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What have we learnt during Remix project?

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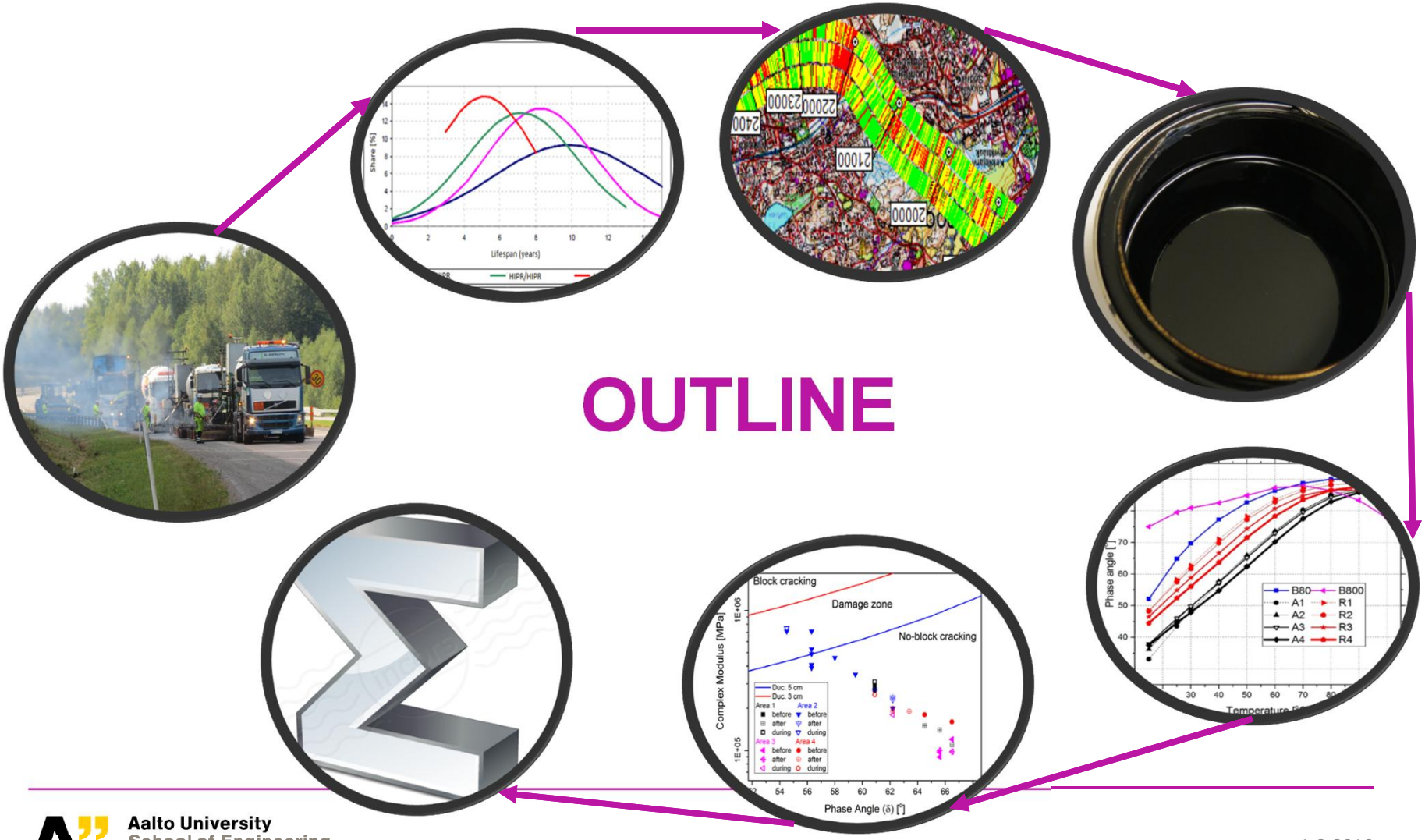
Share [%]
Lifespan (years)
HIPR/HIPR
24000
23000
22000
21000
20000
Block cracking
Damage zone
No-block cracking
Complex Modulus [MPa]
1E+06
1E+05
Duc. 5 cm
Duc. 3 cm
Area 1
Area 2
Area 3
Area 4
before
after
during
Phase Angle (δ) [°]
Phase angle [°]
B80
B800
A1
R1
A2
R2
A3
R3
A4
R4
Temperature

OUTLINE

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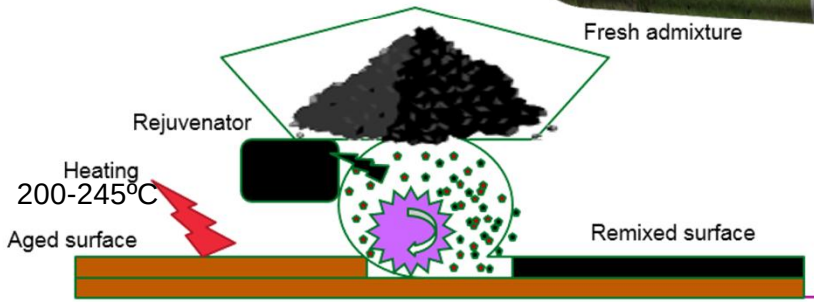
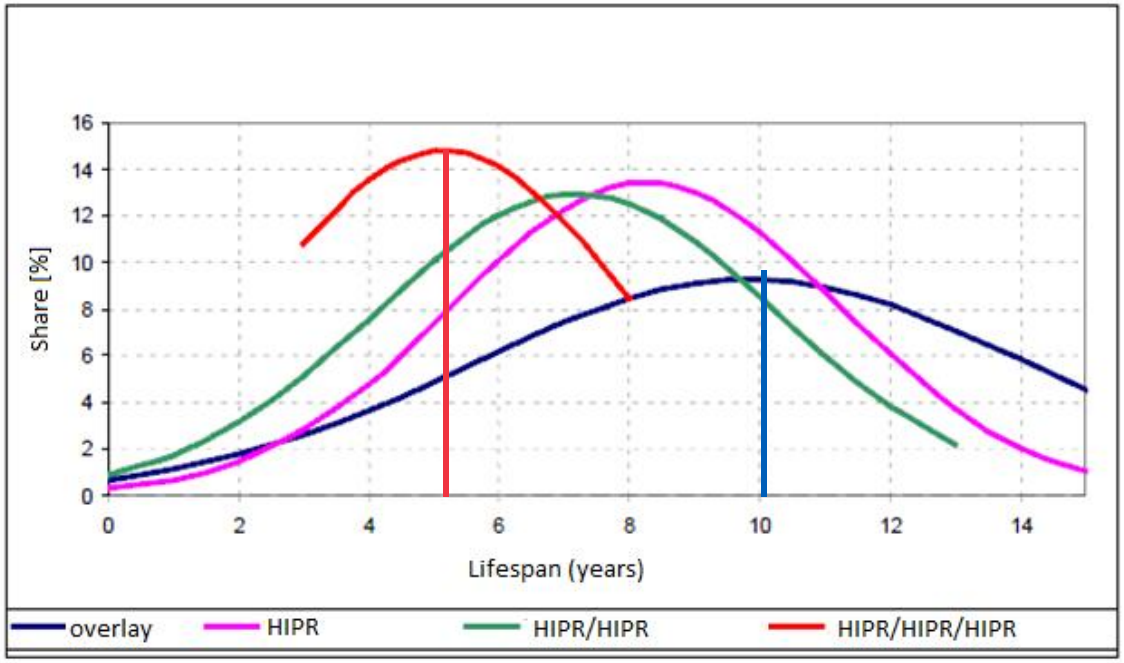
The why?
The what?
And the how?

Hot In-place recycling



30 minutes later

The aim is to understand why recycling for the 3rd time fails and how to fix it



Criterion for rehabilitation is rut depth

REM/REM/REM

↓

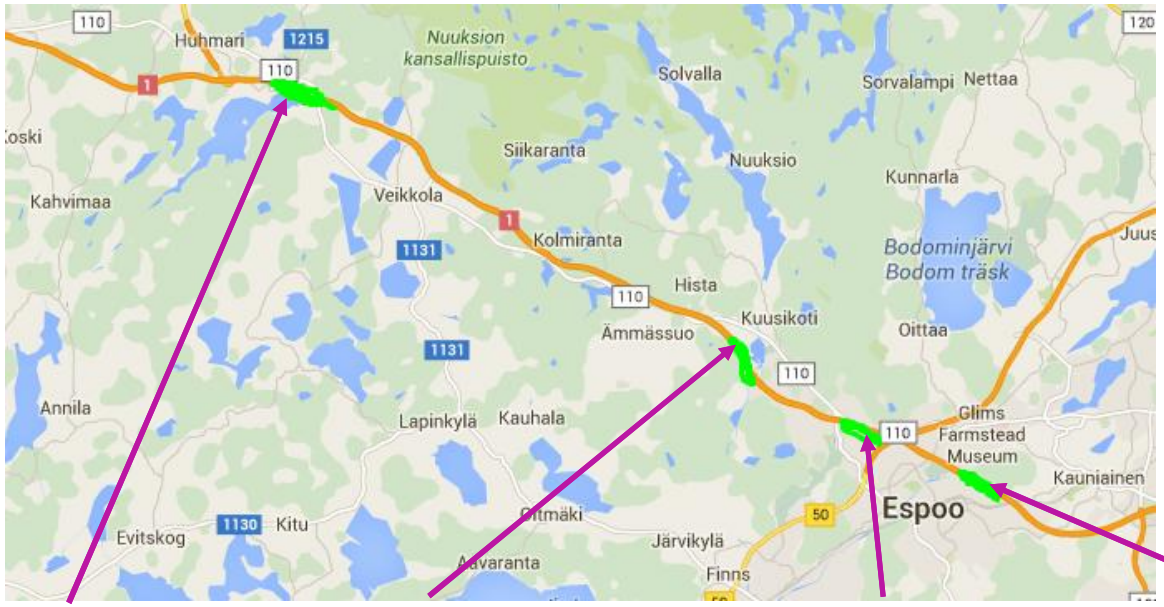
½ Price
½ Lifetime

↓

LTA

F(mixture?)
F(addmixture?
F(No. of cycles?)

Maintenance on Highway No. 1 in 2013 - a unique opportunity to study triple recycling

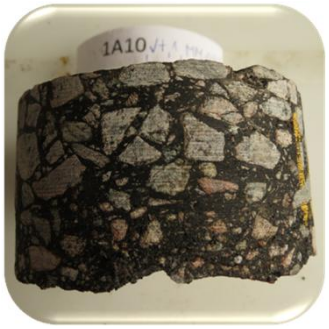


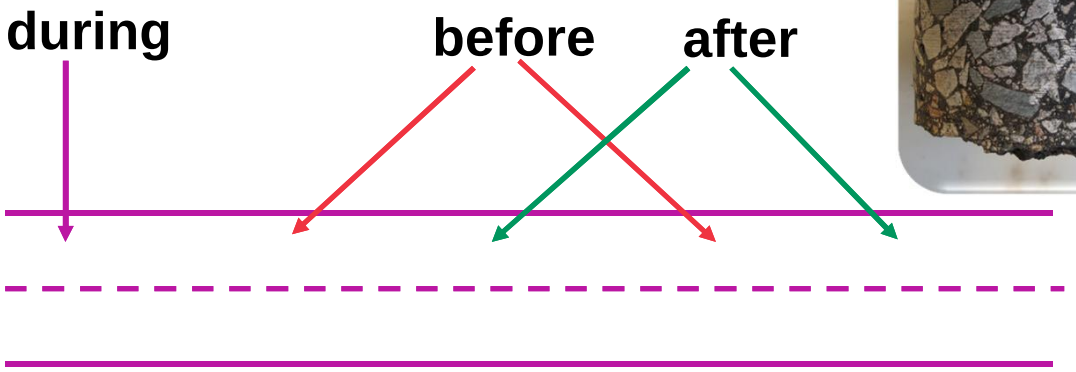
Total length of construction: **26,5 km!!!**

HIPR	HIPR/HIPR	HIPR/HIPR/HIPR	HIPR
Cycle 1	Cycle 2	Cycle 3	Cycle 1’
Area1	Area2	Area3	Area4

Similar lifecycle for all test sites (2008/2009 à 2013, SMA)

VT1 sampling






Roads
Aggregate
Fines
Bitumen

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Performance

How to choose sampling site?

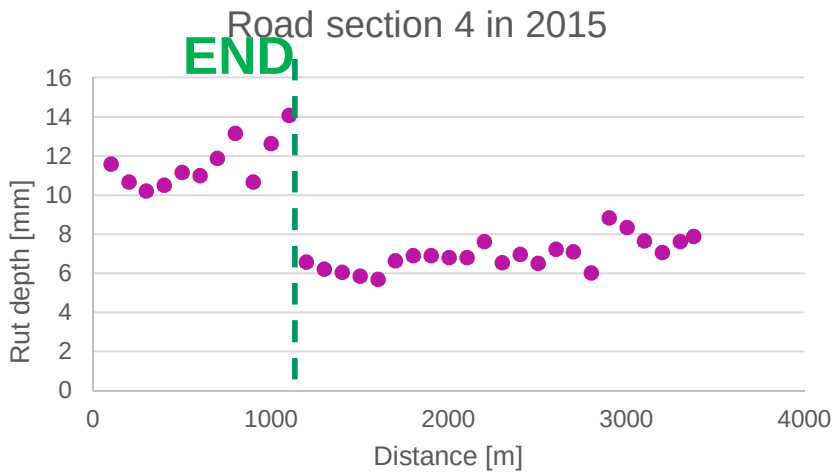
Current practice: 5 from one homegenous area (current)

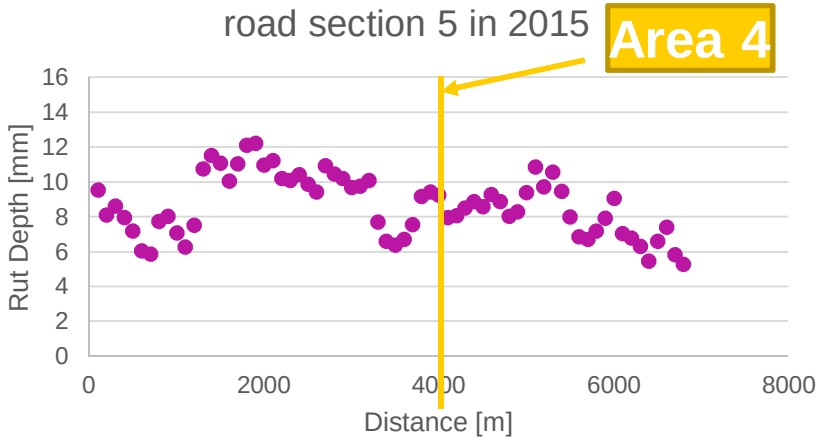
During the project we took samples from many areas:

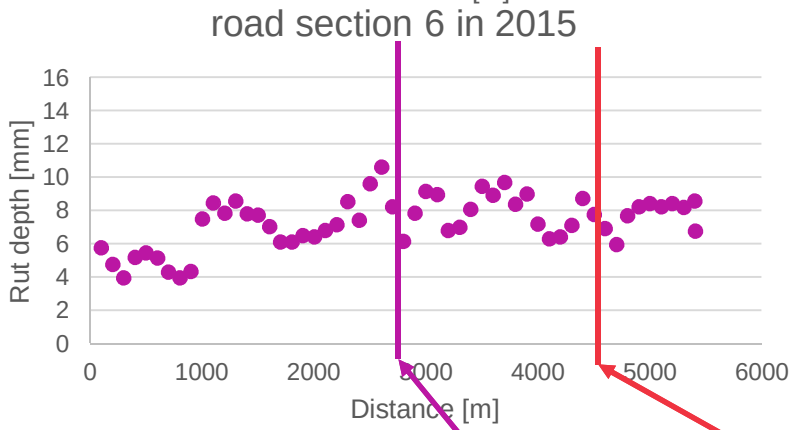
- Area = stretch of the road with same history
- Rut depth was averaged per area
- In the 100-200 m stretch where rut depth was closest to the average rut à collection of samples

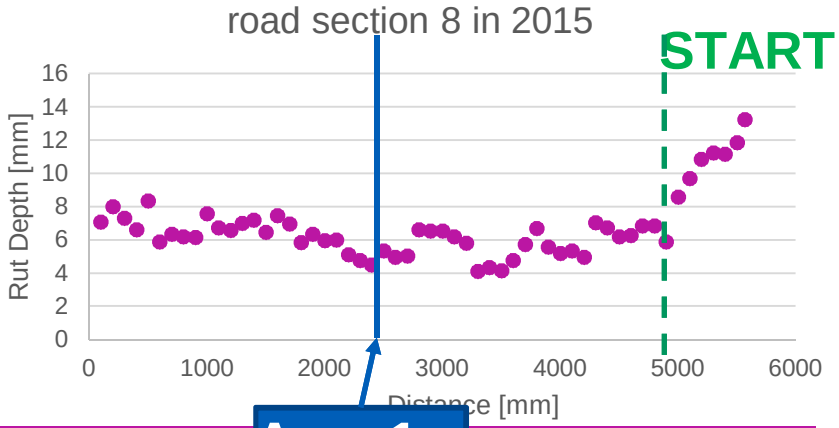
Good or bad?
How should we factor the rut depth?

The rut depth is highly variable after REM'13, but…









Area 3
Sampling site

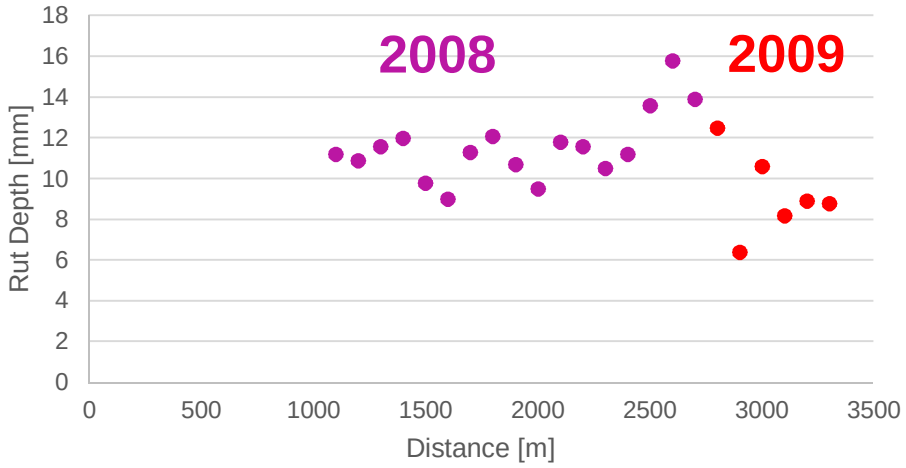
Area 2
Sampling site

Area 1
Sampling site

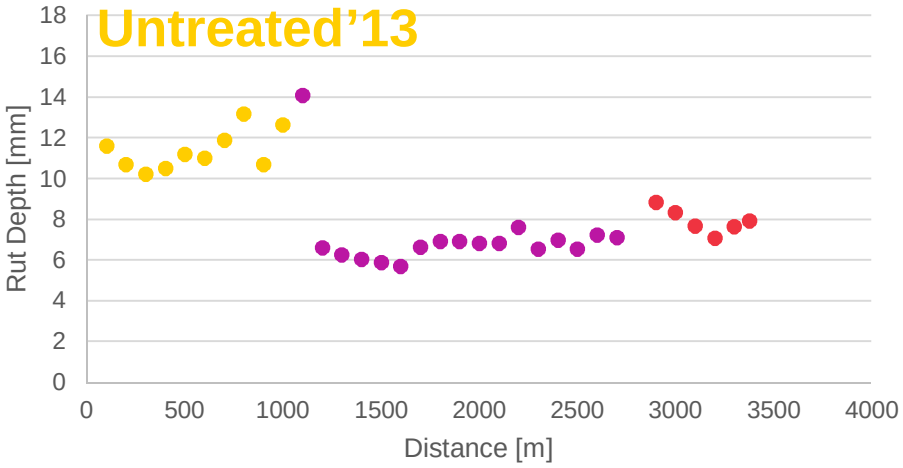
Some sections improved in homogenity

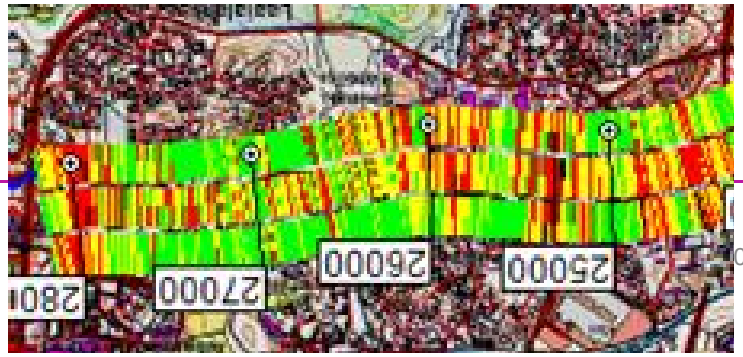
Traffic rearrangments due to neighboring construction site

road section 4 - before



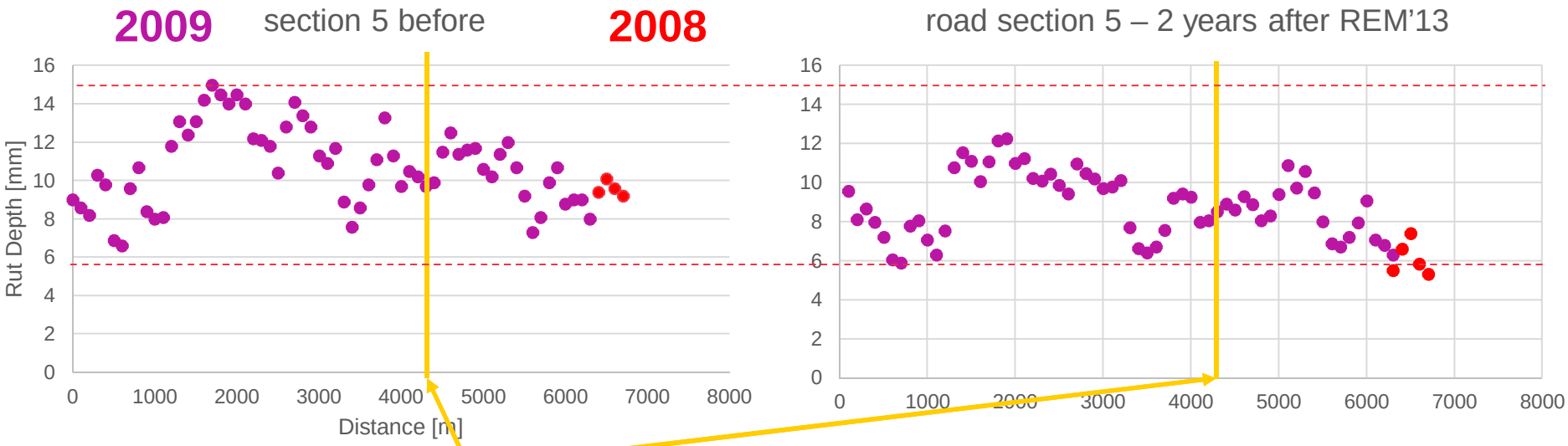
road section 4 – 2 years after





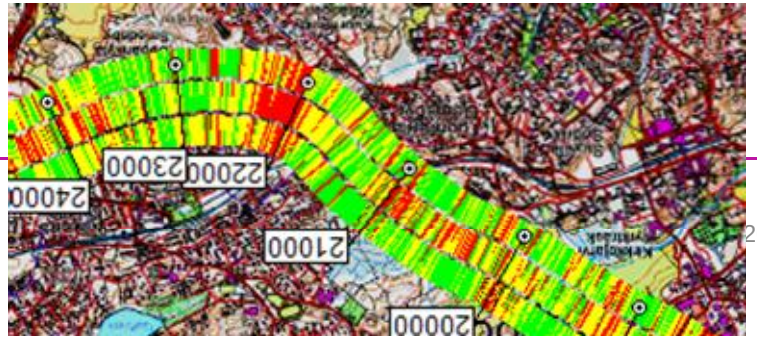
Some sections retain heterogenity of original mixture

Damage in recycling?



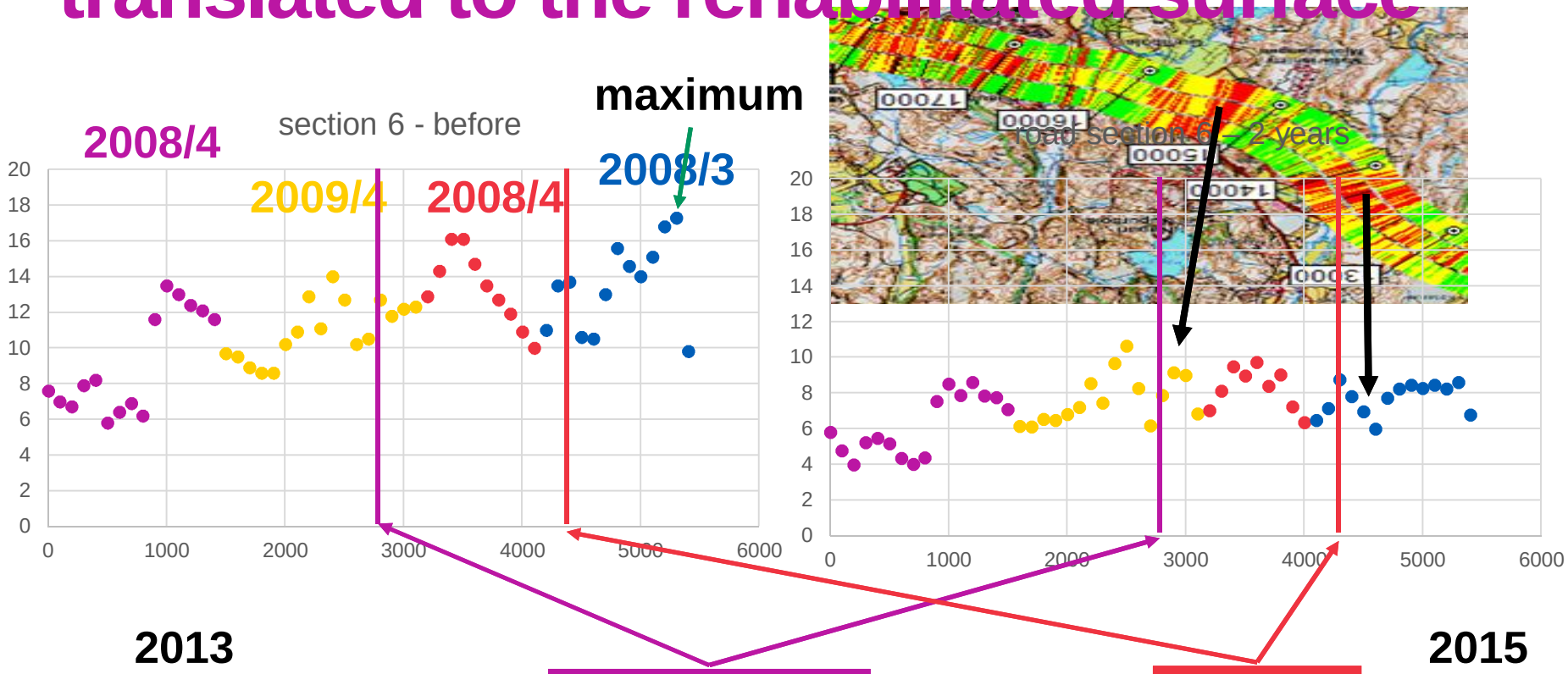
2013

Area 4 LTA Cycle 1'



2015

Some initial mixture properties are translated to the rehabilitated surface



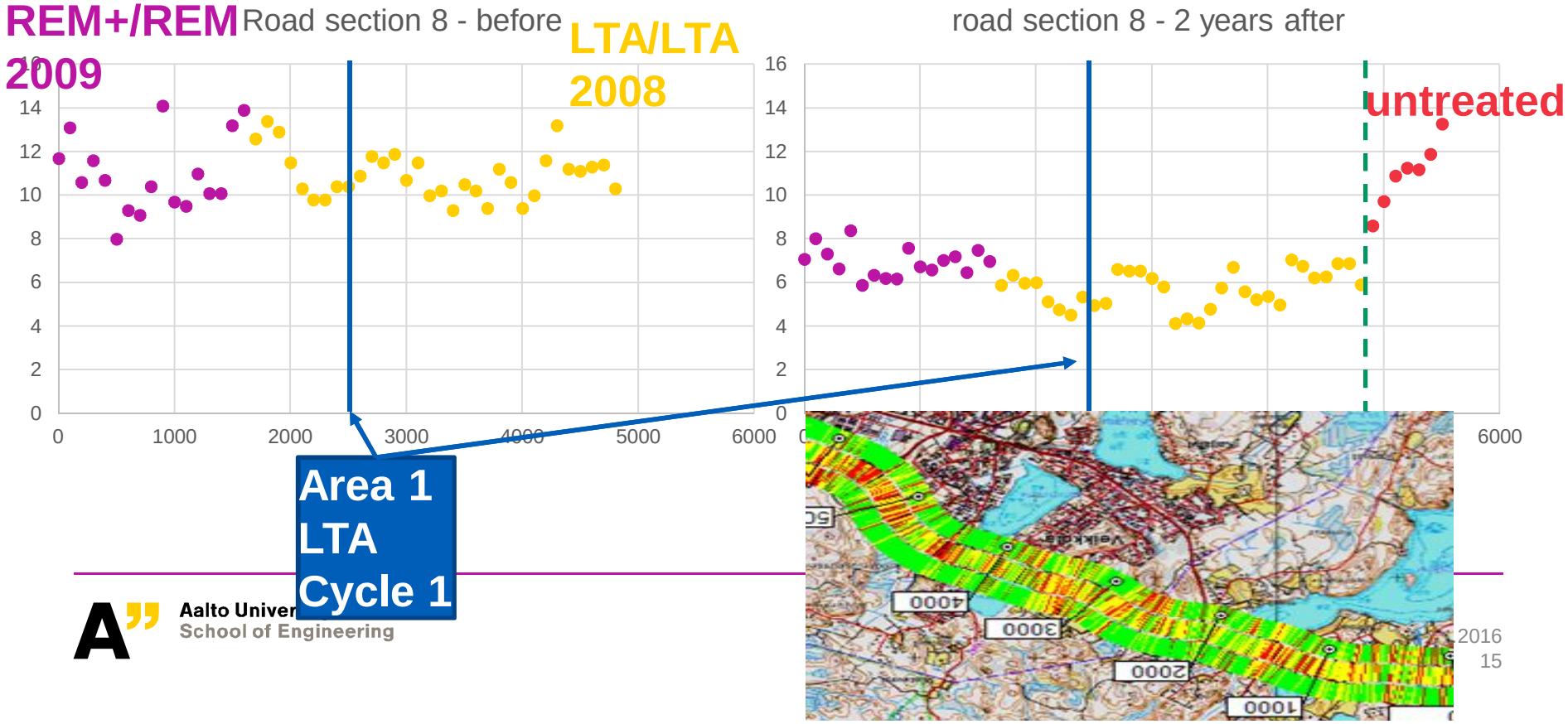
2013

2015

Area 3
REM/REM/REM
Cycle 3

Area 2
REM/REM
Cycle 2

Some initial mixture properties are translated to the rehabilitated surface - with improved homogenity



The secret is in a good initial mix design

The improvement can be done with addmixture

Sampling prior to construction:

- Highest and lowest rut depth (suggestion)
- Look at the rut depth profile before sampling
  - Anticipate the problematic areas – aim to fix them

Rheology and quality control of bitumen extraction

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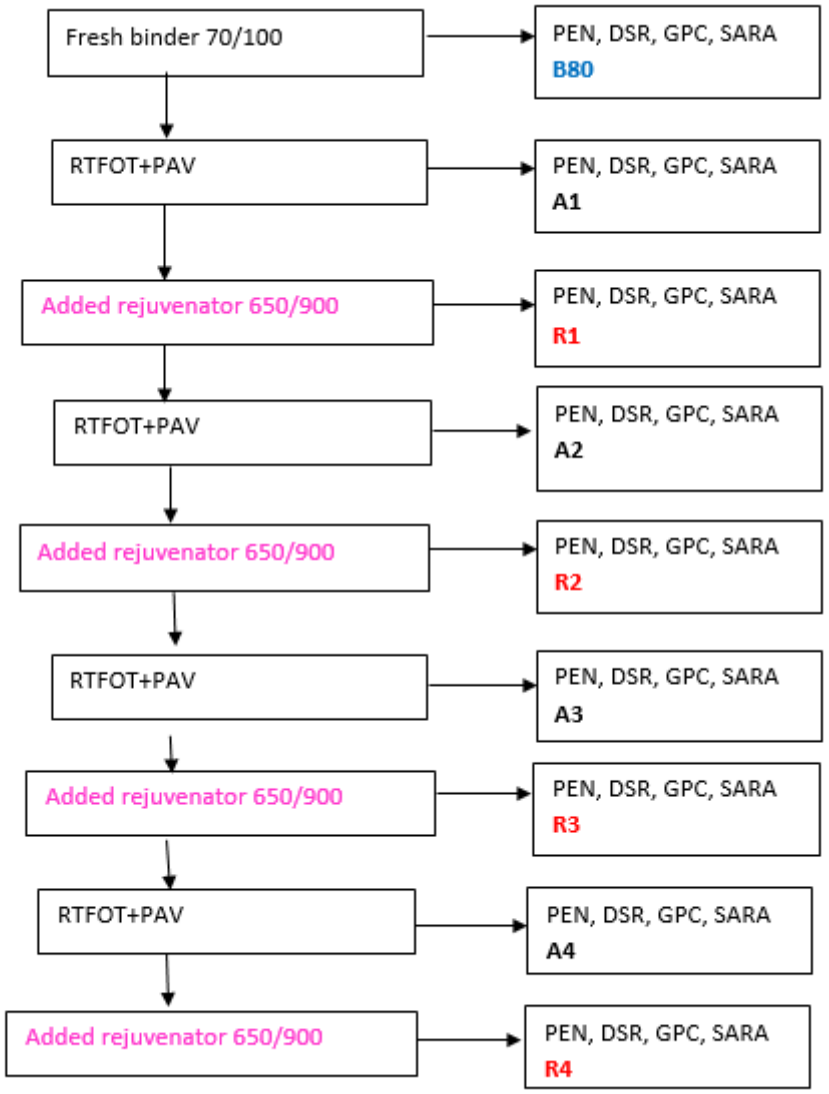
Laboratory aging

Multiple Aging Laboratory Simulation by Nynas Oy laboratories

“Laboratory simulation of bitumen aging and rejuvenation to mimic multiple cycles of reuse”, Blomberg T., Makowska M., Pellinen T., Transportation Research Arena 2016, Warsaw, Poland



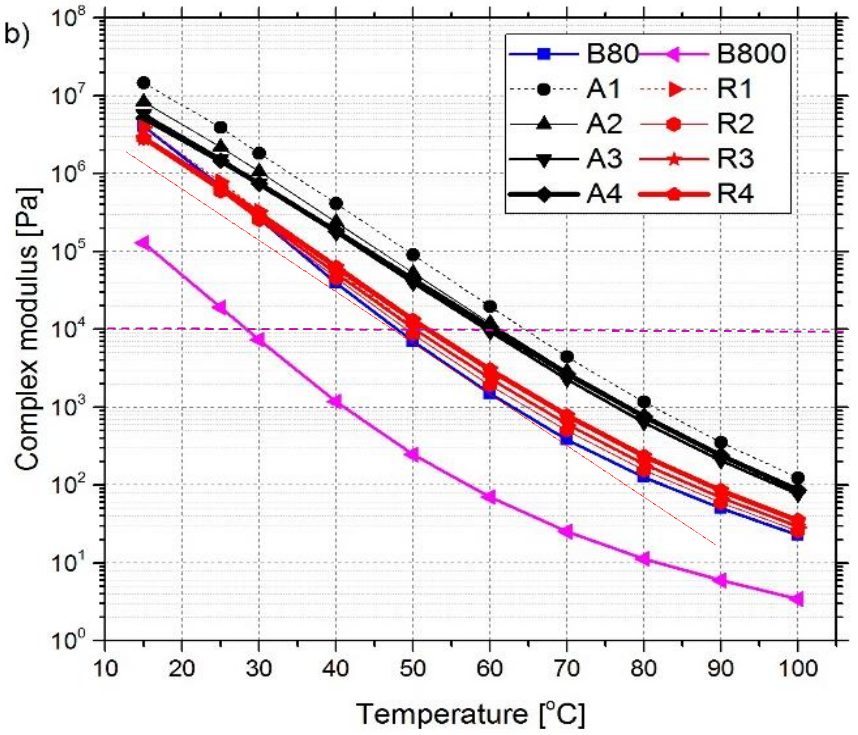
Chosen optimisation method

For the calculation of the amount of rejuvenator used:

- **By Penetration value**
- **Back to properties of fresh 70/100**

$$\log G^*_{blend} = a_1 * \log G^*_{aged} + b_1 * \log G^*_{rejuv}$$

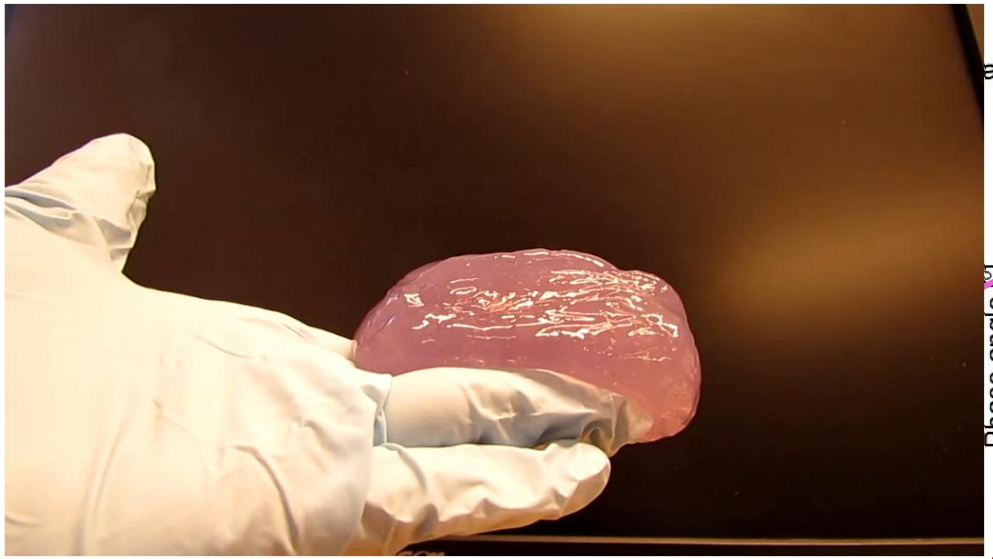
		R1	R2	R3	R4
B800 addition (executed)					
Recipe used based on Pen 25°C[1)]	%	33	28,5	23	21
B800 addition (simulated)					
Recipe based on G* at 15°C[2)]	%	27,1	17,5	9,7	6,7
	%	34,4	27,6	22,7	22,5
Recipe based on G* at 30°C[2)]	%	45,7	40,6	37,5	39,2
Recipe based on G* at 60°C[2)]					

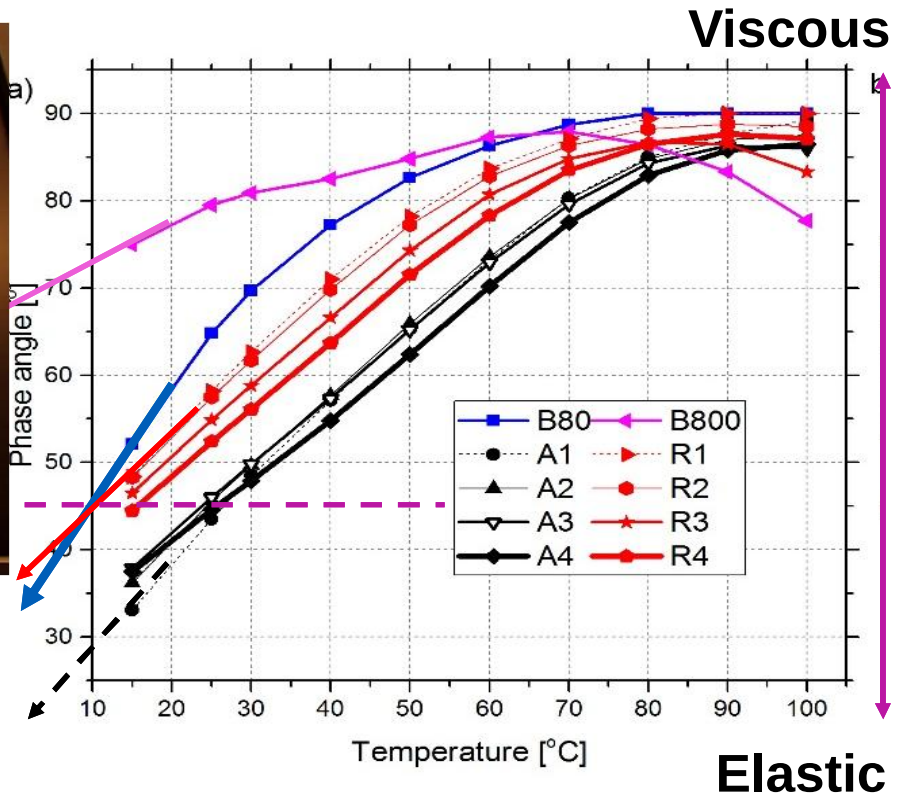


Typical split in REMIX:

79.9% old bitumen
3.4 % 650/900
16.0% 70/100 in the addmixture

The phase angle did not recover completely





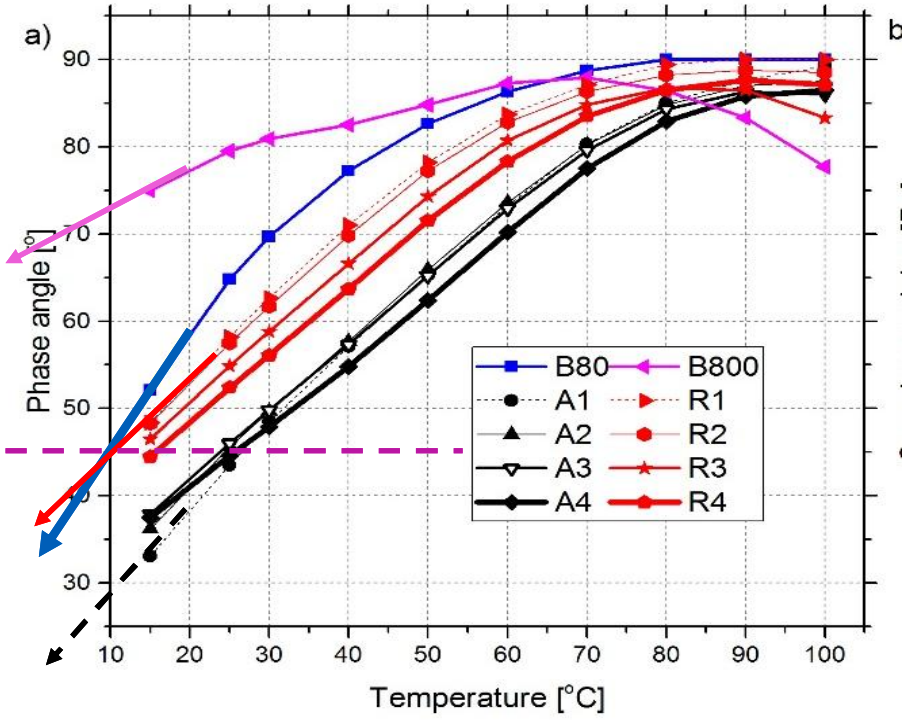
The phase angle did not recover completely

Crucial aspects of REMIX:

-rejuvenation

-recovering phase angle

Softer rejuvenator could perhaps aid phase angle recovery?



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Field samples - general

What do we know about VT1 (sampling sites)?

	Area1 (Cycle 1)	Area 2 (Cycle 2)	Area 3 (Cycle 3)	Area 4 (Cycle 1')
Rut* before HIPR'13 Rut* after HIPR'13 **Rut* 2015**	10.4 1.7 5.1	10.5 1.5 6.8	10.4 1.6 7.2	9.8 1.9 8.8
Rejuvenator used	190 g/m^2	150 g/m^2	150 g/m^2	80 g/m^2
Pen before	25	21	35	33
Pen After	33	28	32	28
Type of filler	limestone	limestone fly ash	limestone fly ash	fly ash
Annual Daily Traffic	36926	42604	42604	54652

0

Do the problems come from :
Original mixture? Addmixture? Lack of rejuvenator? Daily traffic?

*Road surface monitoring vehicle, max rut depth

Bleeding in asphalt concrete

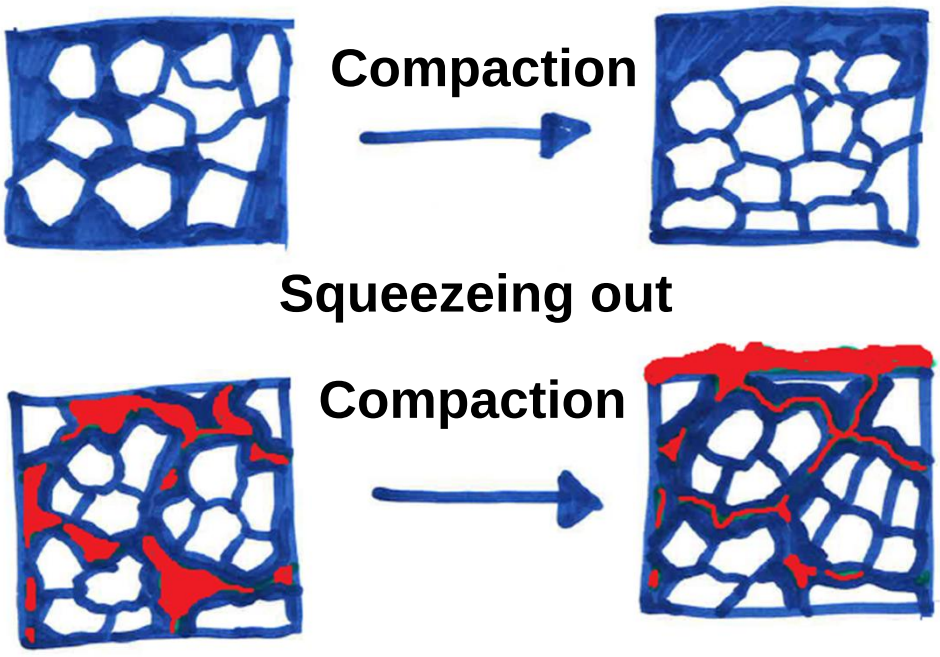
1. **Excessive asphalt binder**

   - Too thick bitumen film per surface area of aggregate (crushed rock and filler)

2. **Too low air voids**

à voids overfilled with bitumen

3. **Non-uniform heating of the RAP before aplication of rejuvenator (RAP clusters)**

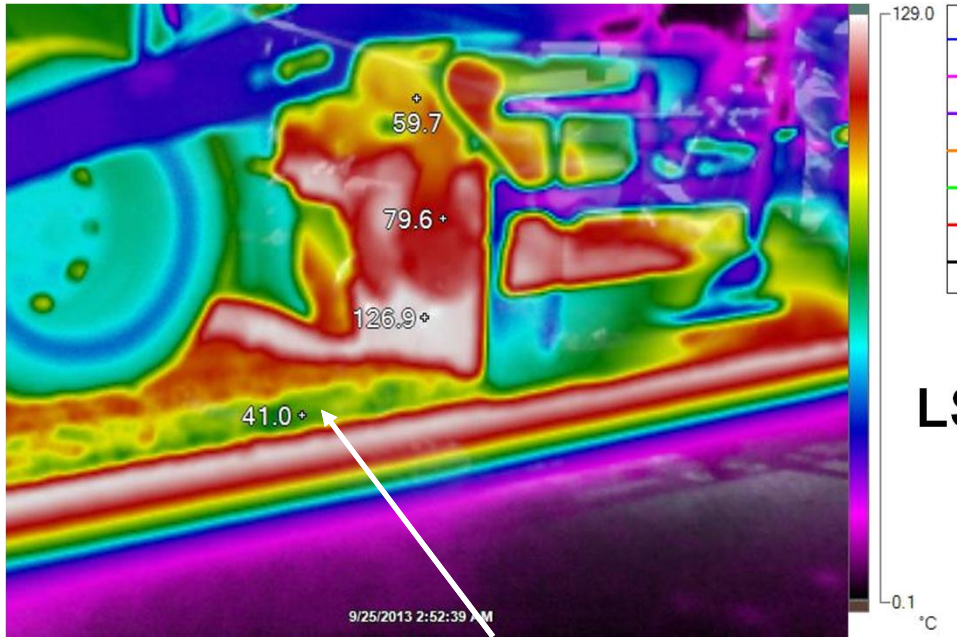


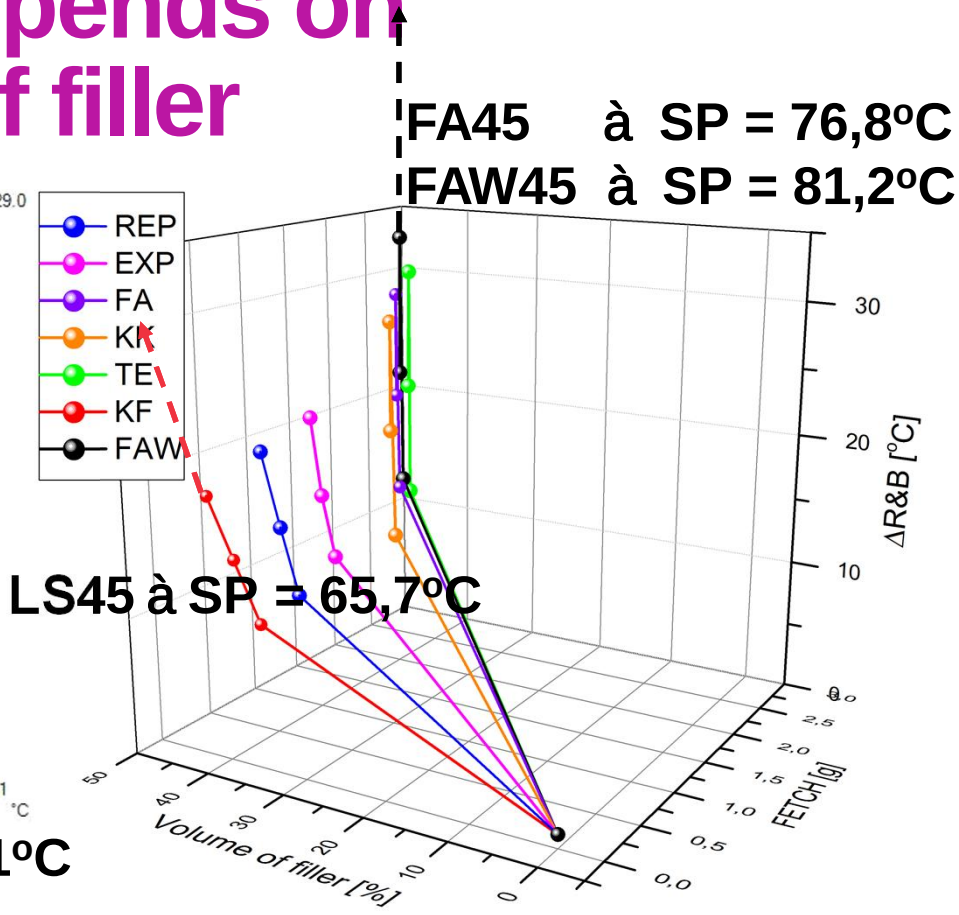
What are the basics?

	Area 1 before	Area 1 after	Area 2 before	Area 2 after	Area 3 before	Area 3 after	Area 4 before	Area 4 after
Fines passing 0,125 mm [%]	14,4	14,5	14,5	14,4	15,7	17,1	15,9	14,2
Filler type	Limestone			Limestone + fly ash				fly ash
SA_{fines} [m^2/g]	1,27	1,17	1,24	1,3	0,98	1,14	1,11	1,12
P_b [%]	5,9	6	6,2	6,1	6,6	6,6	6,3	5,9
P_b/Fine area [g/m^2]	0,32	**0,35**	0,34	0,33	0,42	**0,34**	0,35	**0,37**
Density of fines [g/cm^3]	2,67	2,69	2,57	2,6	2,6	2,6	**2,4**	2,5
Volume of filler [%]	48,37	47,94	48,26	48,20	48,39	50,53	**51,87**	**49,67**

Most bleeding
(stiffest mastic or most P_b/SA)

Mastic stiffening depends on Type and Amount of filler





FA45 à SP = 76,8°C

FAW45 à SP = 81,2°C

LS45 à SP = 65,7°C

Surface under removed layer was 41°C

(before REM top surface was ~0°C)

Stiffer mastic – less bitumen active for rejuvenation

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Field samples – rheology of bitumen

Strong contribution from Kalle Aromaa, B. Sc.

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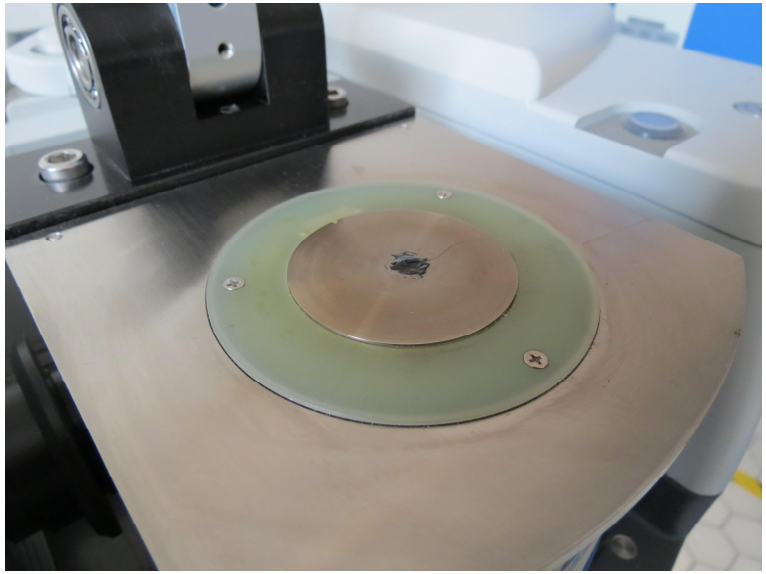
Issues with methods

FT-IR with ATR (Attenuated Total Reflectance) as a quality control and research tool

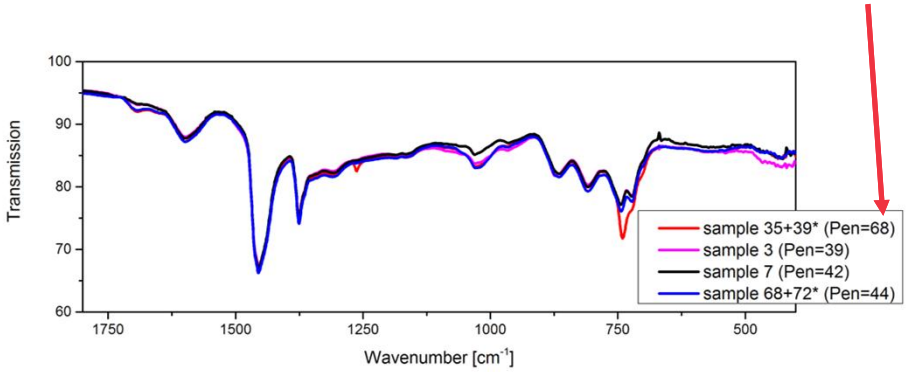
- **No need for separate sample preparation**
- **48 seconds per measurement**
- **Bitumen quality after extraction**
  - Presence of filler
  - Presence of solvent
  - Presence of impurities (e.g. paint)
- **Composition of filler (presence of limestone/hydrated lime)**

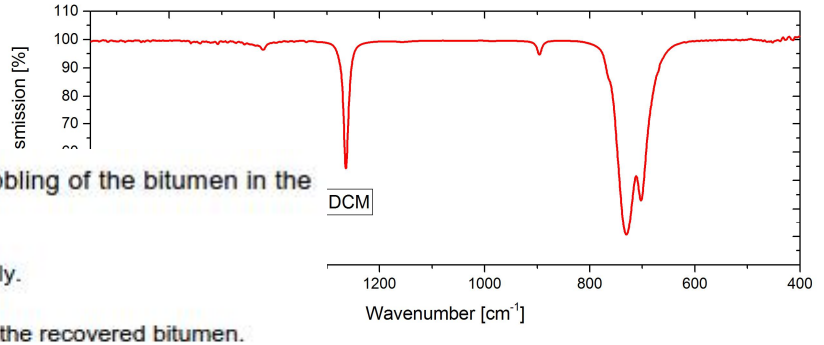


Bitumen extraction – presence of solvent à softening

DCM peaks are visible in extracted bitumens

- This is not only Aalto's problem
- This is not only Finland's problem
- Standard already suggests QC





7.3.12 Continue distillation until the evaporation of solvent is complete and the bubbling of the bitumen in the evaporating flask is finished.

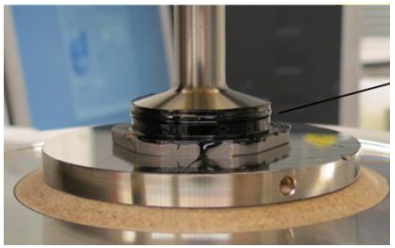
NOTE 1 This is best observed by stopping the rotation of the evaporating flask momentarily.

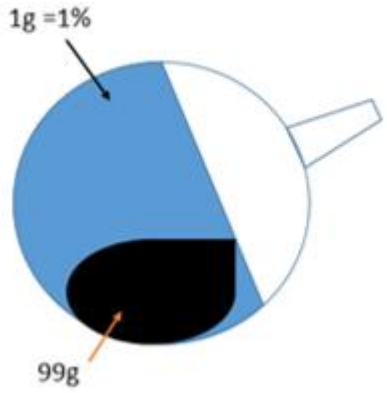
NOTE 2 Spectography can be used to ensure that all the solvent has been removed from the recovered bitumen.

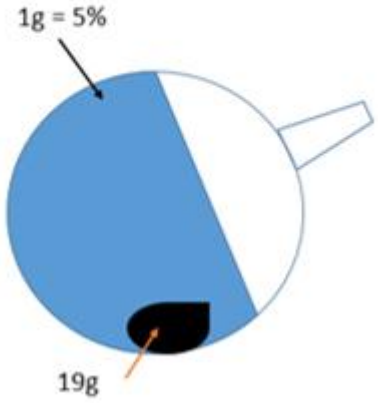
DSR versus Penetration -1 sample versus 3 samples

The samples **without DCM impurity** are within repeatability limit (**+**/-2 for Pen <50)

Caution is advised before switching the methods!

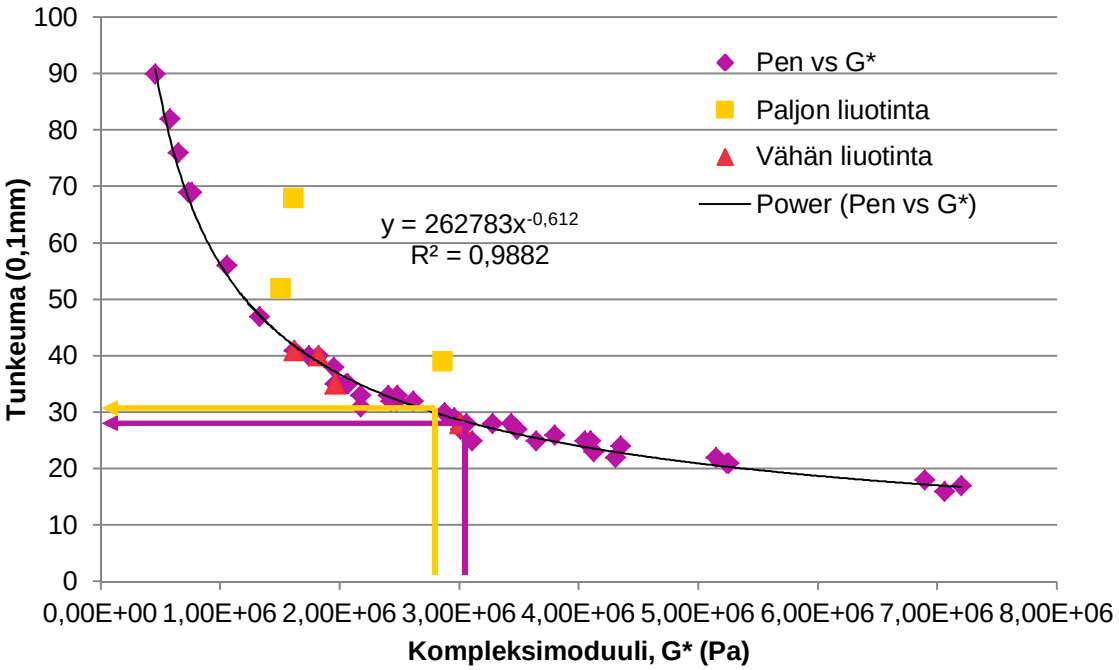






More in DT by Kalle Aromaa

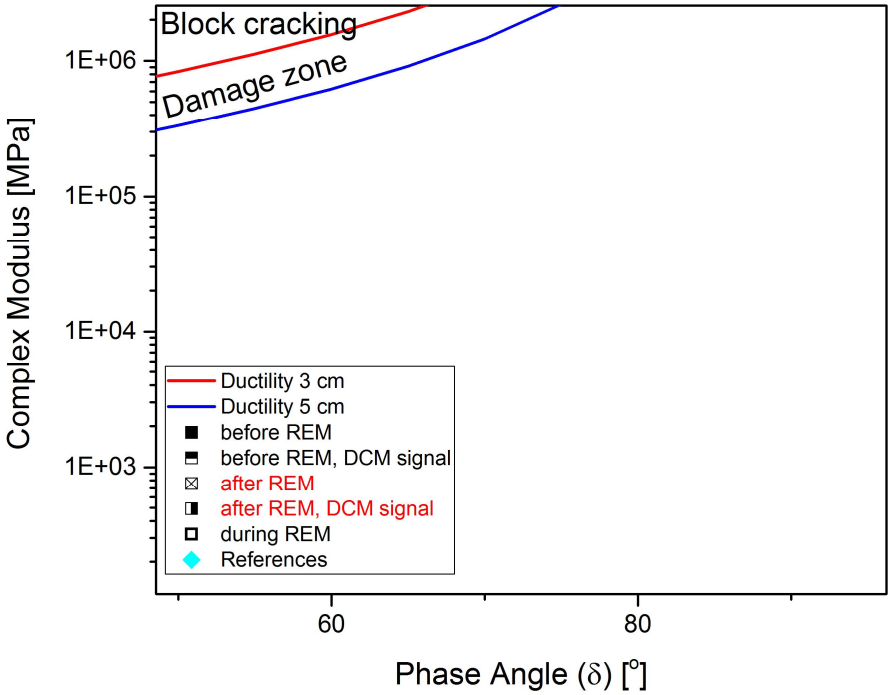
If we brutally switch from Pen (3 core extraction) to Pen calculated from G* (1 core extraction), the calculated ”Pen” will be higher!

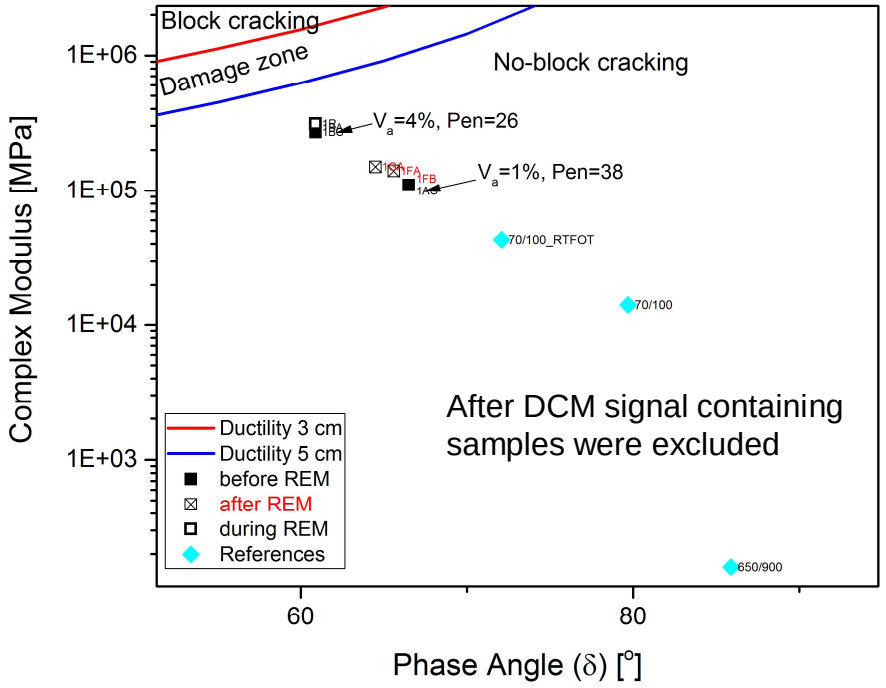


Recalibration of the data/equations will be necessary, if previously determined Pen is an input value.

Korrelaatio tunkeuman ja kompleksimoduulin välillä – Kalle Aromaa, Diplomi Työ

The effect of solvent on data analysis – e.g. Glover-Rowe damage zone





T=15°C,

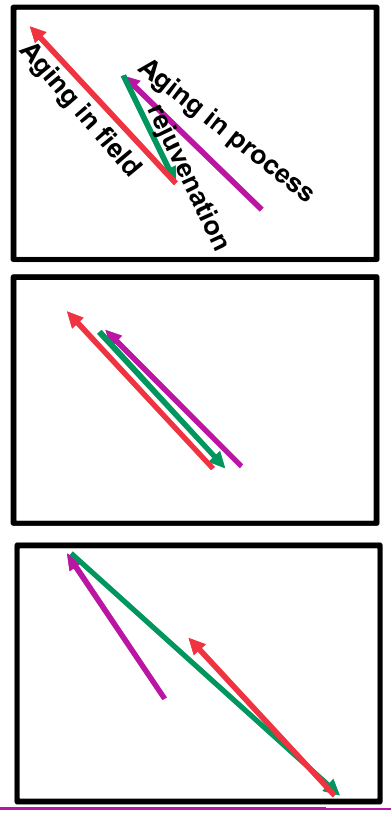
w=0.005 rad/s

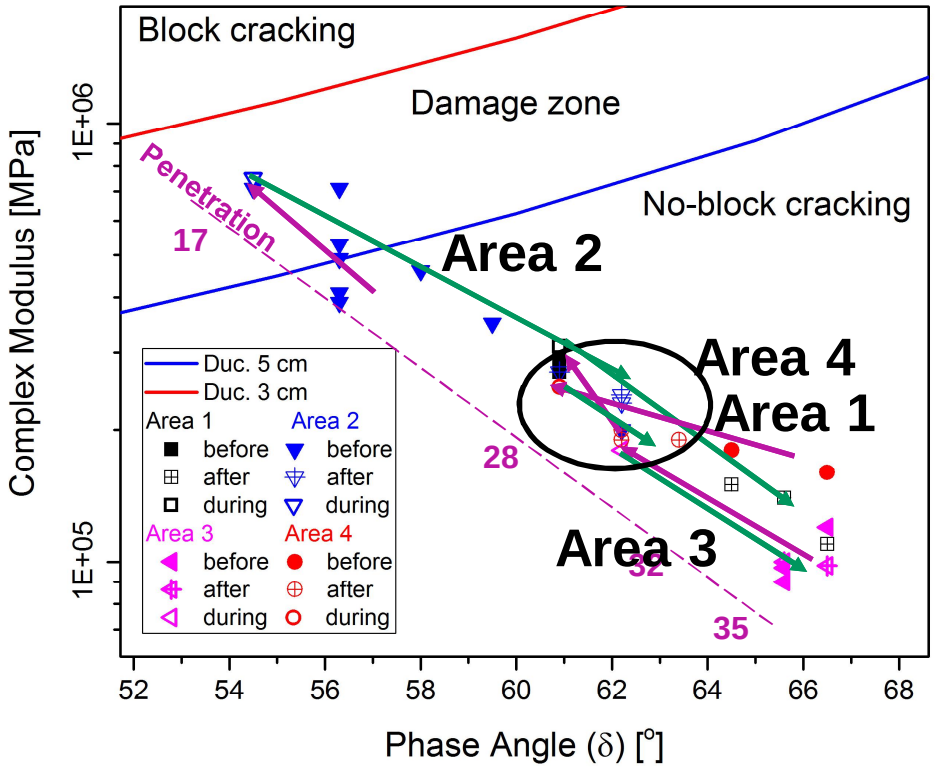
How can we use the damage zone in the future?

Damage in maintenance

Maintenance

Rehabilitation





Conclusions

1. **Bleeding is dominant problem during REMIX**
2. **Bleeding is a function of bitumen properties, mastic properties and insufficient heating**
3. **Bleeding limits rejuvenator use**
4. **Rejuvenator is necessary to recover viscous properties of the binder and prevent cracking**
5. **Currently used rejuvenator is not sufficient for recovery of viscous properties à softer rejuvenators to be tested**
6. **Residual DCM is the highest analythical risk for bitumen**

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Thank you
Kiitos

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