, Cost
 - › Road width (# lanes)
 - › Point laser(s) not sufficient (Stone(a)way)



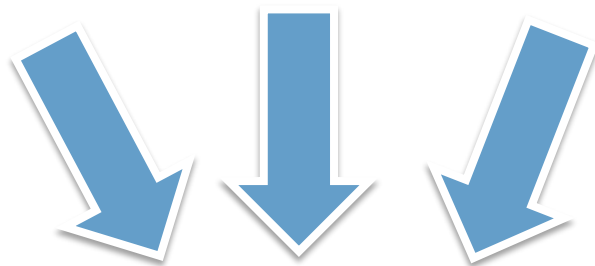
Source: www.bergersmeeting.com/nieuws.htm

GENERAL CONCEPT

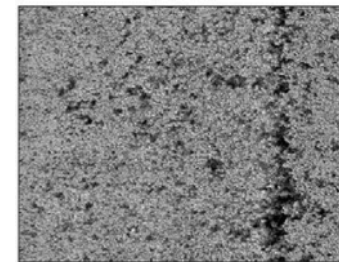
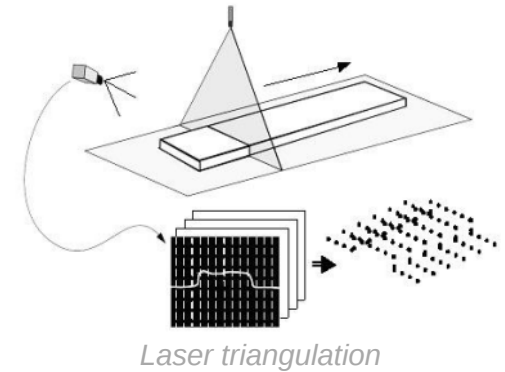
3D data generation



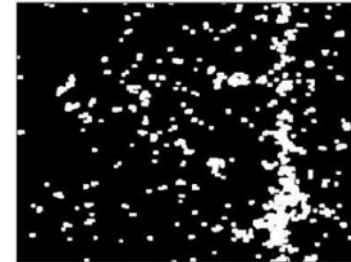
Raveling



Asset management



3D data



Raveling



Maintenance planning

TIMELINE

- › 2009 - 2010: **Feasibility**
- › 2010 - 2011: **Proof of concept**
- › 2012 - 2013: **First generation**
- › 2013-2014: **New vehicle**
- › 2014-2015: **Update (colour)**



TRL – 1

TRL – 2

TRL – 3

TRL – 4

TRL – 5

TRL – 6

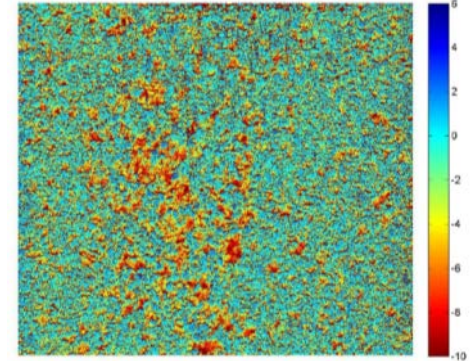
TRL – 7

TRL – 8

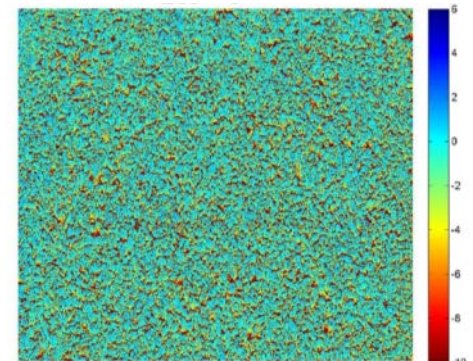
TRL – 9

FEASIBILITY PHASE

- › Questions:
 - › Raveling from 3D surface?
 - › Possible at high speed?

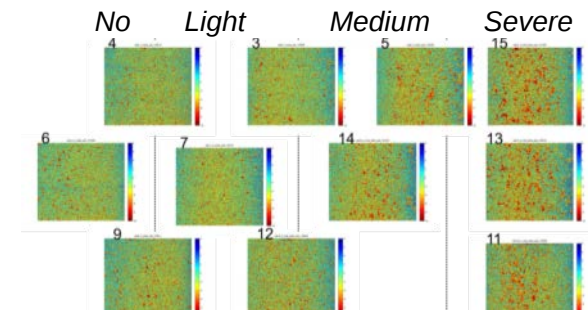


Severe raveling



No raveling

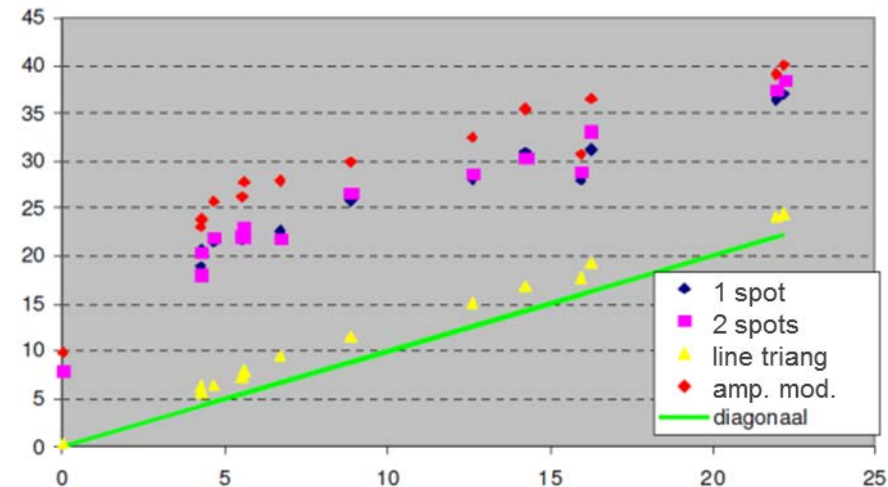
- › Test location: A65:
 - › 15 sections (1m²)
 - › Visual inspections
 - › 3D surfaces



Visual score

FEASIBILITY PHASE

- › Simulation of measurement systems
- › State of the art systems:
 - › Laser triangulation (1 or 2 spots)
 - › Laser triangulation (2 lines)
 - › Amplitude phase modulation lasers
- › Selected: line laser triangulation
 - › LCMS sensors (INO/Pavemetrics)

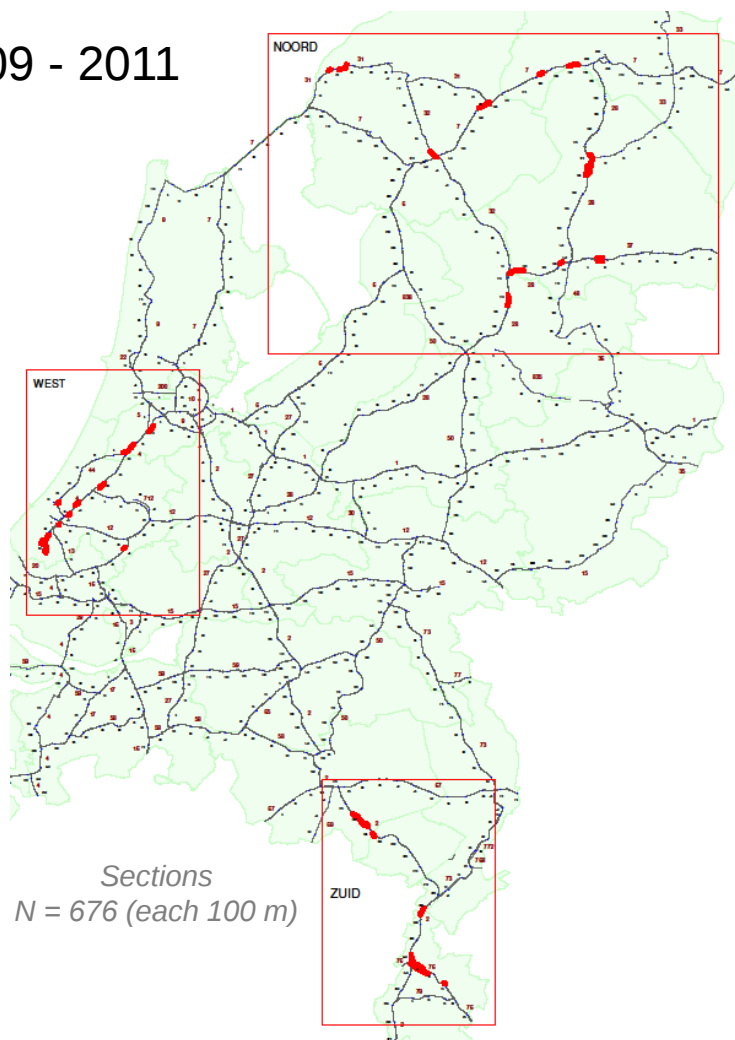


LCMS system

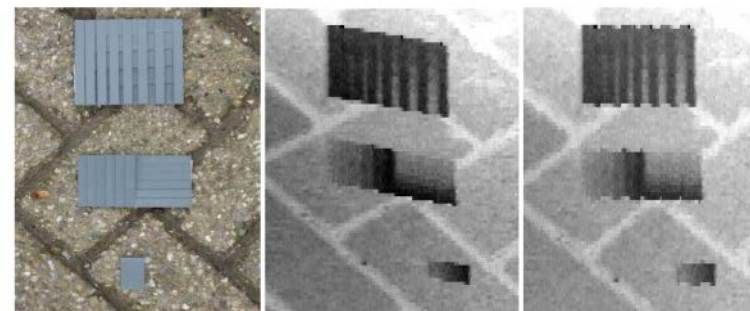
Source: www.pavemetrics.com

PROOF OF CONCEPT

› 2009 - 2011



RWS ARAN 2 equipped with the LCMS system



Test objects used to validate system specifications

PROOF OF CONCEPT

› Visual versus Model:

pljr model →	0	1	2	3	4	5	6	totaal
pljr adviseur								
0	29	12	2					43
1	7	21	20	3				51
2	3	19	34	9				65
3		1	10	38	19	4		72
4			1	22	21	21	4	69
5			1	3	7	20	8	39
6				3	4	16	44	67
totaal	39	53	68	78	51	61	56	406



› Good correlation with visual inspections!

› 93% (+/- 1 year)

FIRST GENERATION

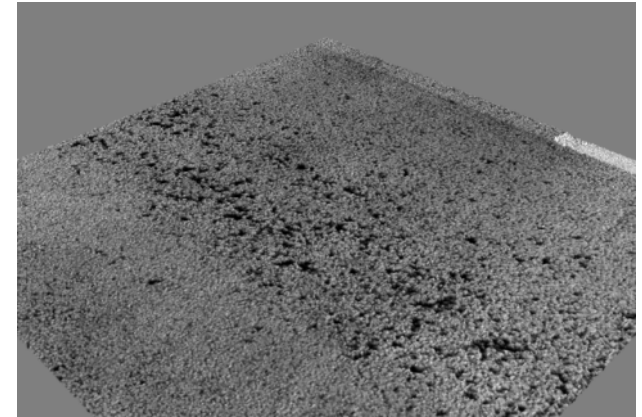
Main components

- › LCMS sensors & controller (3D data)
- › Laser Safety Controller (tilt, speed, ...)
- › RTK – GPS (positioning)
- › DMI (triggering)
- › Front- & side camera's (reference)
- › FPGA framegrabber (HW timing)
- › Acquisition pc (Windows)
- › Control pc (Unix)

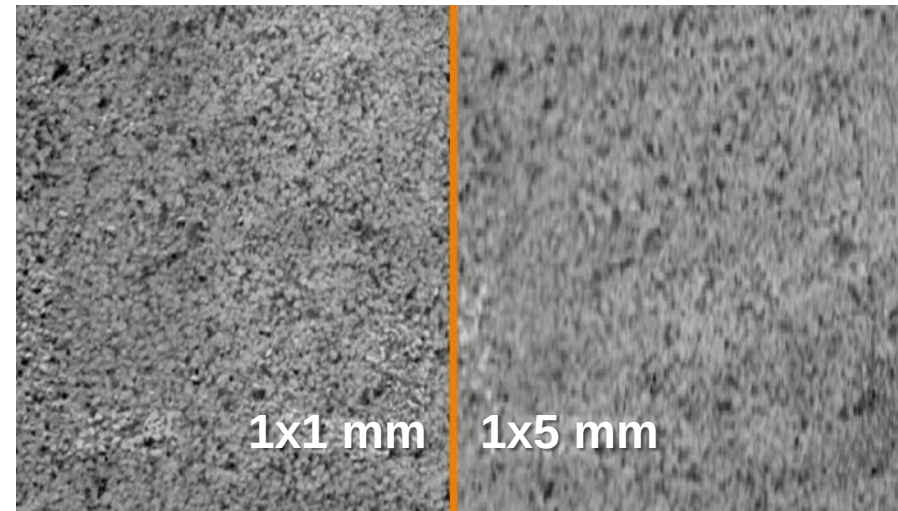


SPECIFICATIONS

- › High speed 'in-traffic' measurements
 - › ~120 km/h
 - › Lane wide: 4 meters
- › 3D range data
- › 2D intensity data
- › Resolution:
 - › 1.0 mm (transversal)
 - › 4.7 mm (longitudinal)
- › Accuracy (height):
 - › ~ 0.5 mm (σ)

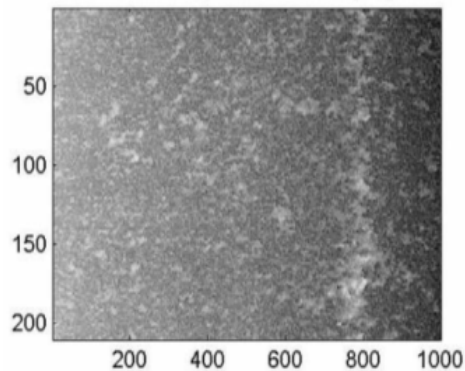


2 x 2 m section

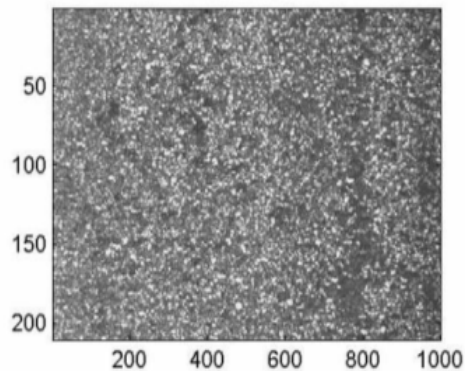


EXAMPLE DATA

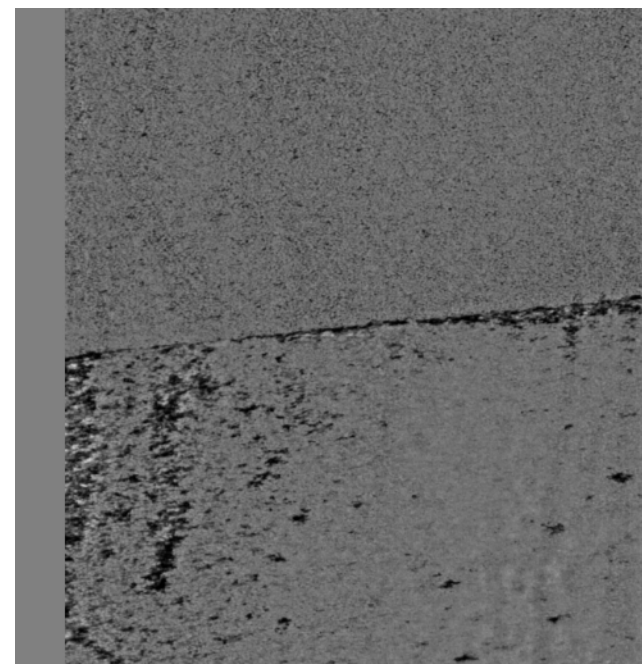
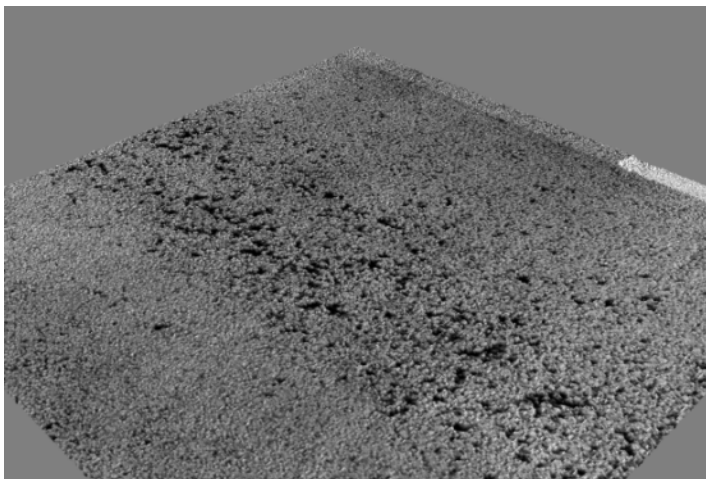
Range



Intensity



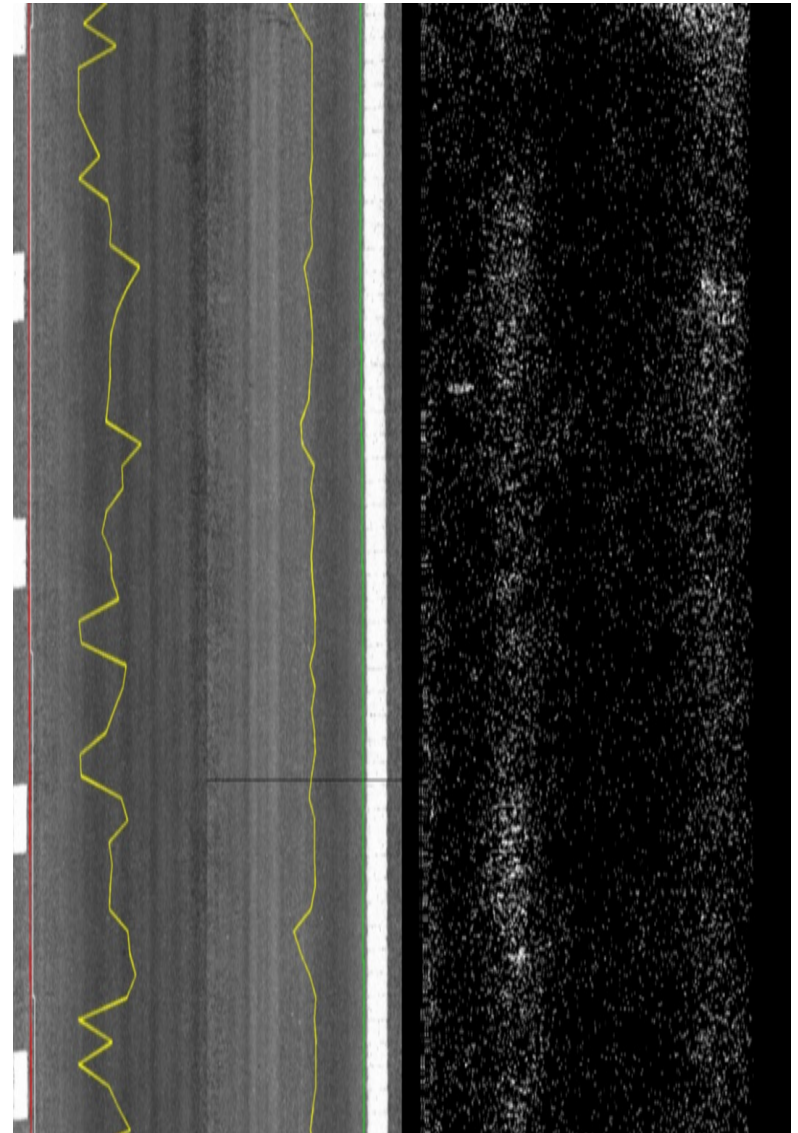
3D print



DATA PROCESSING

› Steps

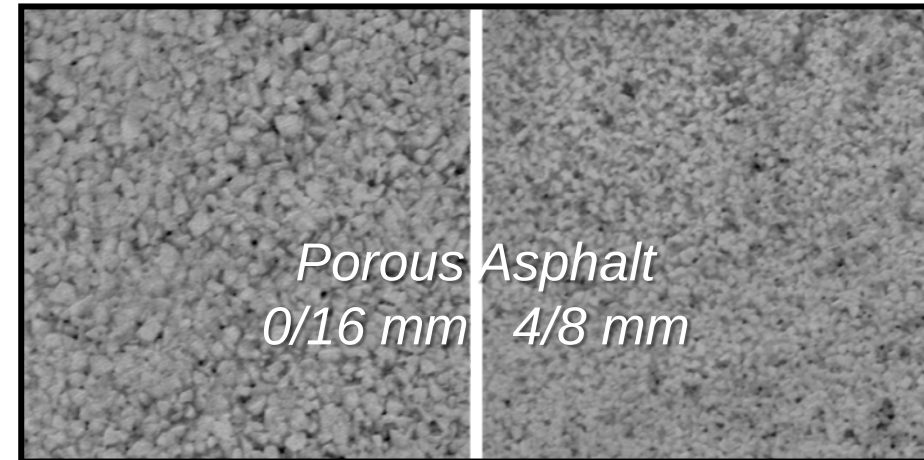
1. Road-marking detection
2. Flattening (road & vehicle motion)
3. **Texture analysis** (pavement type)
4. Removal of:
 - Mechanical damage (rim marks)
 - Joints
5. Wheel path (maximum damage)
6. **Raveling** (per m² in wheel path)
 - % stone loss
 - % clustered stone loss

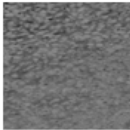
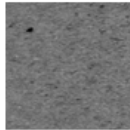
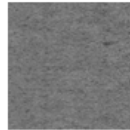
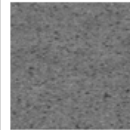
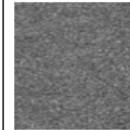
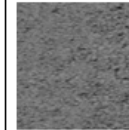
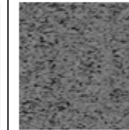
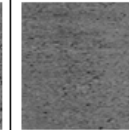
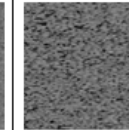
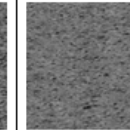
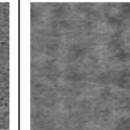


PAVEMENT TYPE CLASSIFICATION

- › Dependencies on pavement type
 - › Raveling
 - › Maintenance interval

- › Two approaches:
 - › Spectrum based (FFT)
 - › Texture based (various descriptors)

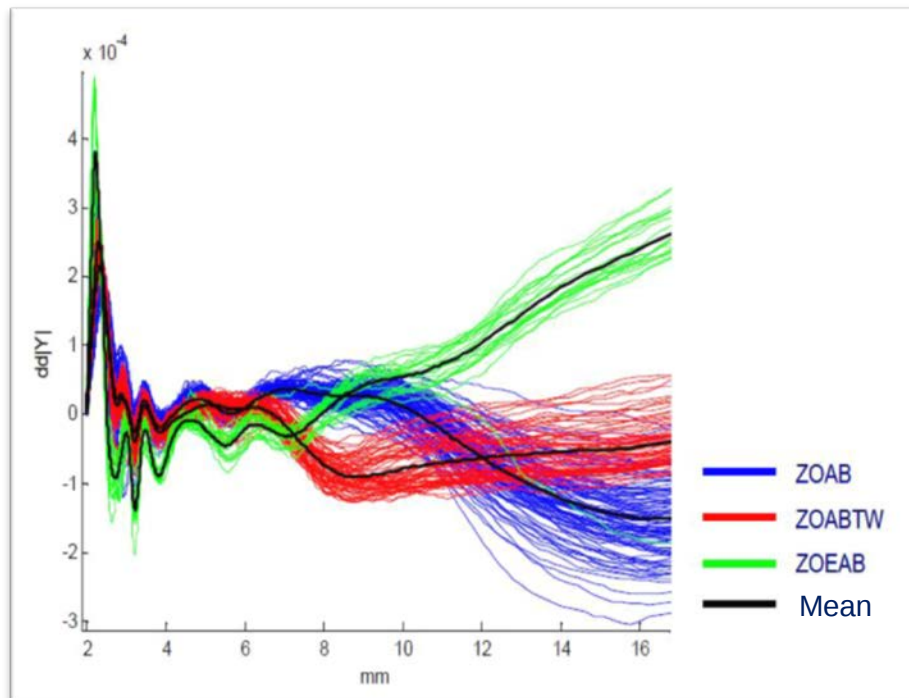


										
COMBID	DAB	DAD	EAB	EOB	NOVACP	OAB	SMA	ZOAB	ZOABTW	ZOEAB

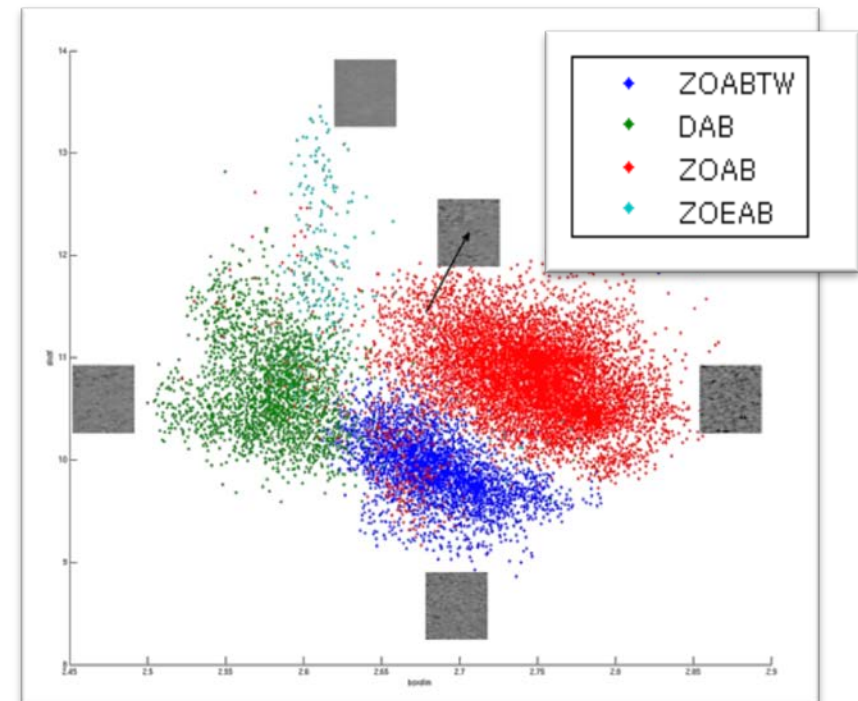
PAVEMENT TYPE CLASSIFICATION

› Examples:

Spectrum analysis



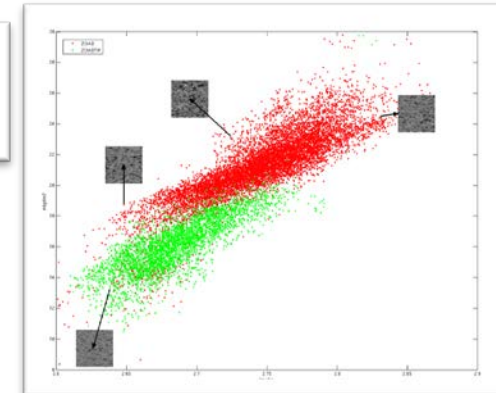
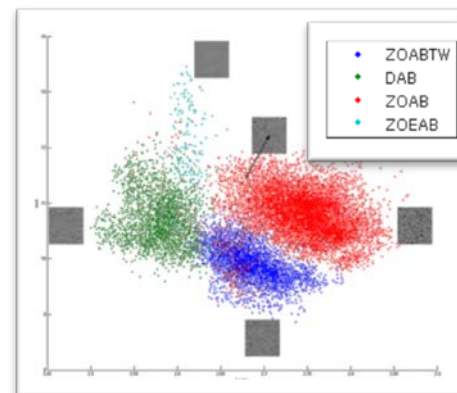
Texture analysis



PAVEMENT TYPE CLASSIFICATION

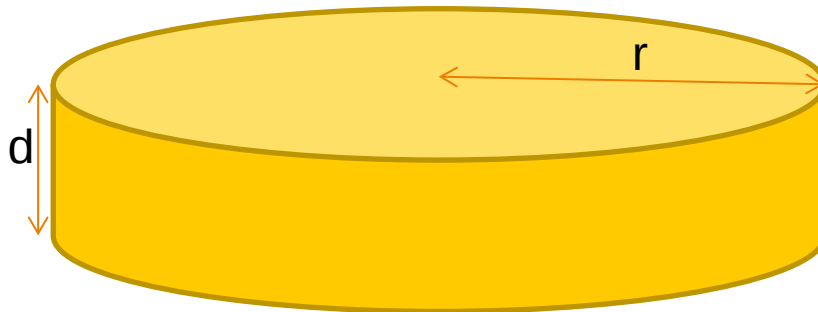
- › Classification
 - › 11 texture measures
 - › Quadratic classifier
- › Evaluation set
 - › N = 27.128 (100m)
- › Results
 - › Overall: > 98.8% correct
 - › Porous Asphalt: > 99,7 % correct

		Dicht								Open					
	Berekend	COMBID	DAB	DAD	EAB	EOB	NOVACP	OAB	SMA	ZOAB	ZOABTW	ZOEAB	Totaal	% correct	
	Admini- stratief														
Dicht	COMBID	27											27	100,0%	92,5%
	DAB		2326	2	31	2			100	5	7	10	2483	93,7%	
	DAD			163	2								165	98,8%	
	EAB		10		70						2	1	83	84,3%	
	EOB					8							8	100,0%	
	NOVACP						53						53	100,0%	
	OAB							17					17	100,0%	
	SMA		64			1			598	22	6		691	86,5%	
Open	ZOAB	1									19155		19156	100,0%	99,7%
	ZOABTW		3		8				5	24	4195	1	4236	99,0%	
	ZOEAB		7		13				3		1	185	209	88,5%	
	Totaal	28	2410	165	124	11	53	17	706	19206	4211	197	27128	98,8%	
		96,4%	96,5%	98,8%	56,5%	72,7%	100,0%	100,0%	84,7%	99,7%	99,6%	93,9%			
		92,8%								99,7%					



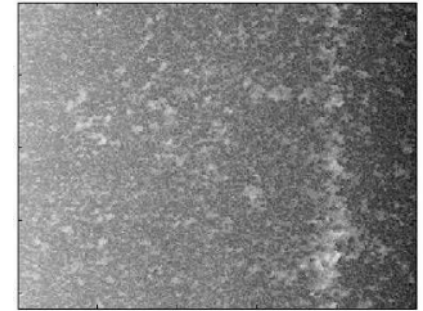
RAVELING

- › Flatten & clean data
- › 'Coin' algorithm
 - › Radius (r)
 - › Depth (d)

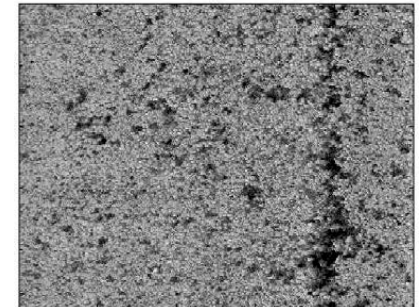


- › '3D Stone(a)way'

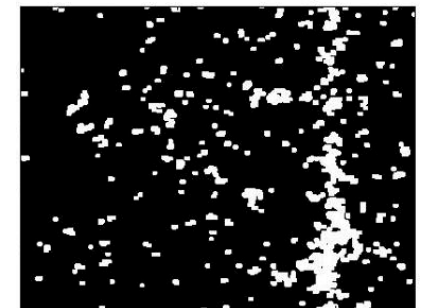
Raw 3D data



Flattened
& cleaned

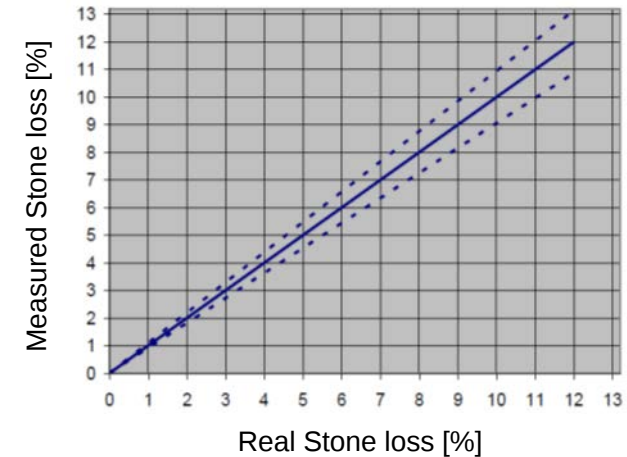
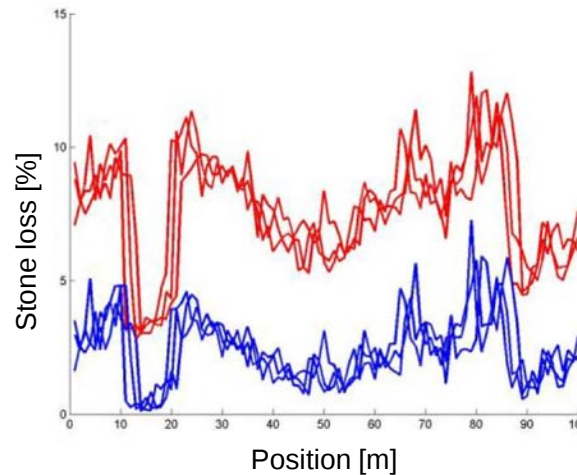


Raveling

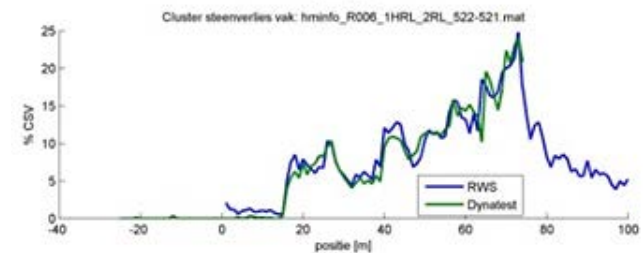
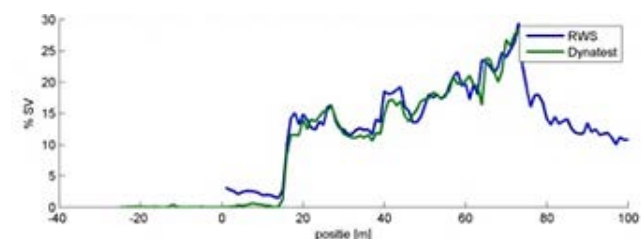
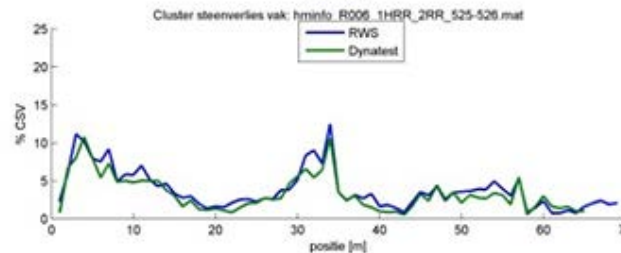
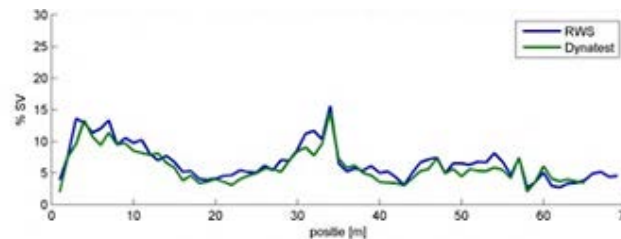


RAVELING

- › Repeatability:
 - › Very good!



- › Reproducibility:
 - › Very good!



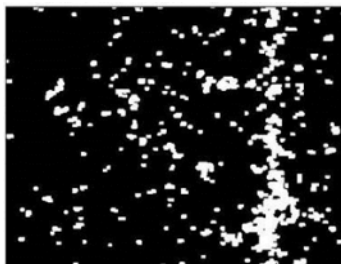
MAINTENANCE INTERVAL

› ‘Old’ style:

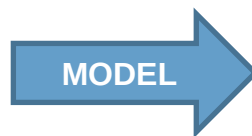
› Visual inspections → Maintenance interval (year)

› ‘new’ style:

› Ravelling data → Maintenance interval



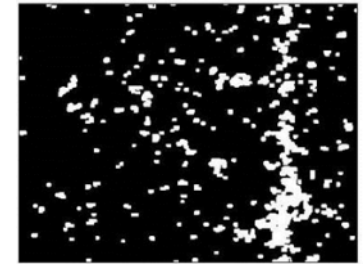
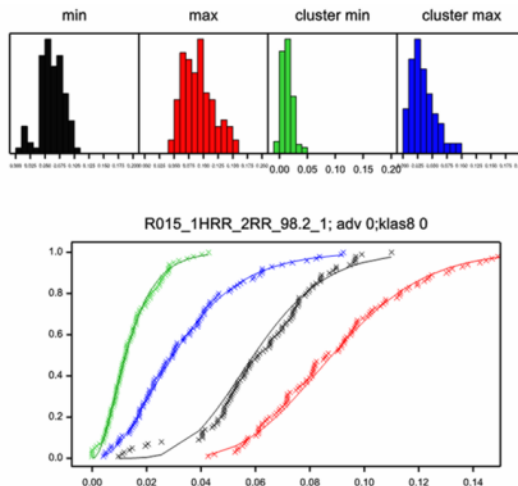
Raveling



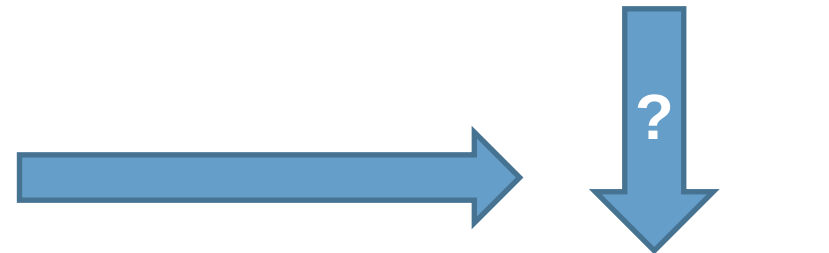
Maintenance interval

MAINTENANCE INTERVAL

- › Input:
 - › Ravelling per m² (both wheel paths)
- › Linear classifier
 - › 28 inputs → 1 output (per 100m)
 - › Trained on visual inspections



Raveling



Maintenance interval

MAINTENANCE INTERVAL

› Results:

› 2012 : ~ 99 % correct (+/- 1 year to visual inspection)

› Two districts: Venlo & St. Joost

› Visual inspections

Interval [years]	Model							
Visual	0	1	2	3	4	5	6	Grand Total
0	2	1						3
1	2	4	5	2				13
2			18	48	5			71
3			13	86	110	6		215
4				7	26	111	7	151
5					7	127	63	197
6					13	554	1146	1713
X	1			1	3			5
Grand Total	3	6	37	144	164	798	1216	2368

RESULTS

2012

2013

2014



› Results:

› 2014

typeLCM:MJPV15		0	1	2	3	4	5	6
ZOAB(+)	0	143	34	31	9	7	2	4
	1	23	67	30	20	10	6	4
	2	26	71	162	72	64	22	7
	3	17	59	152	247	217	125	40
	4	7	14	50	134	529	297	81
	5	4	2	28	71	375	1238	325
	6	10	15	24	40	420	2675	34214
ZOAB(+) Total		230	262	477	593	1622	4365	34675

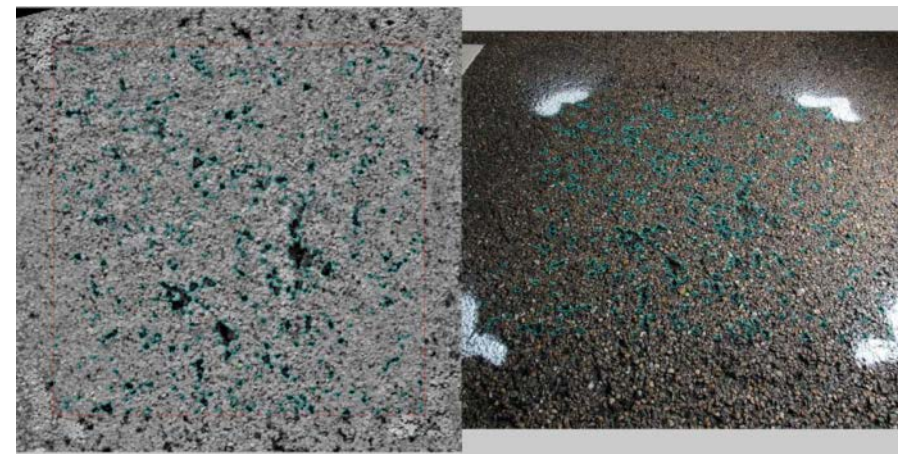
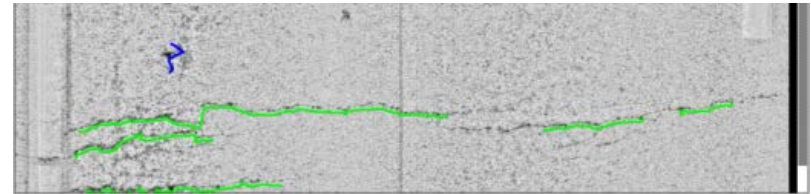
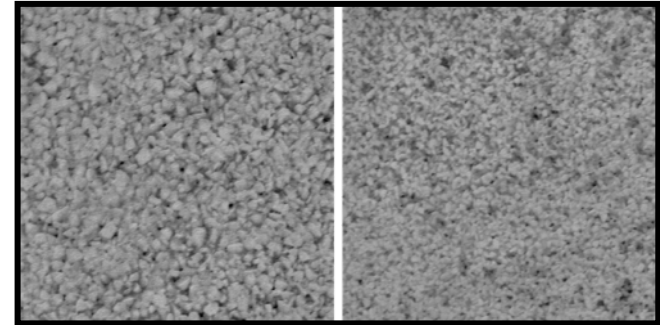
SUMMARY

- › Accurate measurement of raveling op PA (ZOAB)
 - › High speed and 'in-traffic'
 - › Good repeatability and reproducibility
- › System operational since 2012
 - › Replacing most visual inspections
- › Modelling of maintenance interval
 - › Based on raveling
- › Accurate pavement type classification



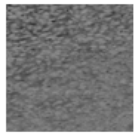
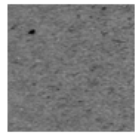
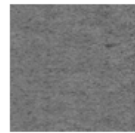
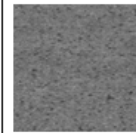
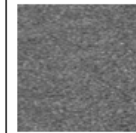
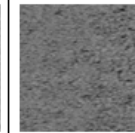
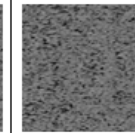
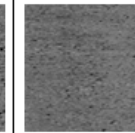
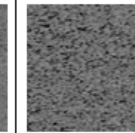
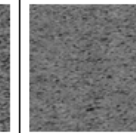
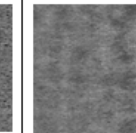
ONGOING & FUTURE RESEARCH

- › Cracking on PA (ZOAB)
- › Raveling on fine PA and SMA
- › Commercialisation
- › (EU-)collaboration
- › (Standardisation)



CHALLENGES FUTURE

› Variety in pavements versus Monitoring & Prediction

										
COMBID	DAB	DAD	EAB	EOB	NOVACP	OAB	SMA	ZOAB	ZOABTW	ZOEAB

› Fine porous asphalt versus Measurements



› **THANK YOU FOR YOUR ATTENTION**

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Rijkswaterstaat
Ministry of Infrastructure and the
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