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REMIX - first results

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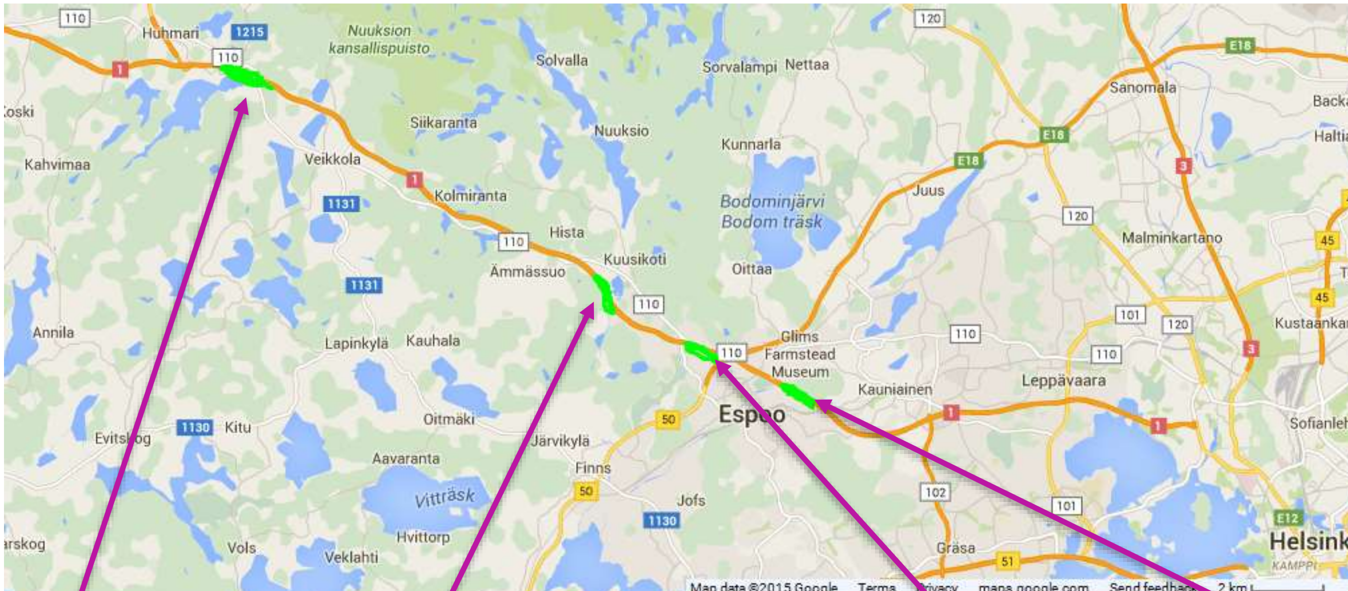
Maintenance on Highway No. 1 in 2013
- a unique opportunity to study triple recycling



HIPR **Cycle 1**	**HIPR/HIPR** **Cycle 2**	**HIPR/HIPR/HIPR** **Cycle 3**	**HIPR** **Cycle 1'**

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

Identification of risk (construction site and laboratory works)

- **Bleeding problem**
- **Correct aggregate gradation?**
- **Rejuvenator amount and type?**
- **Addmixture amount and gradation**
  - Cannot be outside of real asphalt
  - Bridges, spots where 100% of addmixture
- **Bitumen extraction**


Roads
Aggregate
Fines
Bitumen

Performance (a.k.a. rutting)

Visual evaluation

	Area1	Area2	Area3	Area4
Before REM'13	Cracked (TC=15 m)	Ravelling Segregation	Good	Cracked (TC=60 m)
After REM'13	Bleeding	Bleeding	Bleeding	High air voids esp. joint porosity
2years after REM'13	Good, but segregation-like spots	Bleeding, Ravelling, cracking	Good condition, slight ravelling on the joint	Bleeding, high rutting, joint porosity
	Cycle 1	**Cycle 2**	**Cycle 3**	**Cycle 1**

AREA 1

Area 2

Area 3

Change of day

Area 4

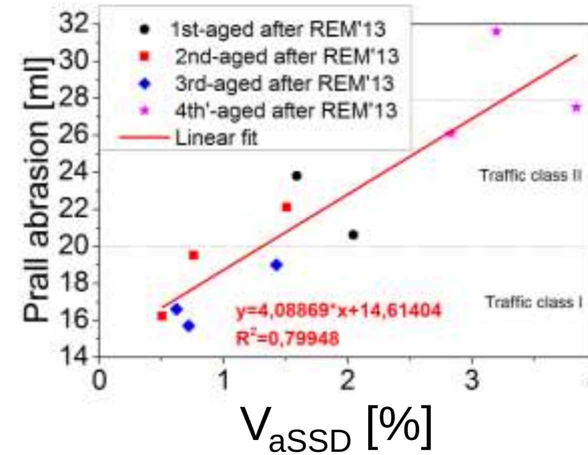
What do we know about VT1?

	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 (6.2-8.2→10.6)	9.8 1.9 8.8
Rejuvenator used	190 g/m²	150 g/m²	150 g/m²	80 g/m²
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

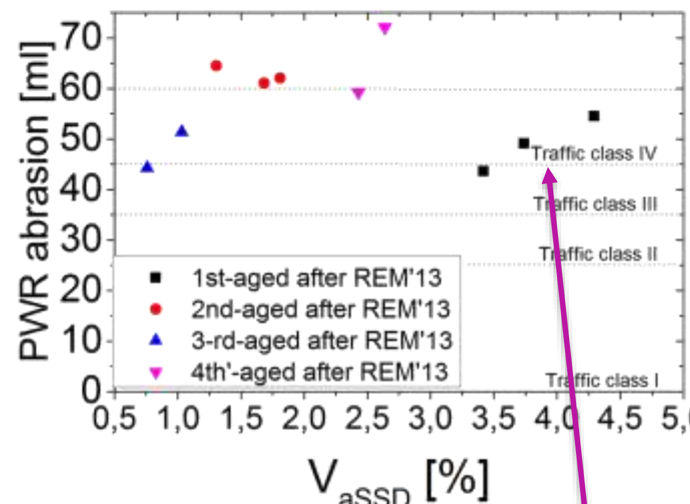
*Road surface monitoring vehicle, max rut depth

Dominant rutting type can be established from cross section analysis

Area 4
- assumed abrassion



Abrassion increases with air void content

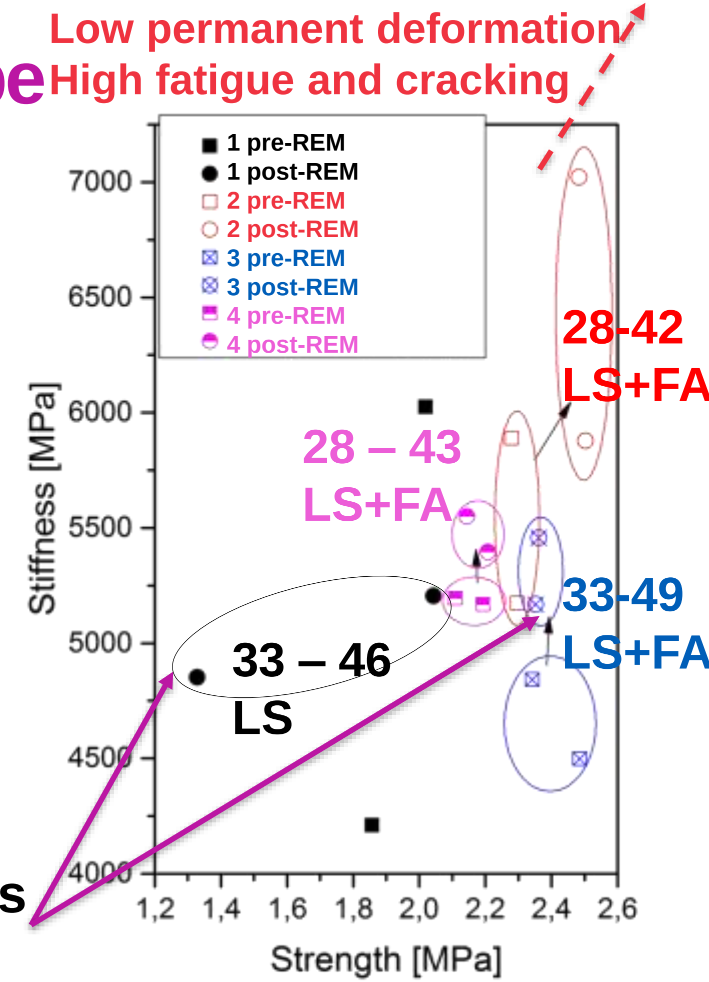


Why?

Stiffer more elastic bitumen could be a reason for a higher cracking, ravelling and abrassion

Penetration after REM→ **28 – 48** ← Phase angle at 20ºC

LS- Limestone
FA- fly ash
Phase angle:
Elastic <45< viscous



Least rutted areas (SRK, ura syvys)

If we used the same aggregate – bitumen is the reason

But: We had different aggregate and bitumen stiffness

Mixture analysis in the context of bleeding

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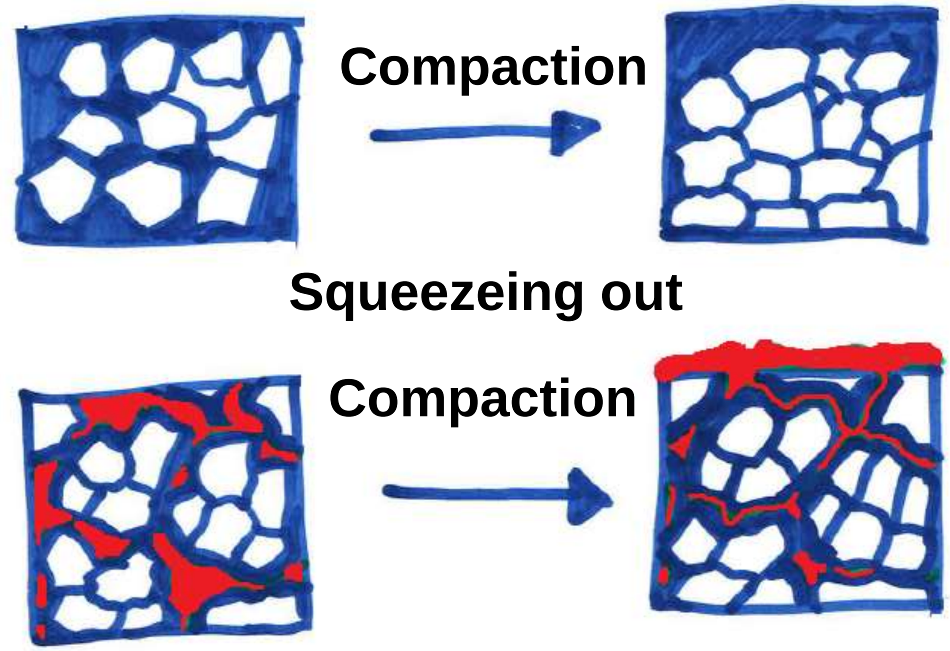
Bleeding in asphalt concrete

1. Excessive asphalt binder
2. Too low air voids

→ voids overfilled with bitumen

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



→ Bitumen / surface area of aggregate

What are the basics?

Finest, but sufficient bitumen

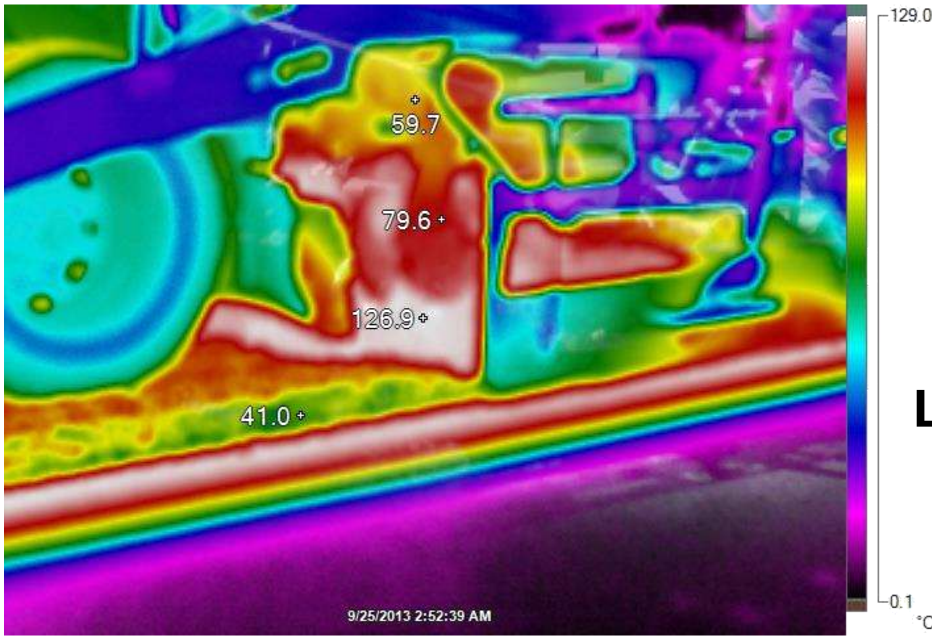
	Area 1 before	Area 1 after	Area 2 before	Area 2 after	Area 3 before	Area 3 after	Area 4 before	Area 4 after
Fines passing 0,125 mm [%]	14,4	14,5	14,5	14,4	15,7	17,1	15,9	14,2
V_{aSSD}	2,5	2,9	1,4	1,2	0,7	1	0,6	2,8
V_{aDIM}	5,2	8,8	5,3	6,2	1,6	5,3	1,2	7,6
SA^{fines} [m^2/g]	1,27	1,17	1,24	1,3	0,98	1,14	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

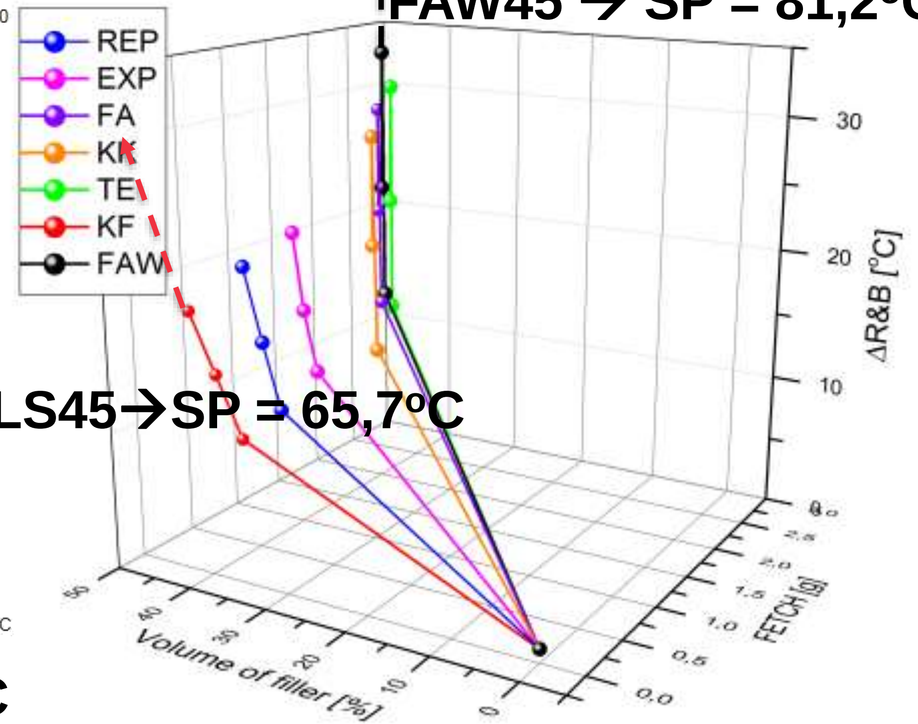
11% more but P_b lowest, least fines, (stiffest mastic)

Mastic stiffening depends on Type and Amount of filler



Surface under removed layer is 41°C

FA45 → SP = 76,8°C
FAW45 → SP = 81,2°C

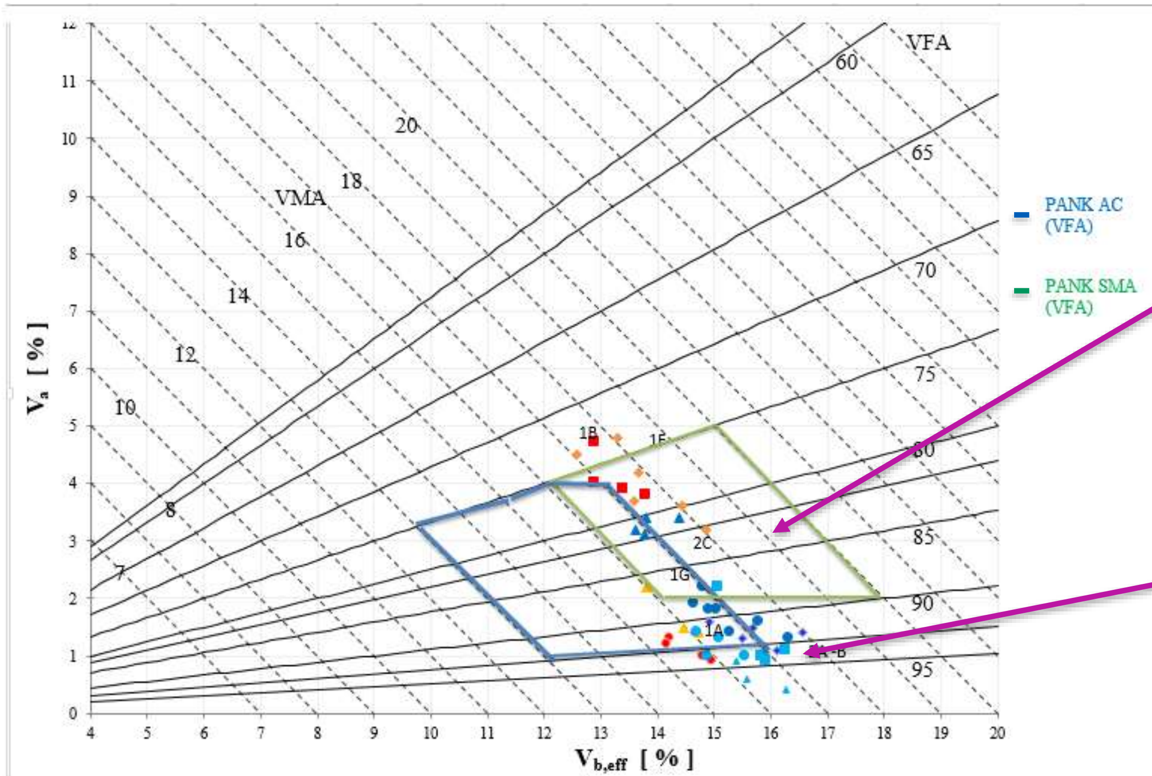


LS45→SP = 65,7°C

Stiffer mastic – less bitumen active for rejuvenation

Segregation was implied by the results, but more apparent was overfilling of voids filled with bitumen (VFA)

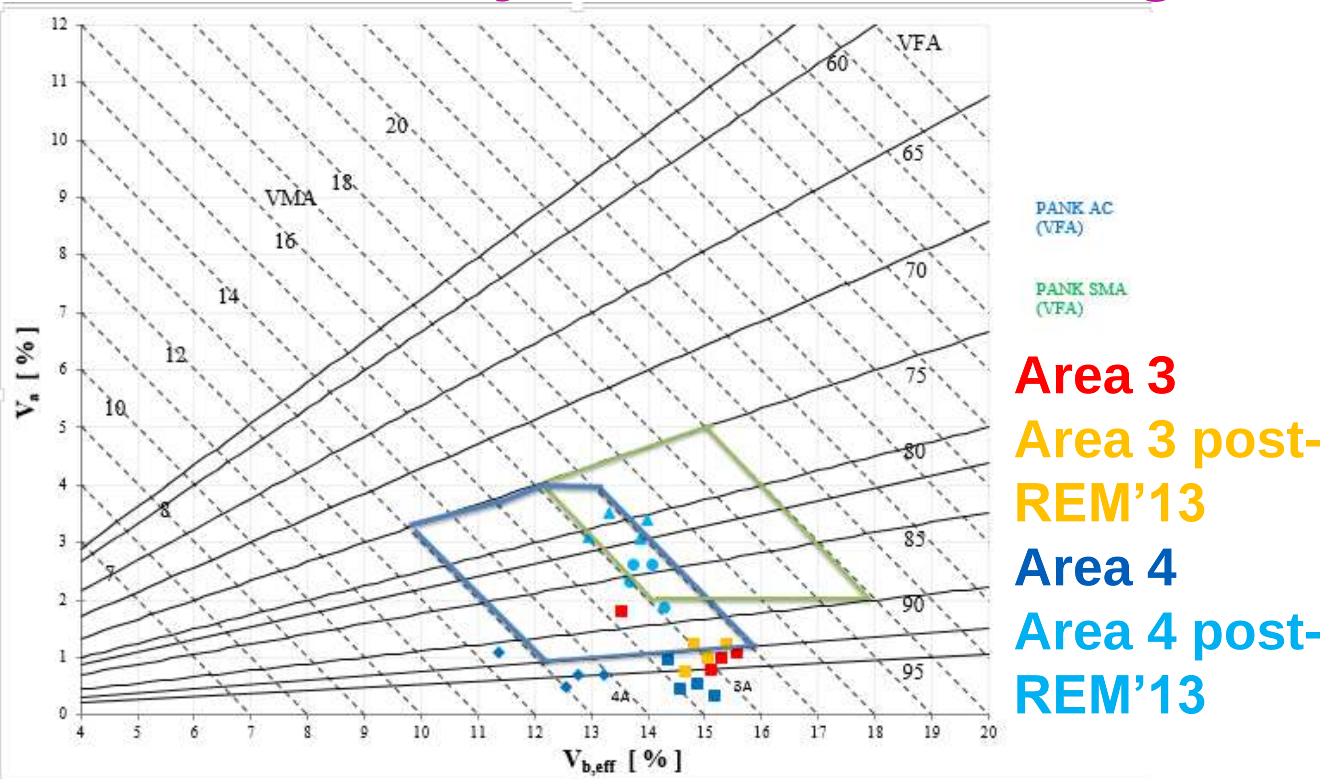
Area 1
Area 1 post-REM'13
Area 2
Area 2 post-REM'13



Some inside allowed range

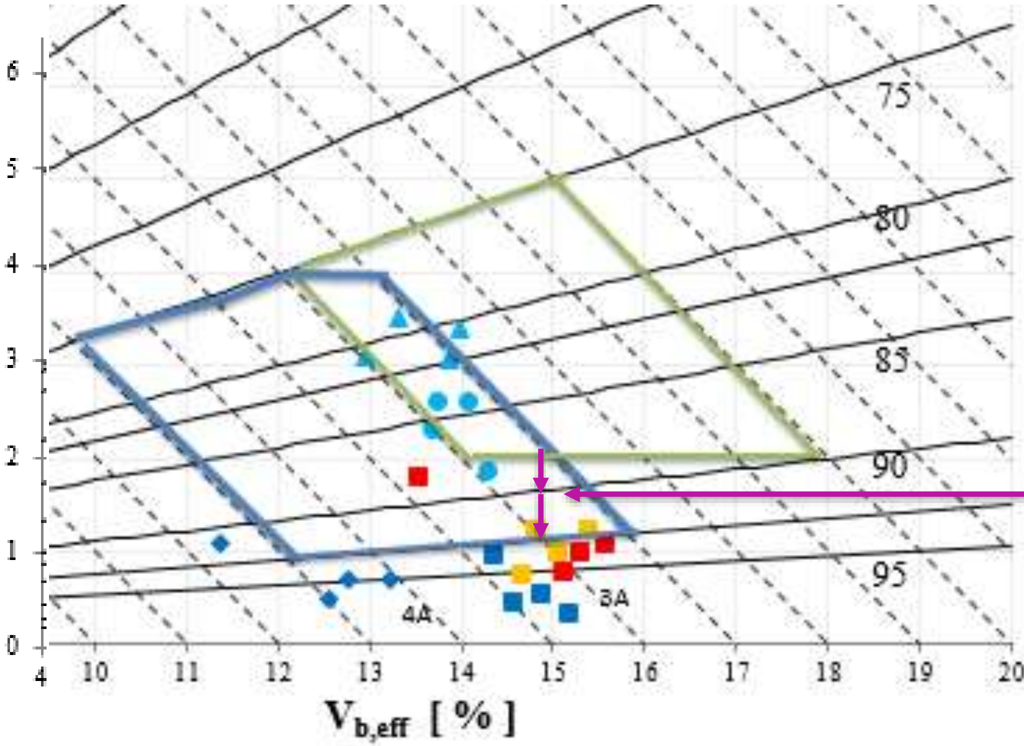
Outside and overfilled (post-REM'13 Area 2)

In Area 3 and 4 the voids were overfilled to start with and most likely this led to bleeding



Reducing rejuvenator springs it back to the window but doesn't recover bitumen properties

Comparison with the past studies



Are we overfilling voids in third REM?

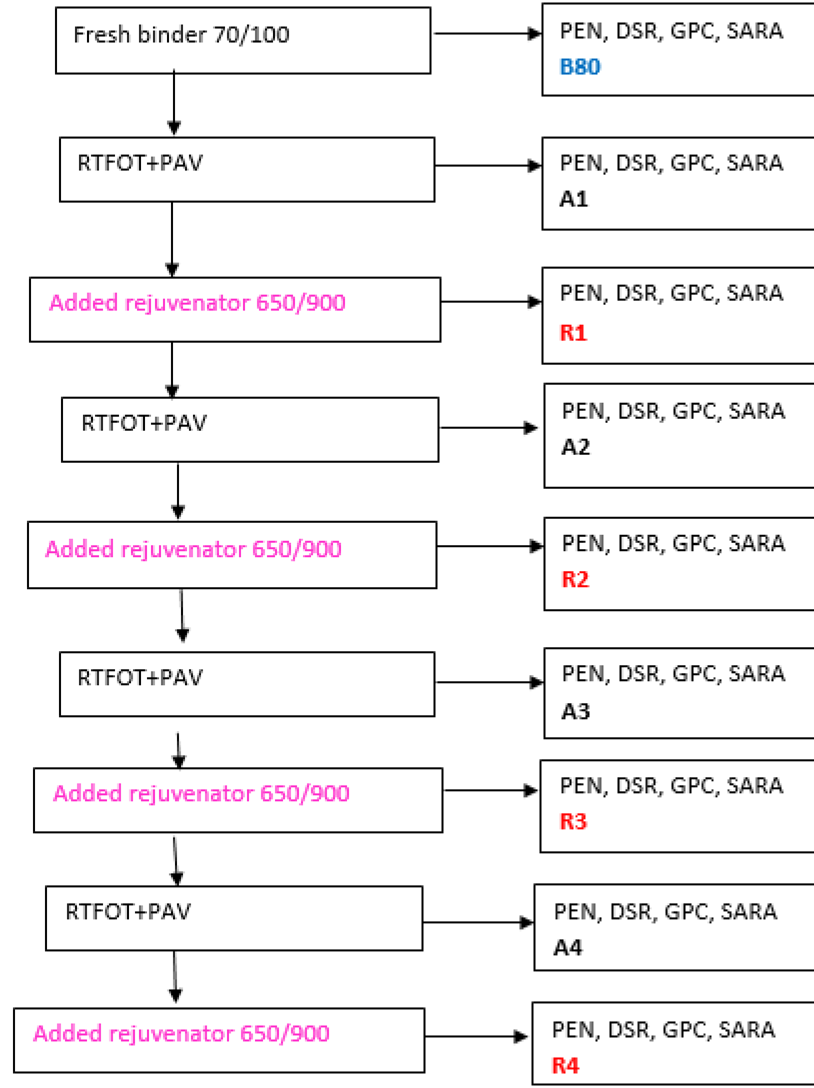
Change between REM1, REM2 and laboratory REM3 in previous research
→ High initial rut depth

Bitumen
- Straight run

What was done?

- Laboratory studies in **Nynas Oy** laboratories (Finland) – straight run bitumen
  - *Rejuvenation and aging simulation*
- Laboratory analysis of field bitumens in **Nynas AB** (Sweden)
  - *Bitumen solubility in context of rejuvenator*
- Laboratory analysis of field bitumens in **Aalto University** laboratories
  - *Rheology and SARA fractions*

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

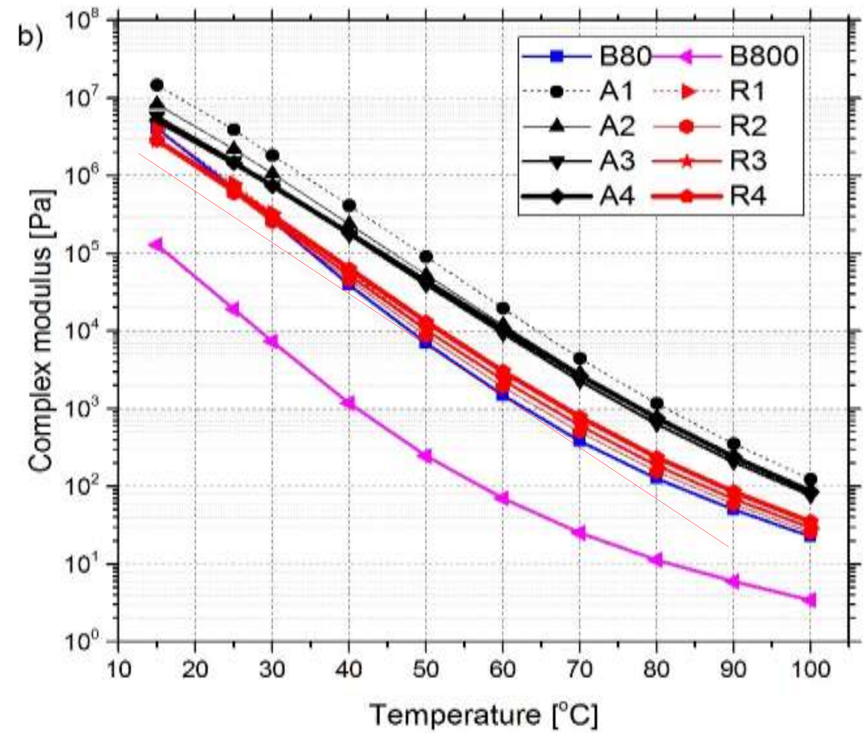
Chosen optimisation method

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
Recipe based on G* at 30°C[2)]	%	34,4	27,6	22,7	22,5
Recipe based on G* at 60°C[2)]	%	45,7	40,6	37,5	39,2



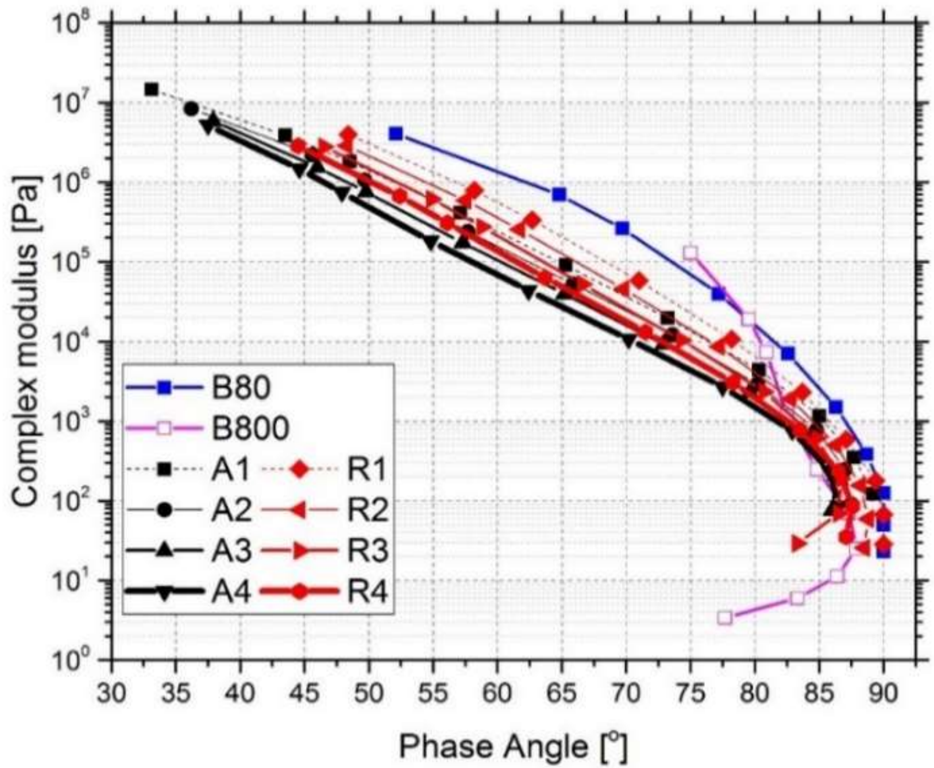
Typical split in REMIX:

79.9% old bitumen

3.4 % 650/900

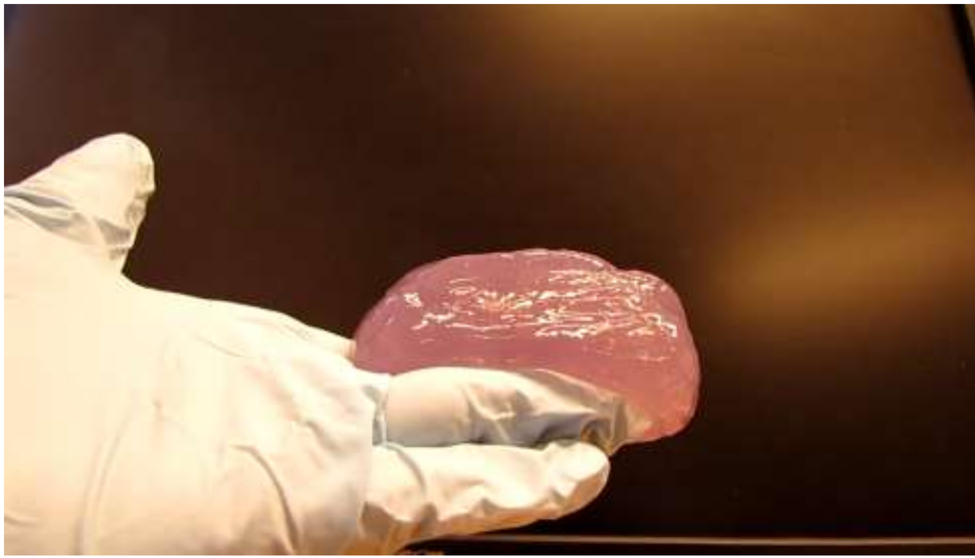
16.0% 70/100 in the addmixture

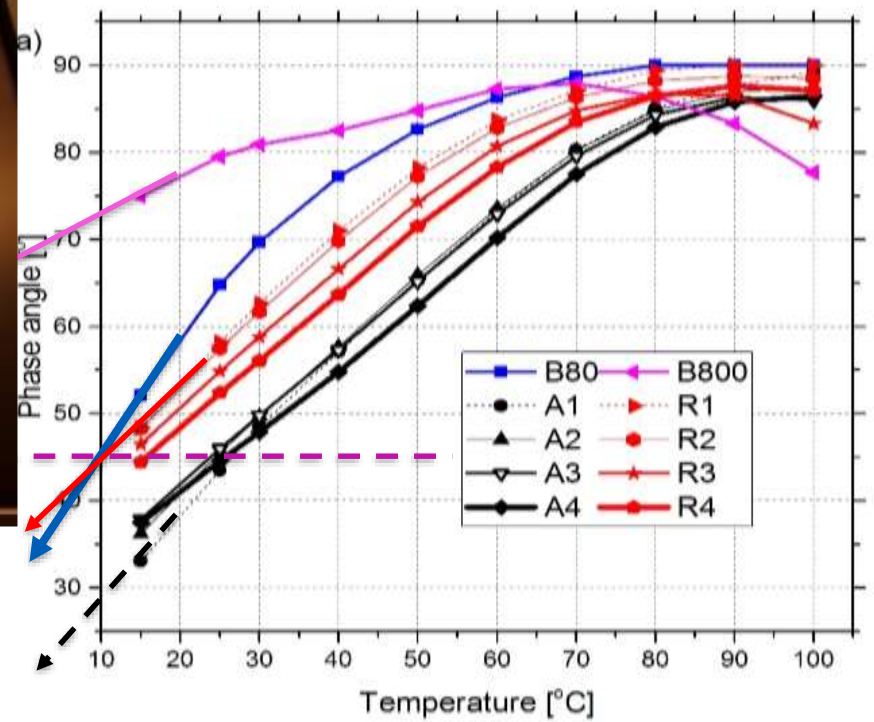
The shape of the master curve flattens but is partially recovered



R4 is similar to A2

The phase angle did not recover completely





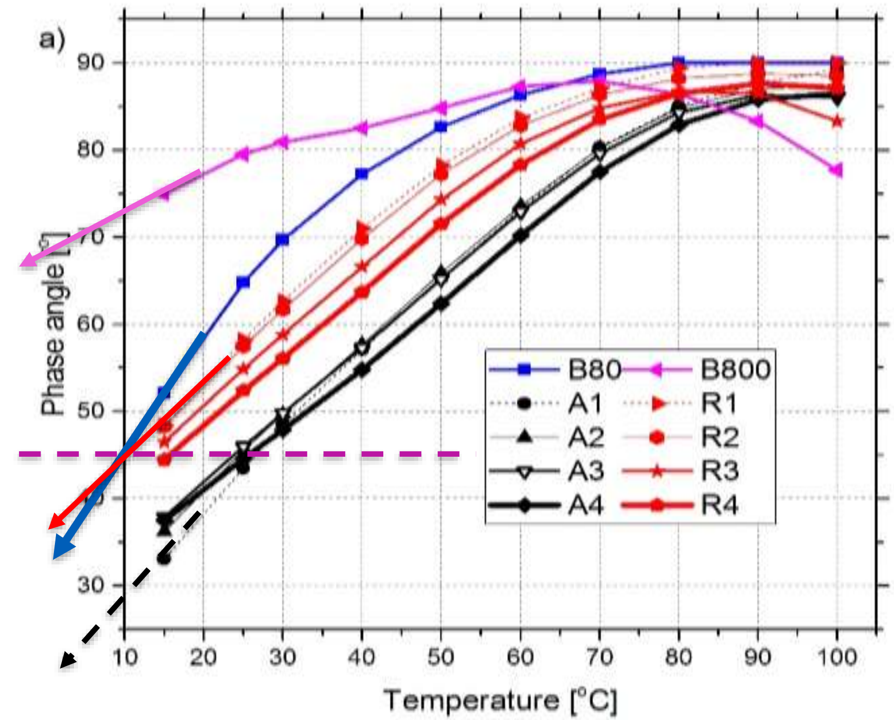
The phase angle did not recover completely

Crucial aspects of REMIX:

-rejuvenation

-recovering phase angle

Softer rejuvenator could perhaps aid phase angle recovery?



Rejuvenator

-solubility studies executed in Nynashamn

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Finnish rejuvenator studies up to date suggest that soft bitumen 650/900 is the best rejuvenator for this process (abrassion)

- **Other tested materials up to date: tall oil, heavy oil, bitumen emulsions, V1500, V3000**
- **Studies from 1990's – these products no longer exist (but bitumen)**

- **Can we determine initial rejuvenator definition before expensive road evaluations?**

Can the evergreen rejuvenation rules be defined with Hansen Solubility Parameters

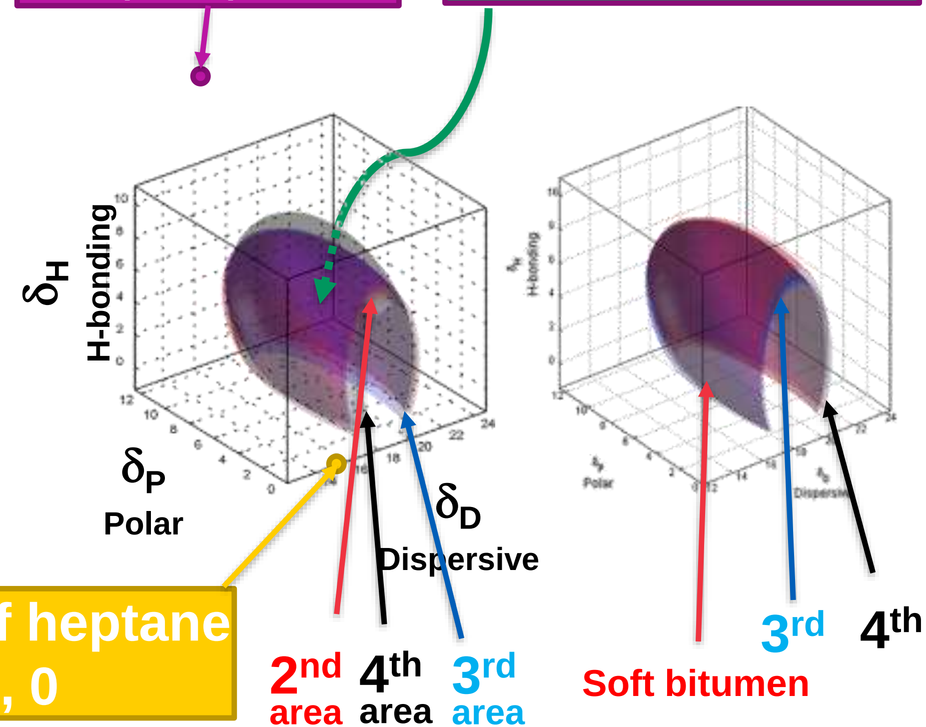
Bitumen + ethanol

Bitumen + heptane

Bitumen + chloroform

HSP of ethanol
15.8, 8.8, 19.4

HSP of chloroform
17.8, 3.1, 5.7



HSP of heptane
15.3, 0, 0

Rejuvenator – extension of the continuum of molecules – HSP within the HSP of bitumen

Bitumen
- field samples

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Without fixing mistakes of <u>field</u> bitumen extraction… optimization is useless

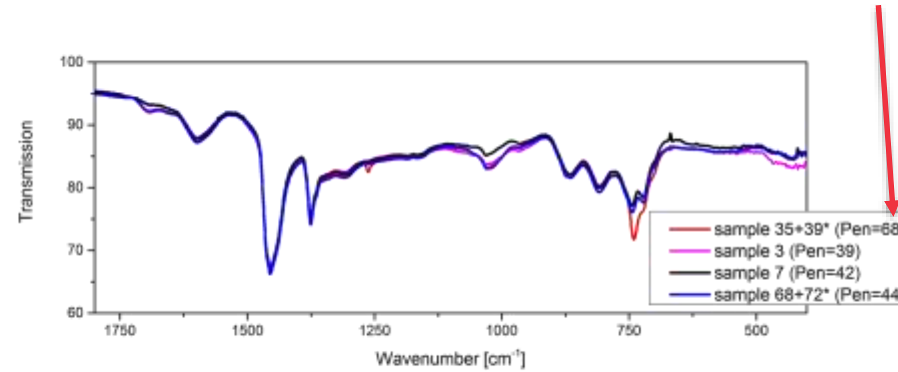
FT-IR with ATR (Attenuated Total Reflectance) as a quality control and research tool

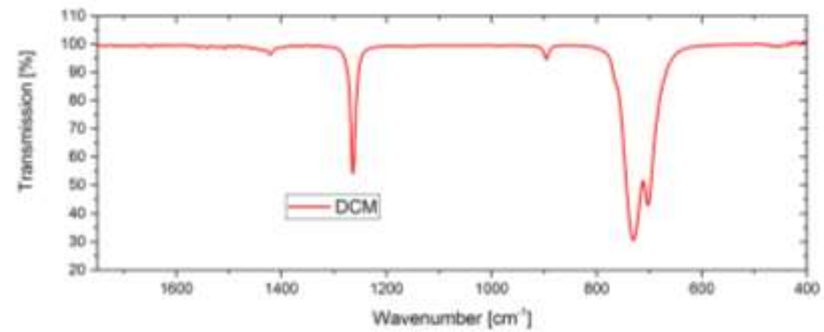
- **No need for separate sample preparation**
- **48 seconds per measurement**
- **Bitumen quality after extraction**
    - Presence of filler
    - Presence of solvent
    - Presence of impurities (e.g. paint)
- **Composition of filler (presence of limestone/hydrated lime)**

Bitumen extraction – presence of solvent → softening

DCM peaks are visible in extracted bitumens

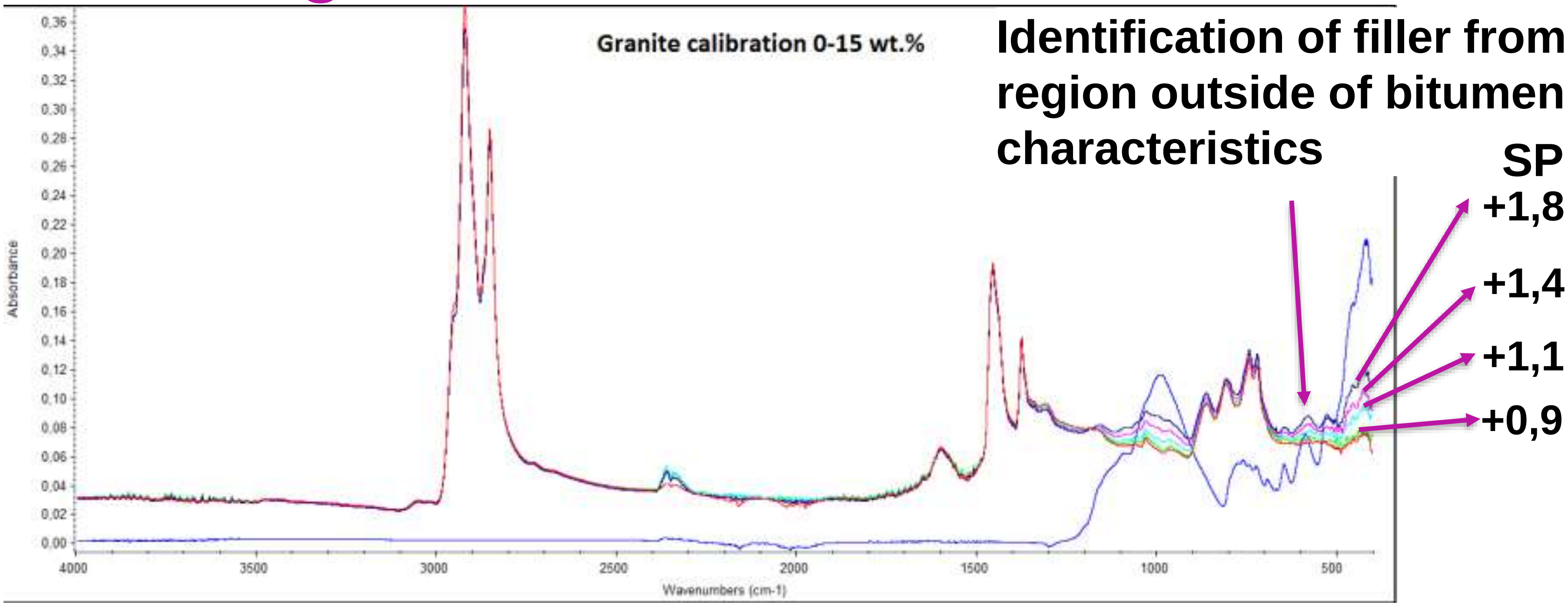
- This is not only Aalto's problem
- This is not only Finland's problem





Optimising for Pen value without checking DCM may result in errors and construction failures

Bitumen extraction – presence of fines → hardening



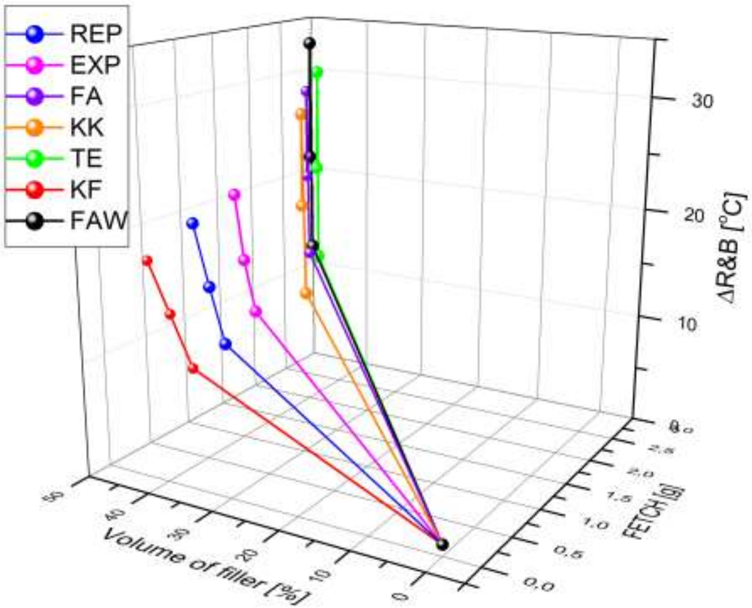
Identification of filler from region outside of bitumen characteristics

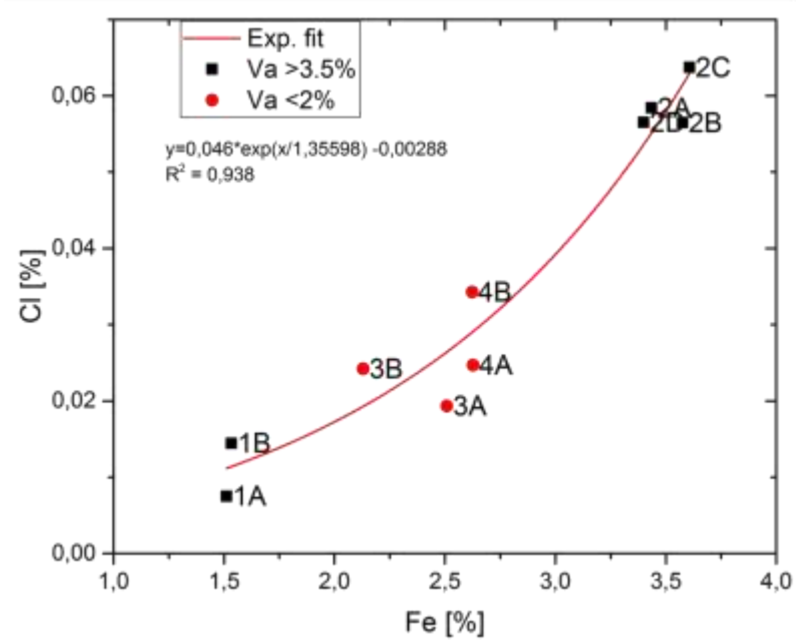
The more fines in sample the higher possible fine transfer

The "false positive" on the antiaging properties of asphalt fines investigated by RTFO laboratory aging of mastics", M. Makowska, T. Pellinen, Chinease European Workshop 2016, Delft, June 2016

Aging over aggregate and salts

The effect of minerology on the life cycle of the asphalt concrete?





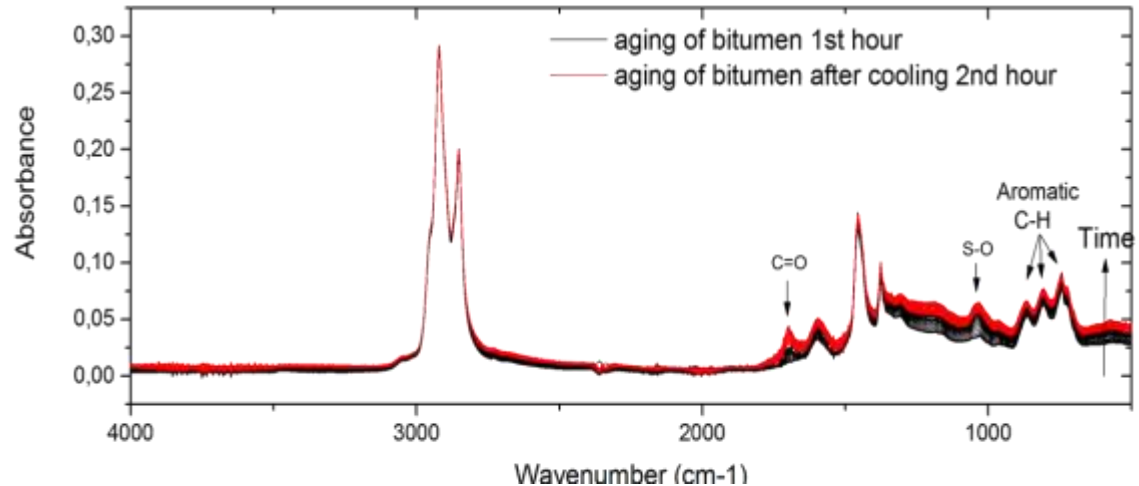
More iron = more stiffening

More iron = more chloride accumulation

Upon heating a thin film at 163ºC carbonyl and sulfoxyl groups are introduced into bitumen =chemical aging

<u>Experiment:</u>

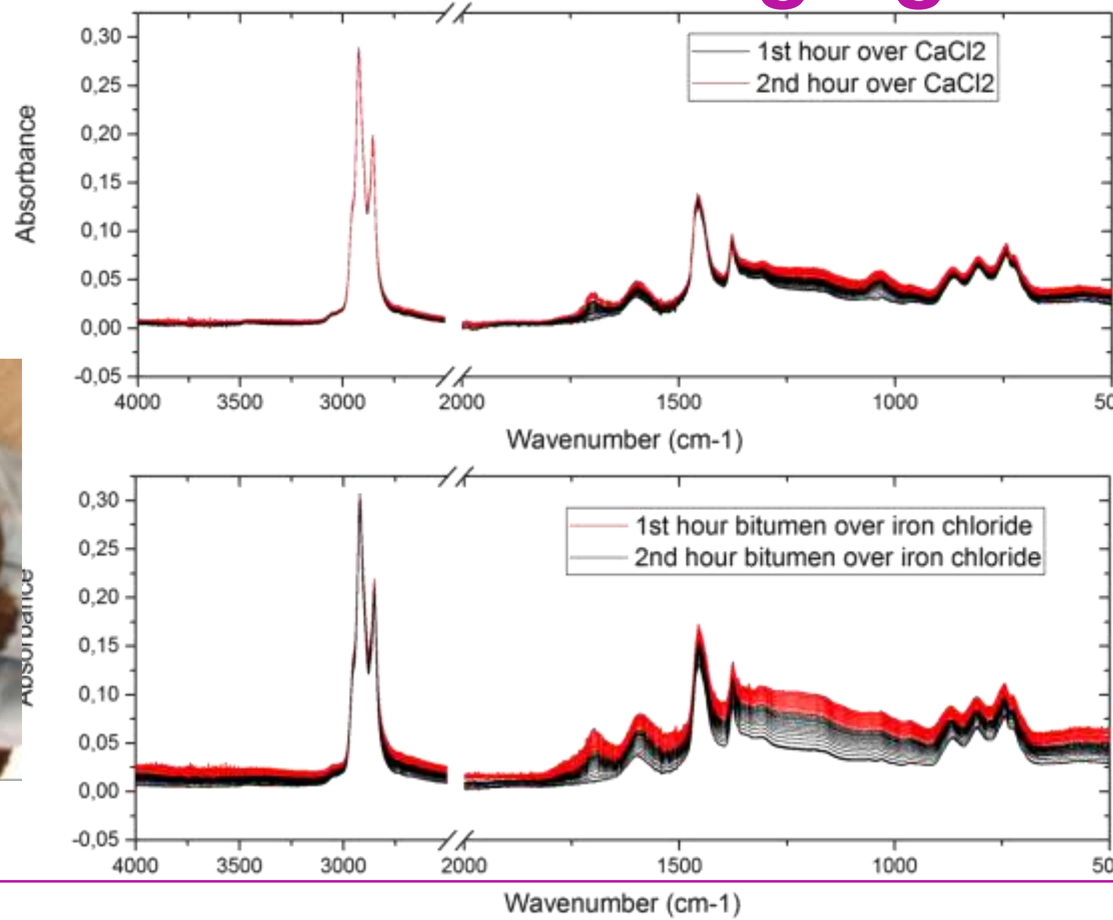
60 minutes – spectra collected every 4 min.
Cool down 20 min.
Reheat
60 minutes – spectra collected every 4 min.



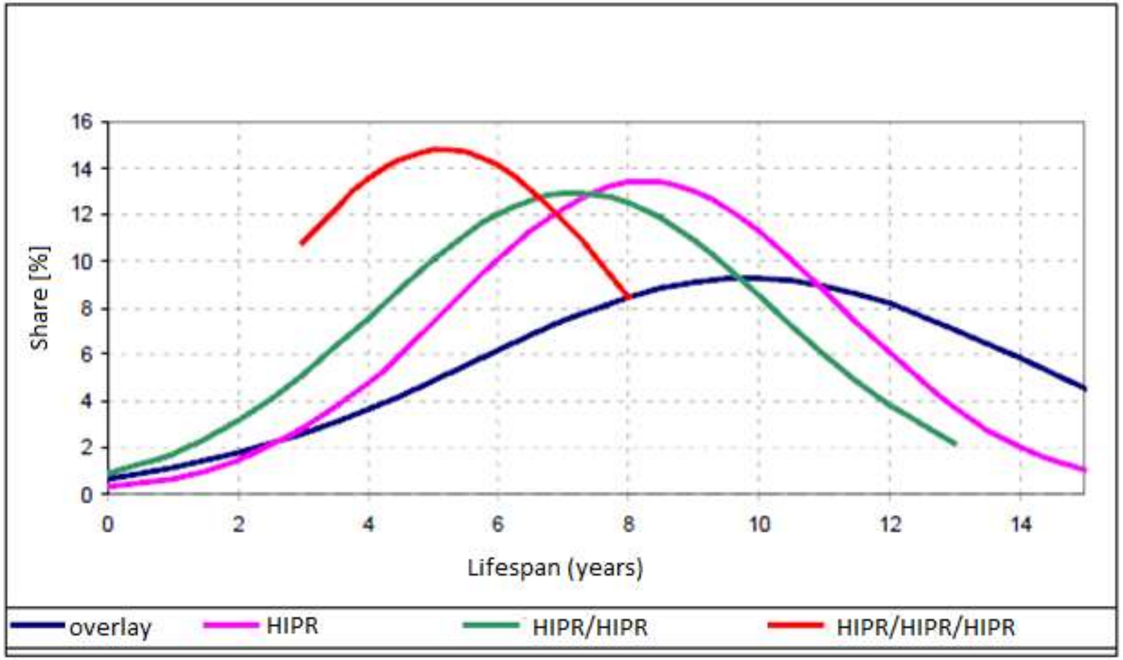
Analogy: Methan turns into mthanol upon ”aging”

The chlorides induced faster aging

$FeCl_3$ is a known cathalyst of air blowing of bitumen



A proof was found that heating bitumen over corroded aggregate can speed the aging



Accumulation of chlorides is a function of :

- **substrate availability** (iron presence, iron reactivity),
- **air voids** (penetration of moisture into the pavement)
- **time**

Conclusions

What we have learnt in this project?

- **Rejuvenation is crucial in recycling**
  - Extends the good performance period of the road
- **Bleeding is inhibiting the use of rejuvenators and bleeding as a problem should be dealt with**
  - Voids Filled with Bitumen (VFA) should be monitored and perhaps the information about them stored
  - Addmixture engineering as a potential mitigator of the problem
  - Control of the uniform heating during the process
- **Most bleeding observed from supposedly stiffest mastic and lowest P_b → explained by P_b/SA ratio**

What we have learnt in this project?

- **Rejuvenation is crucial in recycling**
  - First definition of rejuvenator was provided
  - Same HSP as bitumen and ability to restore phase angle
- **The optimization procedure of rejuvenation in Finland should be decided**
  - Are we aiming at low temperatures, high temperatures, intermediate temperatures, RTFOT values or straight run bitumen
- **For the optimization we need an engineering input from recovered bitumen**

  – quality control of the recovery process needs to increase!

What we have learnt in this project?

- **Rutting – abrassion by studded tires – may be a function of aggregate and bitumen**
- **Filler type and amount influence stiffness of the mastic**
  - Mastic stiffness → melting point of asphalt → homogenous mixing of the RAP in REMIX → Bleeding
- **Iron rich aggregates have tendency to**
  - Stiffen the mastic more
  - Corrode due to the deicing chemical action
    - *Resulting impurity may be toxic for bitumen during REMIX*
    - *Addmixture should aim at diluting the iron levels*

Project status and plans

Status

- Almost all analysis is done for cores on VT1
- Moving into RAP studies
- Cores collected from VT4 (MPKJ→ REM)
- Cores collected from Kt52 (AB → REM)
- Analysis of data and dissemination

Plans

- Participation in some works during next paving season (heating, quality control)
- Heating studies

Questionaire

The goal is to improve the sucess rate by improving knowledge about the material

1. Preparation of the tender [P]
2. Samples are collected [P] (Normal amount + 1)
3. Typical analysis (Penetration, gradation and air voids) [P]
4. Quality control (FT-IR of bitumen and fines) [A]
5. Additional analysis (VFA, DSR, melting) [upon agreement]
6. Survey with ”supportive questions” [P]
7. Evaluation of the applied additional methods [P + A]

[P] – participant
[A] – Aalto

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Thank you