Multiscale Characterization of Field Aged SMA and PA Mixtures

Authors: Ruxin Jing, Aikaterini Varveri & Sandra Erkens
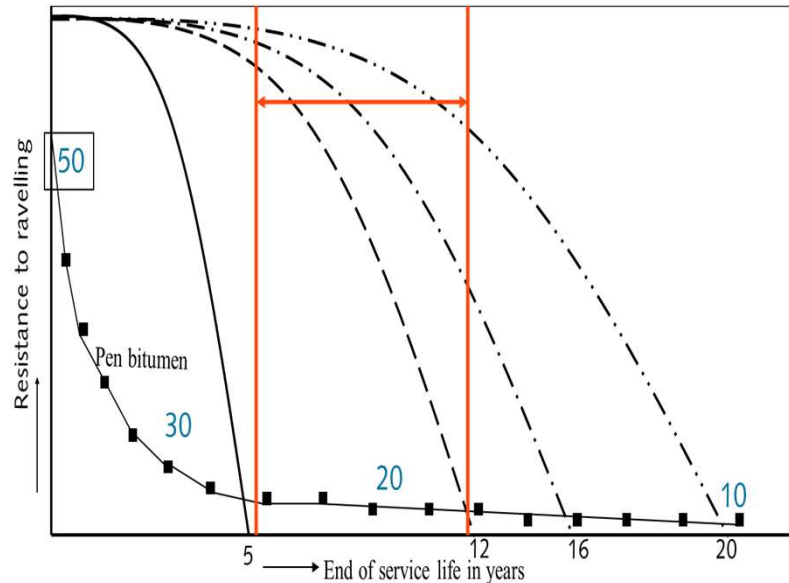
Dr. ir. Aikaterini (Katerina) Varveri, Assistant Professor

a.varveri@tudelft.nl

Department of Engineering Structures, Pavement Engineering

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Photo courtesy: Inge van Vilsteren

Porous Asphalt (PA) on Dutch Highways

Resistance to ravelling

50

Pen bitumen

30

20

10

5 → End of service life in years
12   16   20

—— Ravelling resistance in curves
--- Ravelling resistance of slow lane
-·-· Ravelling resistance of fast lane
-- Ravelling resistance of emergency lane

Between the red lines the ravelling process really takes place (slow lane)

Facts about ZOAB

- 90% Dutch Highways PA
- PA: stone particles, binder, 20% voids
- Advantages of PA:
  - Noise reduction 4~5 dB < ACsurf
  - *Better drainage (Less splash & spray)*
  - *No rutting problems*
- End of life: Raveling > 25% stone loss
- Main cause: Ageing of binder, loss of flexibility, micro-cracks, loss of adhesion
- Service life: 11 years for slow lane, 17 years for fast lane

Ageing of Asphalt Pavements (AAP)

Multiscale approach
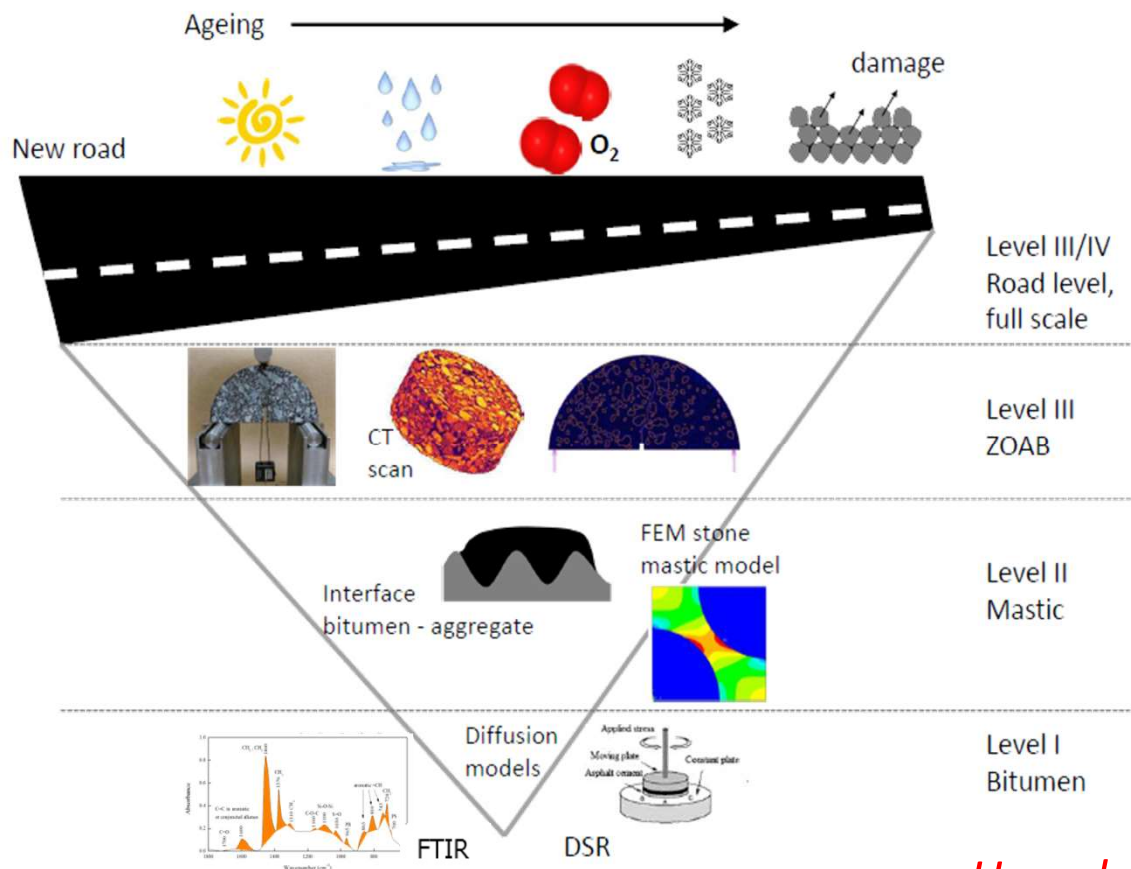
Goal
Identify the ageing processes on a fundamental level and apply that knowledge to develop compatible rejuvenating additives and perpetual recycling approaches.

How does bitumen properties change with field ageing?

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Ageing of Asphalt Pavements (AAP)

How does bitumen and mixture properties change with field ageing?

Experimental plan

Field cores
- SMA and PA test sections
- Stiffness (dynamic modulus) by Cyclic Indirect Tensile Test (IT-CY)

Field-aged bitumen
- Exposed to field environmental conditions
- Bitumen recovered from field cores (three slices)
- Tested by FTIR and DSR

Lab-aged bitumen
- STA: RTFO test at 163 °C for 75 minutes
- STA+ LTA: PAV at 100 °C and 2.1 MPa (20 atm) for 20 hrs
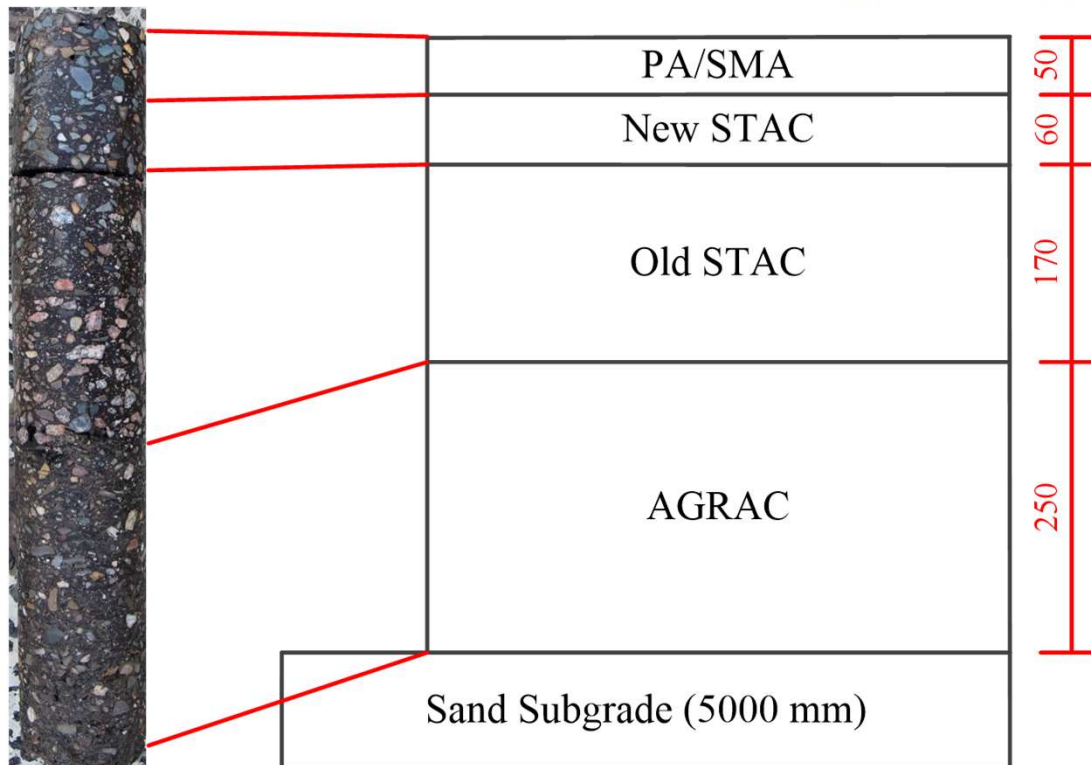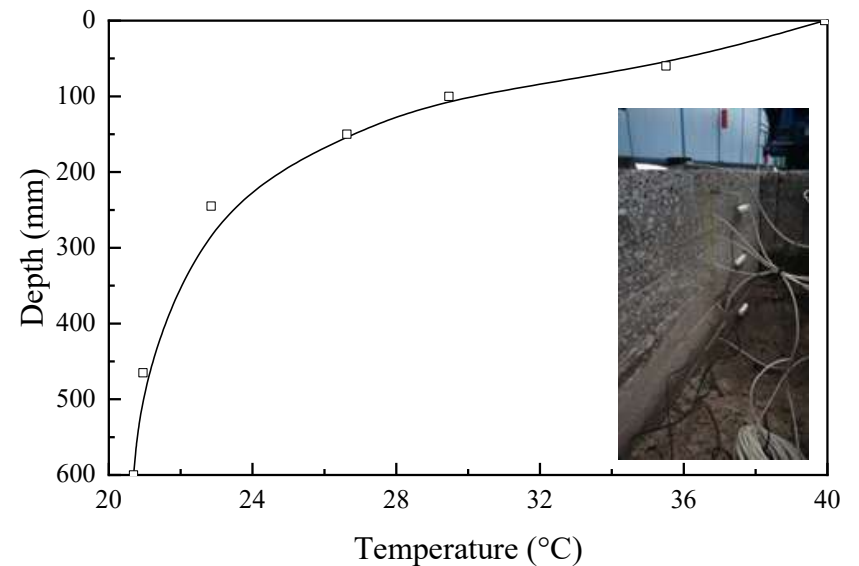- 2 mm bitumen films
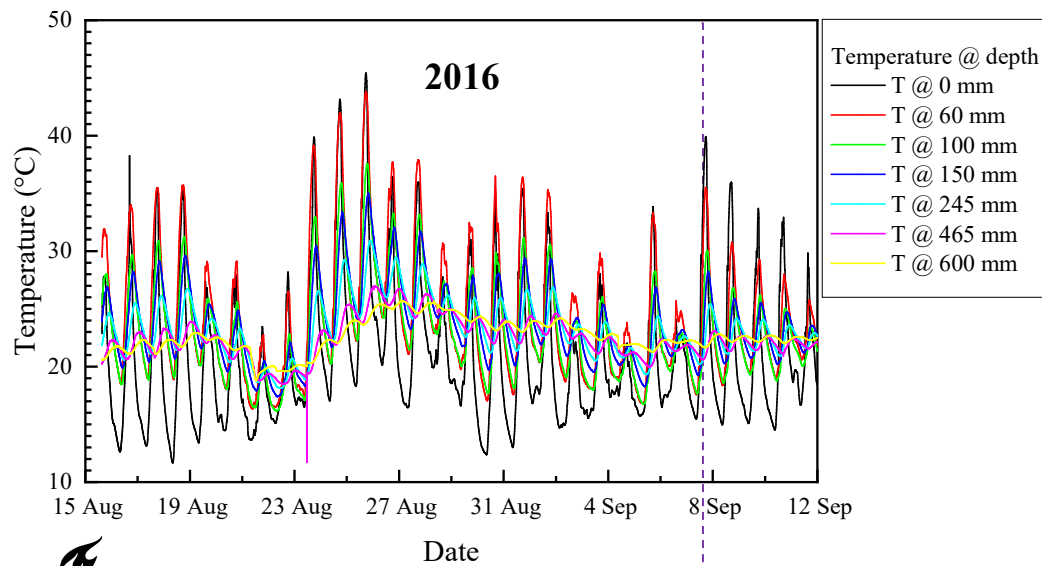- Tested by FTIR and DSR

*TU*Delft

Field test sections @LINTRACK TU Delft

Test sections laid on October 2014

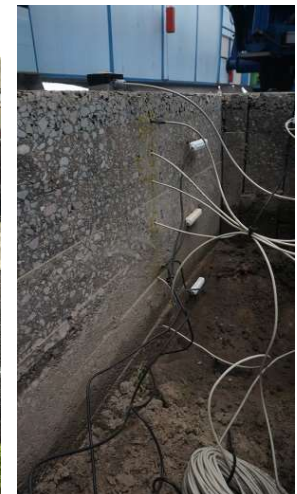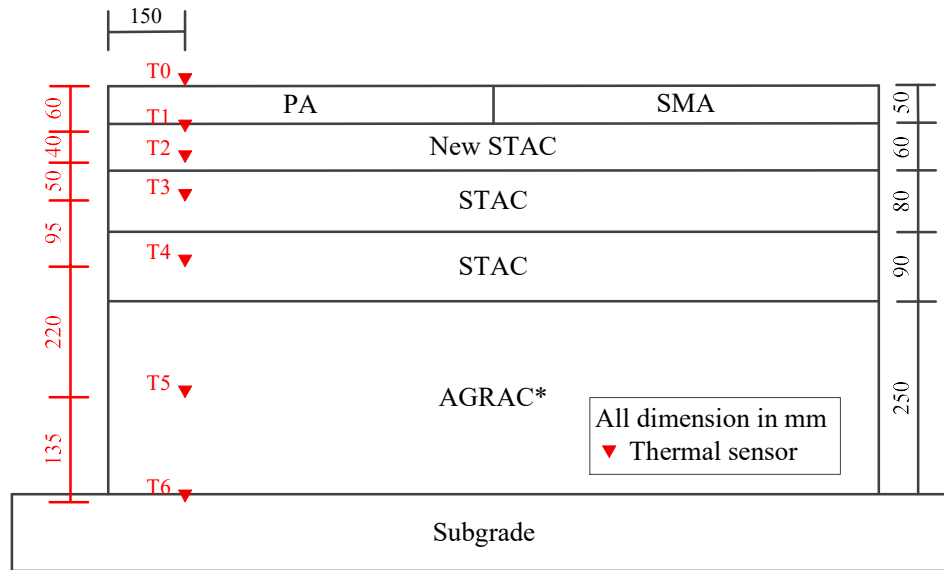# Field test sections @LINTRACK TU Delft

Test sections laid on October 2014

PA/SMA — 50
New STAC — 60
Old STAC — 170
AGRAC — 250
Sand Subgrade (5000 mm)

SMA
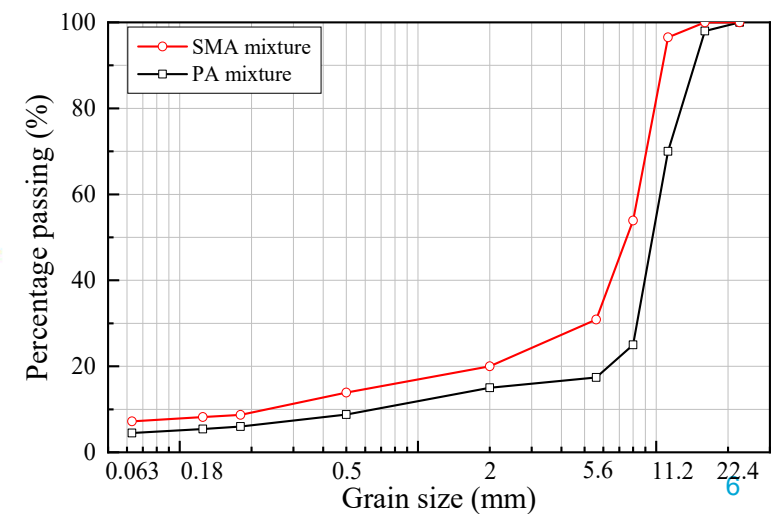
Field test sections

Field test sections

Sample collection once per year!!

Dates (YY. MM. DD)	Events	Explanation
2014.10.09	Pavement construction	
2014.10.24	Coring	4 PA
2015.10.01	Coring	4 PA, 4 SMA
2016.03.03	UV reflective glass-plate installation	
2016.08.05	Thermal sensor installation	
2016.10.07	Coring	4 PA, 4 SMA
2017.10.10	Coring	4 PA, 4 SMA, 4 PA_G. 4 SMA_G
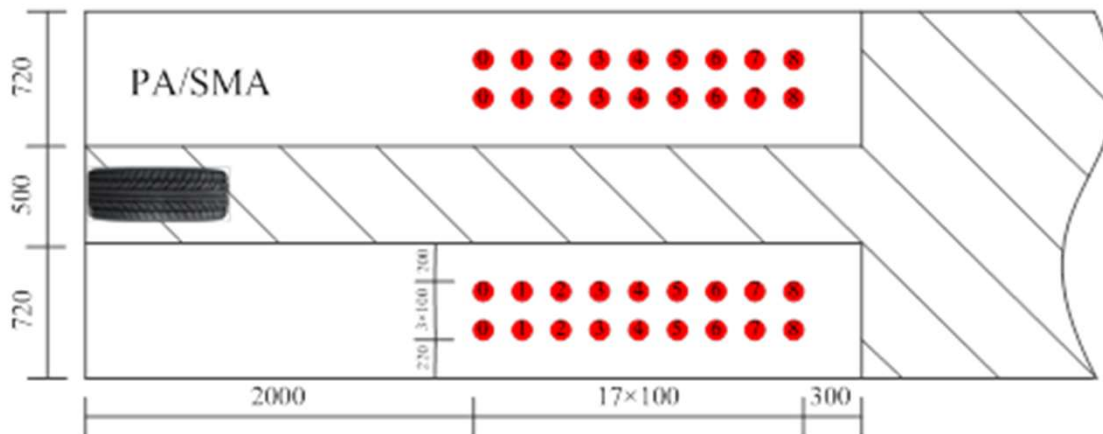
Weather station
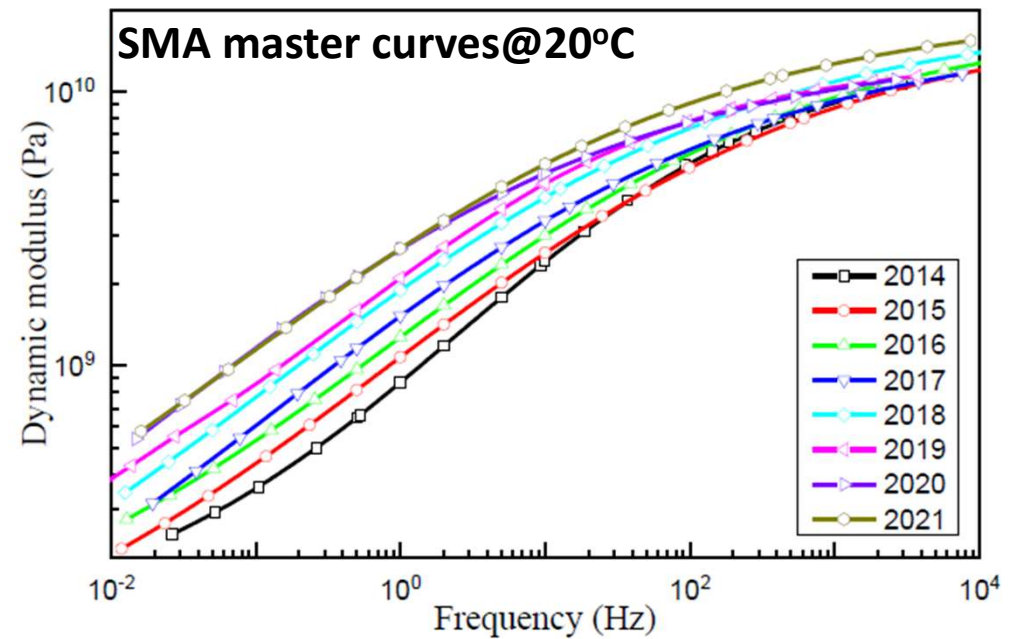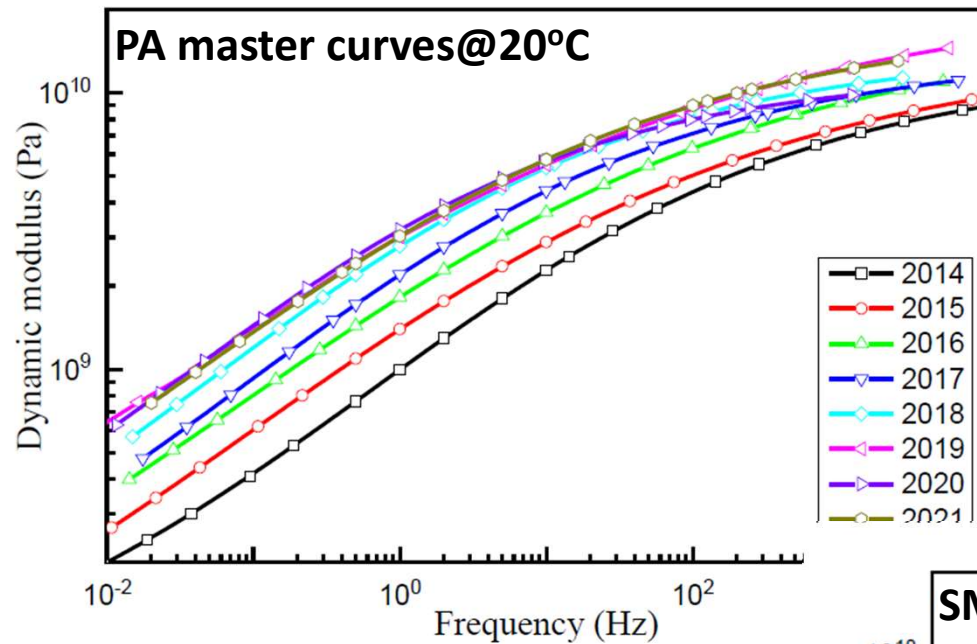
Preparation of field-aged samples
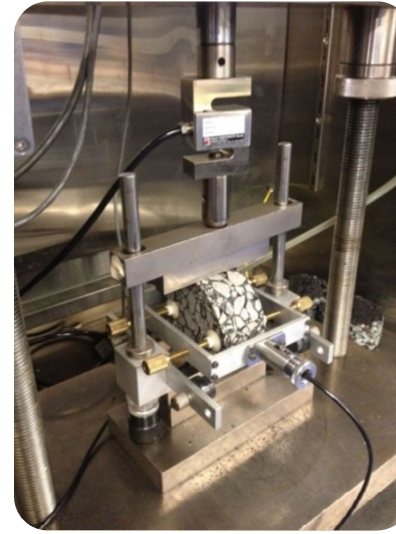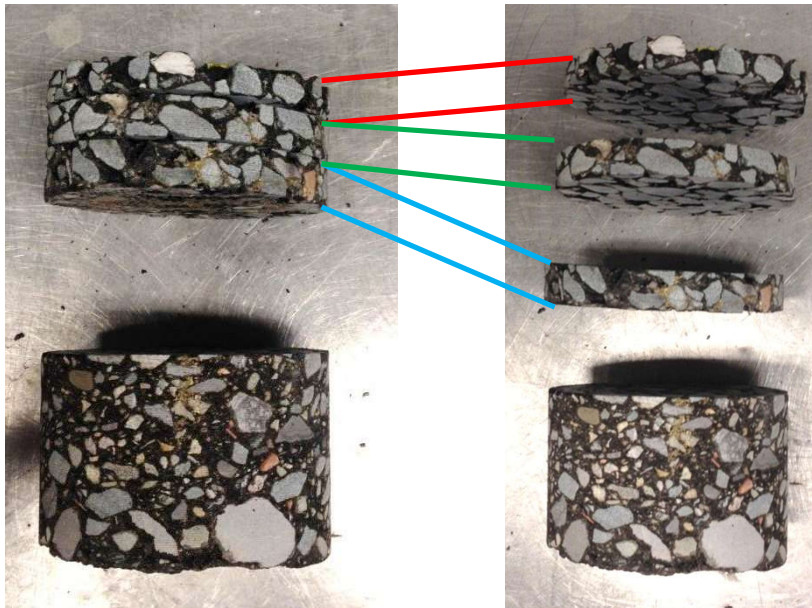
ITSM

DSR

Cut the sample into three slices
(11mm~13mm)

FTIR

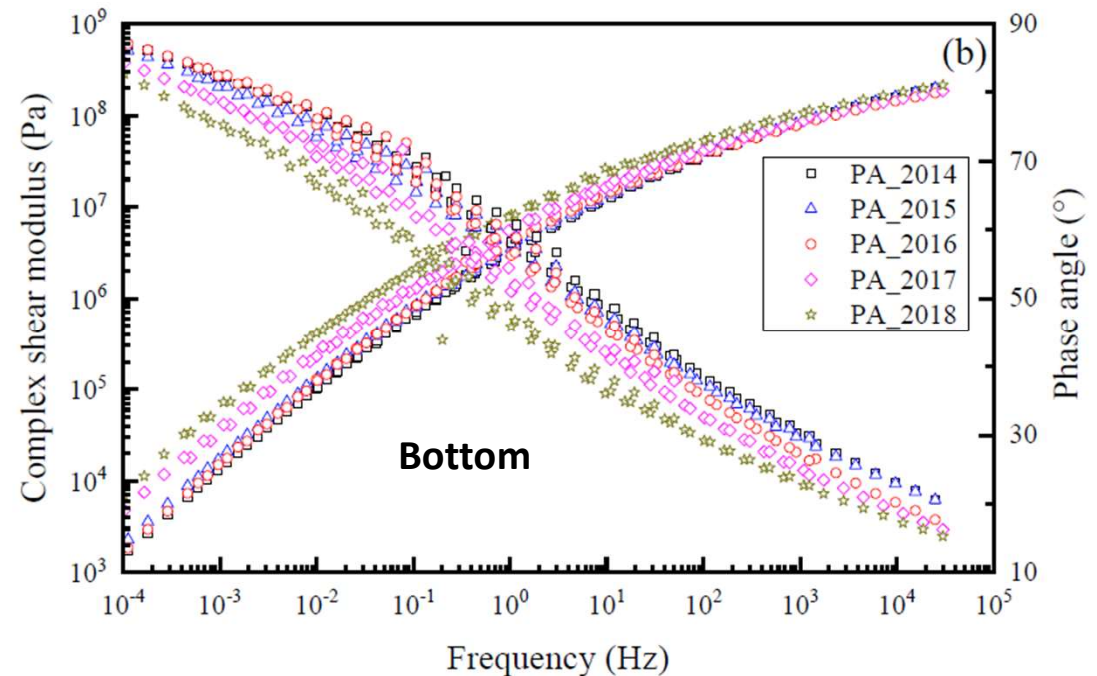Bitumen Extraction

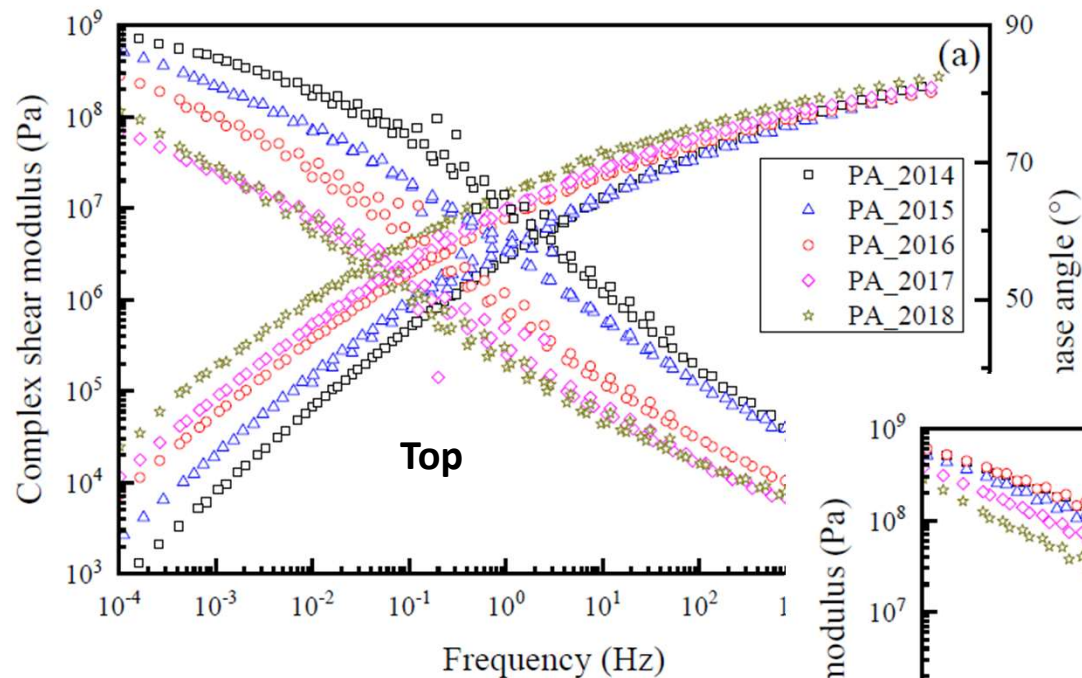**TU**Delft

Field samples - stiffness

Field-aged bitumen – DSR

Field ageing: Variation with PA layer depth

Master curves@20°C

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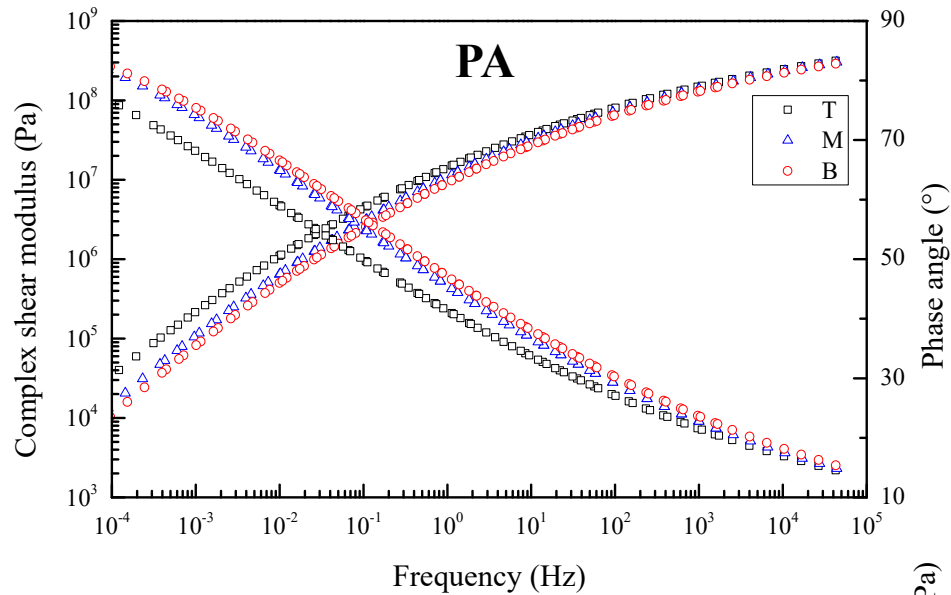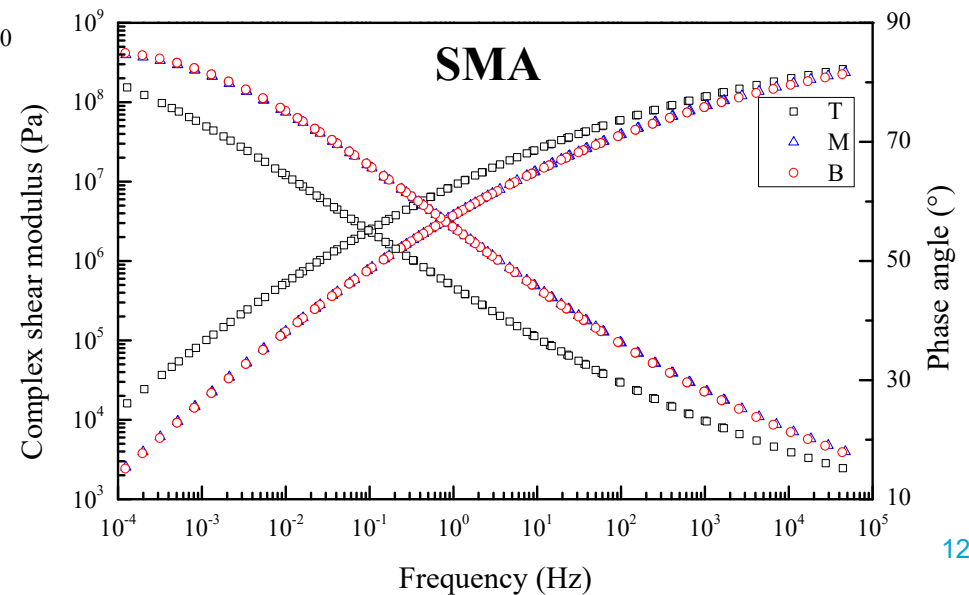
Field-aged bitumen – DSR
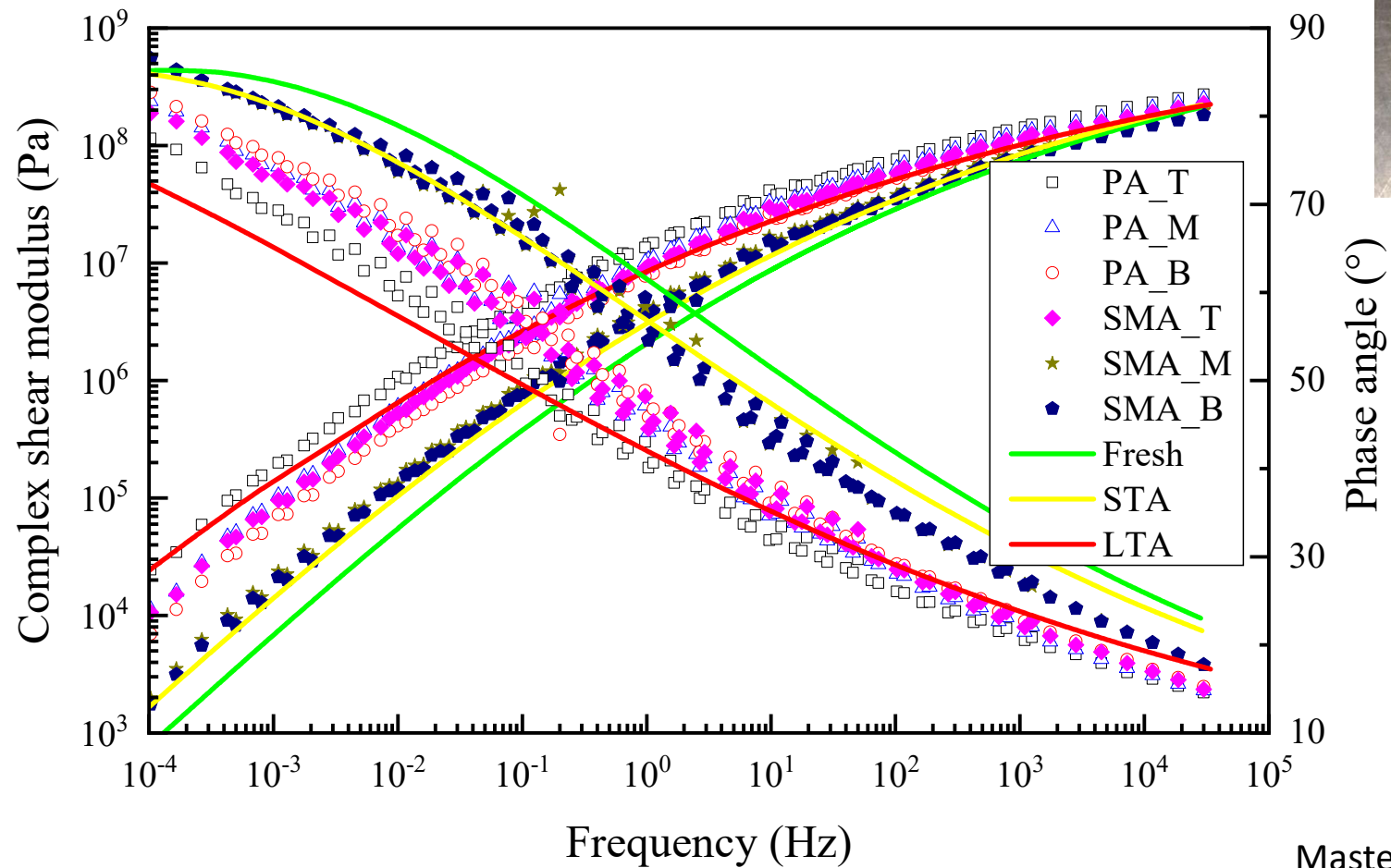
Field ageing: after 4 years in the field (2018)
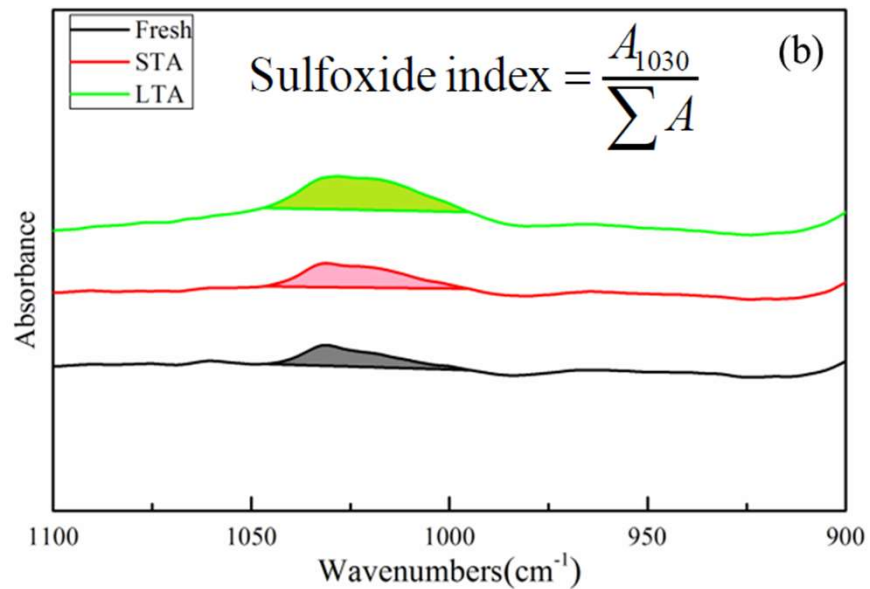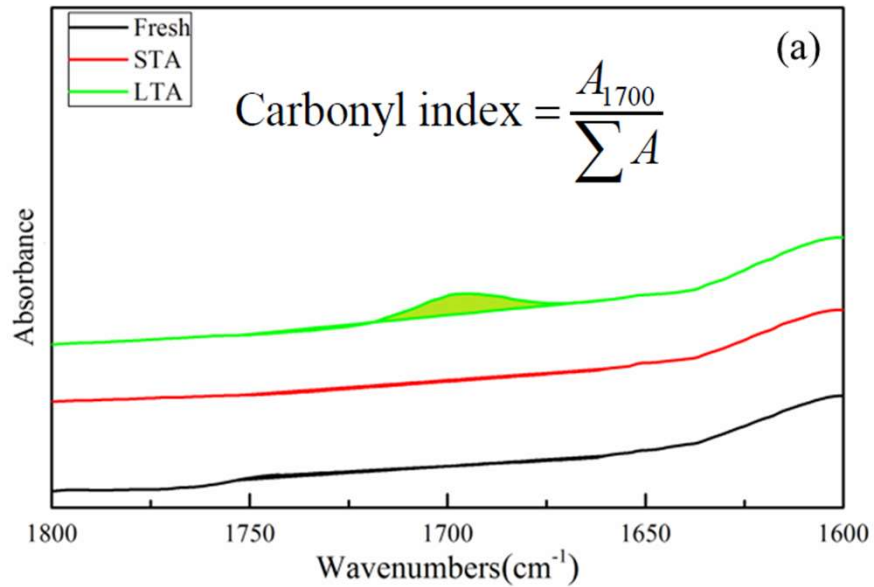

Master curves@20ºC

Field-aged bitumen and standard lab ageing

Field ageing: after 4 years in the field (2018)
Standard protocols: STA and STA+LTA

Master curves@20ºC

Lab-aged bitumen - FTIR

Carbonyl index $= \dfrac{A_{1700}}{\sum A}$

(a)

Fresh
STA
LTA

Absorbance

1800 1750 1700 1650 1600
Wavenumbers(cm^{-1})

Sulfoxide index $= \dfrac{A_{1030}}{\sum A}$

(b)

Fresh
STA
LTA

Absorbance

1100 1050 1000 950 900
Wavenumbers(cm^{-1})

FTIR ageing indices

A_{2953} A_{2862} A_{1460} A_{1376} A_{724} A_{743} A_{1030} A_{814} A_{864} A_{1600} A_{1700}

0.30
0.25
0.20
0.15
0.10
0.05
0.00

Absorbance

4000 3500 3000 2500 2000 1500 1000
Wavenumbers(cm^{-1})

14
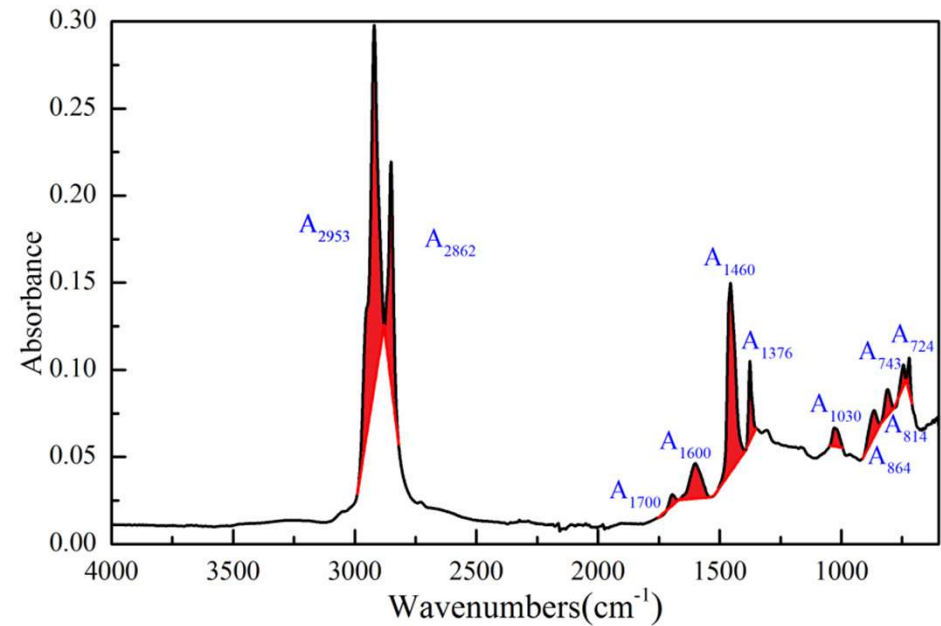
Field-aged bitumen – FTIR
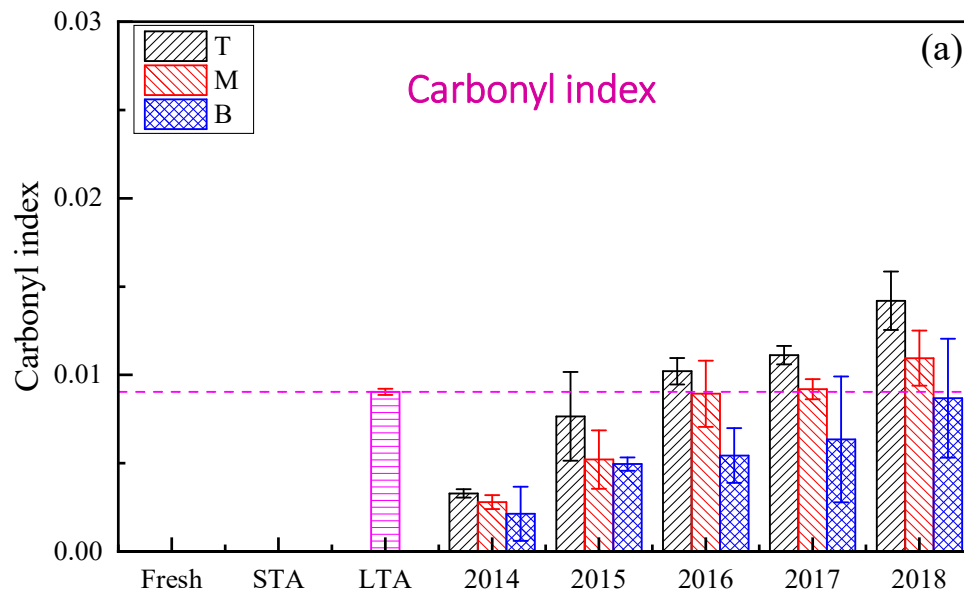
Field ageing: Variation with top layer depth of PA mixture

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Field-aged bitumen – FTIR

Field ageing: 4 years in the field (2018)

Conclusions

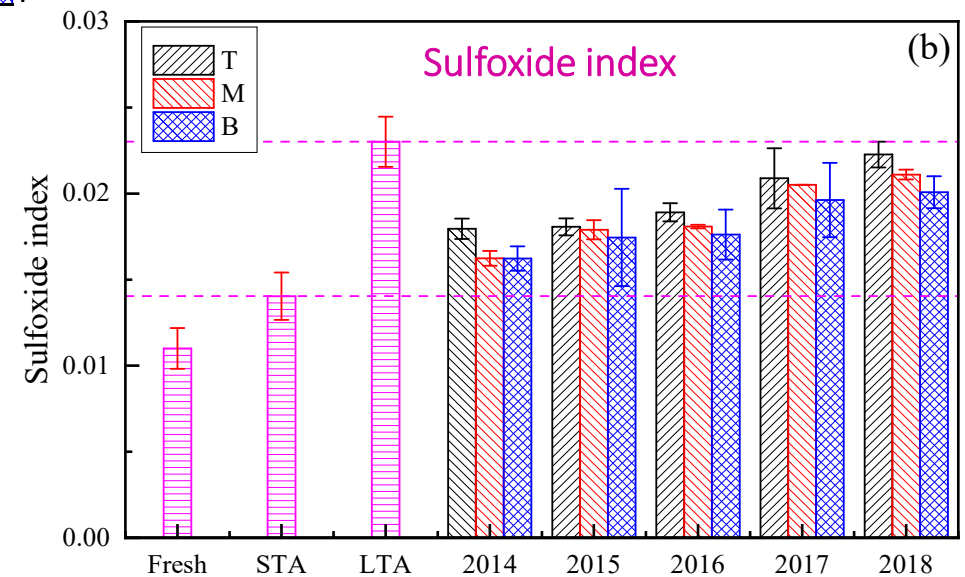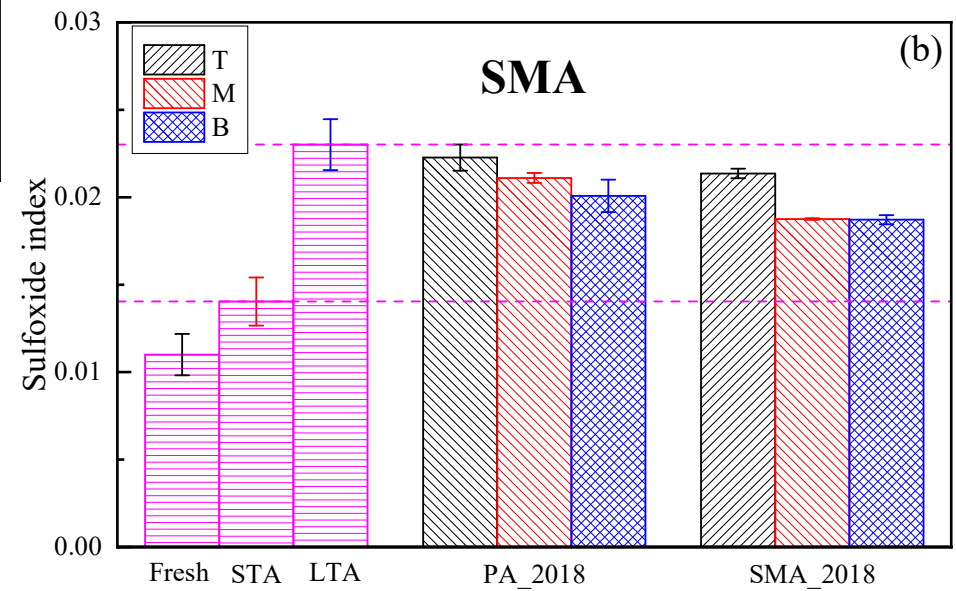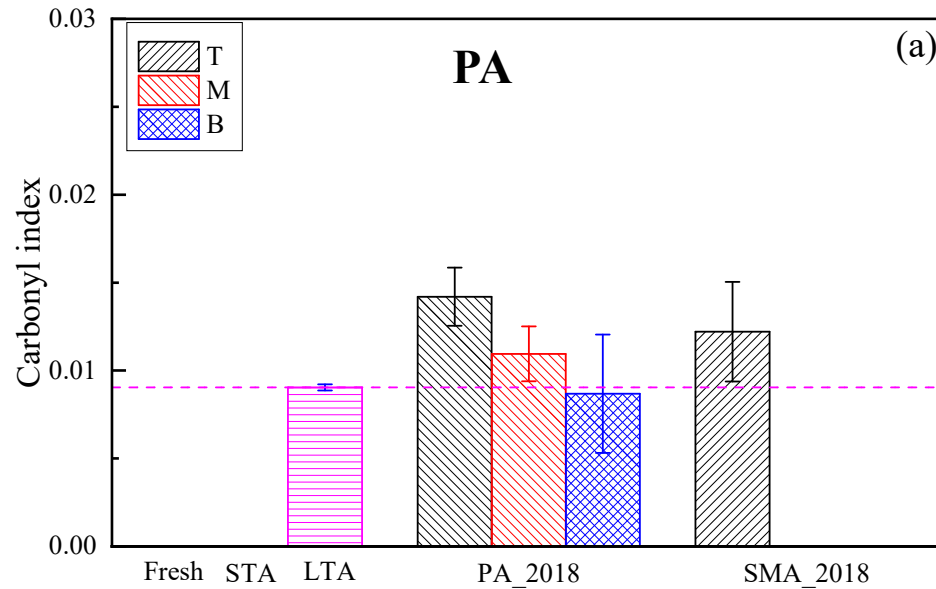- Bitumen **ageing is more severe for the top part** of the pavement, as it is in contact with the atmospheric air and the pavement temperature is higher.

- **Differences in the field-ageing behavior of the PA and SMA.** Ageing gradient exists in the PA mixture, whereas the ageing of the SMA mixture mainly occurs at the surface.

- **Weak relationship** between field ageing and the standard ageing protocols. Field ageing at pavement surface is **more severe than standard laboratory** ageing and cannot be simulated by standard RTFOT and PAV ageing.

…. And motivation for further work

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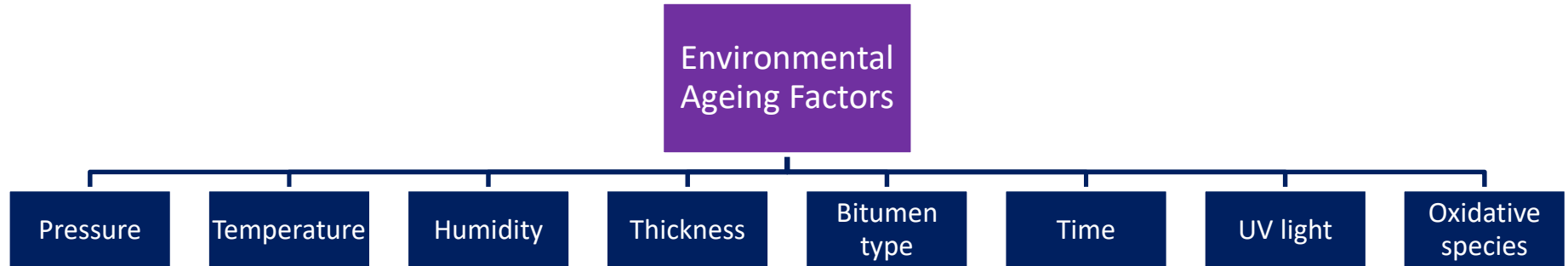# On-going & future work

- What is a representative **binder ageing protocol** considering fundamental knowledge and field data?
- → *Consider **coupled** conditioning protocols: e.g. PAV at moist conditions*
- → ***Feedback loop** so that mechanisms/processes at lab agree with those at **field**.*
- → *What is the role of **filler**?*

- What are the **ageing sensitivity indices** to be used at the design stage for selection of standard and alternative binders?

- → *Identify **critical properties**/ indices from FTIR/DSR data*

- → ***Other** chemo-mechanical **tests**?*

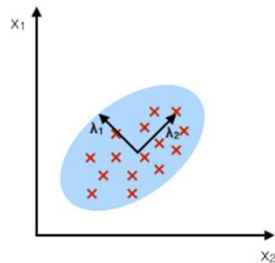
- Are the processes similar for **new/alternative** binders?

Trial coupled protocol → Changes in properties/performance → Agree with field? → YES / NO → Consider fundamental knowledge & new test data →

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On-going & future work

Environmental Ageing Factors

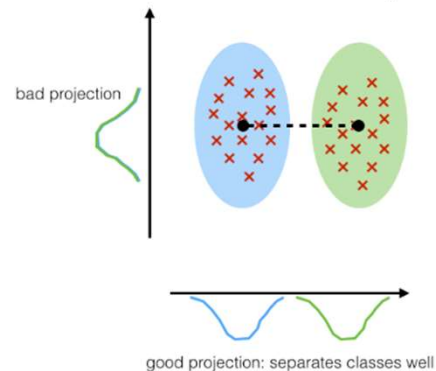| Pressure | Temperature | Humidity | Thickness | Bitumen type | Time | UV light | Oxidative species |
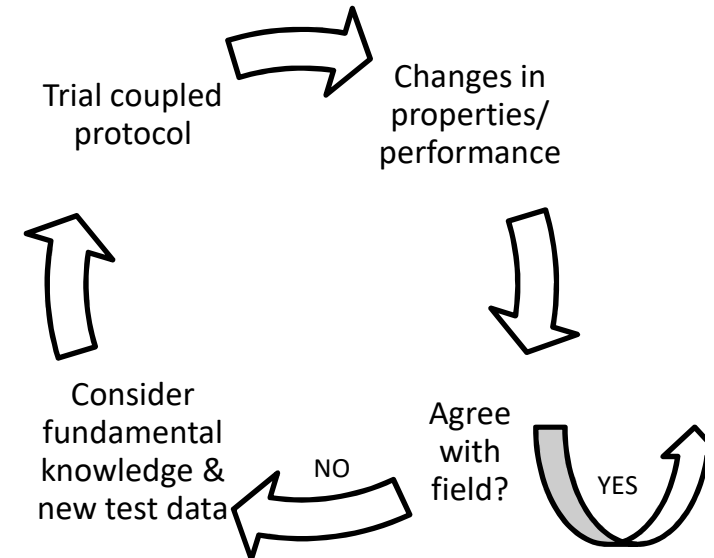
Multivariate Data analysis

PCA:
component axes that maximize the variance
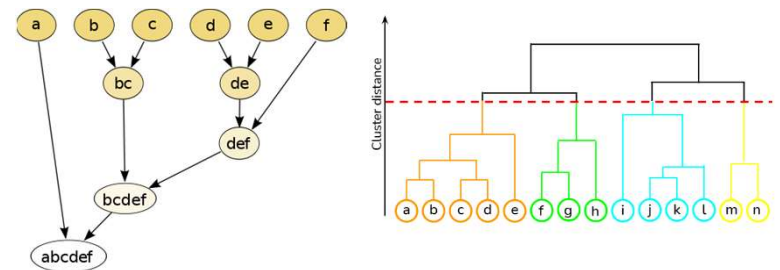
LDA:
maximizing the component axes for class-separation

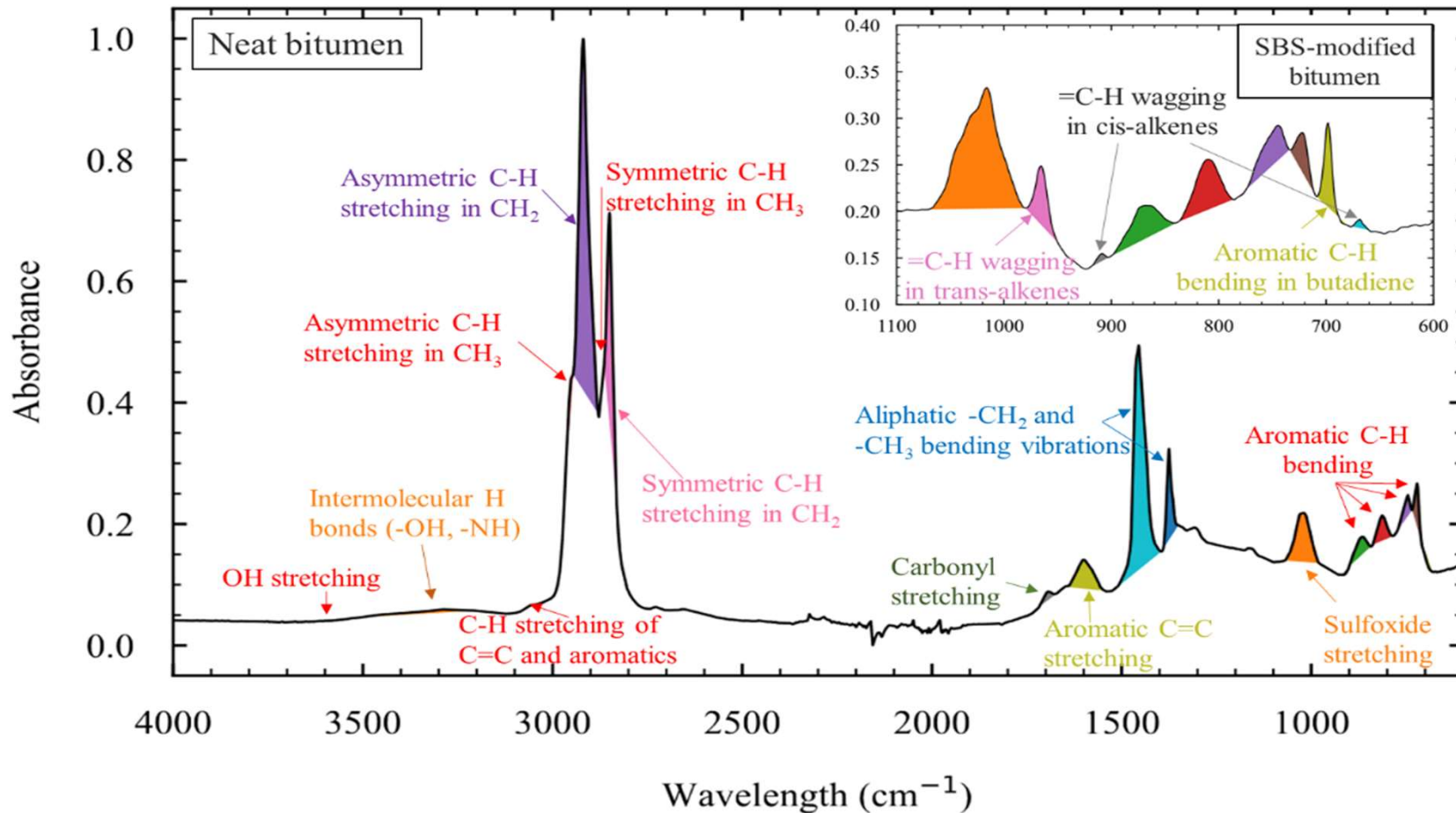**HCA:**
seeks to build a hierarchy of clusters

FTIR data analysis

Which information shall we use?

L. Ma, A. Varveri, R. Jing, S. Erkens (2022). Chemical characterization of bitumen type and ageing state based on FTIR spectroscopy and discriminant analysis integrated with variable selection methods. Under review in *Construction and Building Materials*.

FTIR data analysis - classification

Bitumen type identification

LDA, using peak data

LDA, using all spectra information

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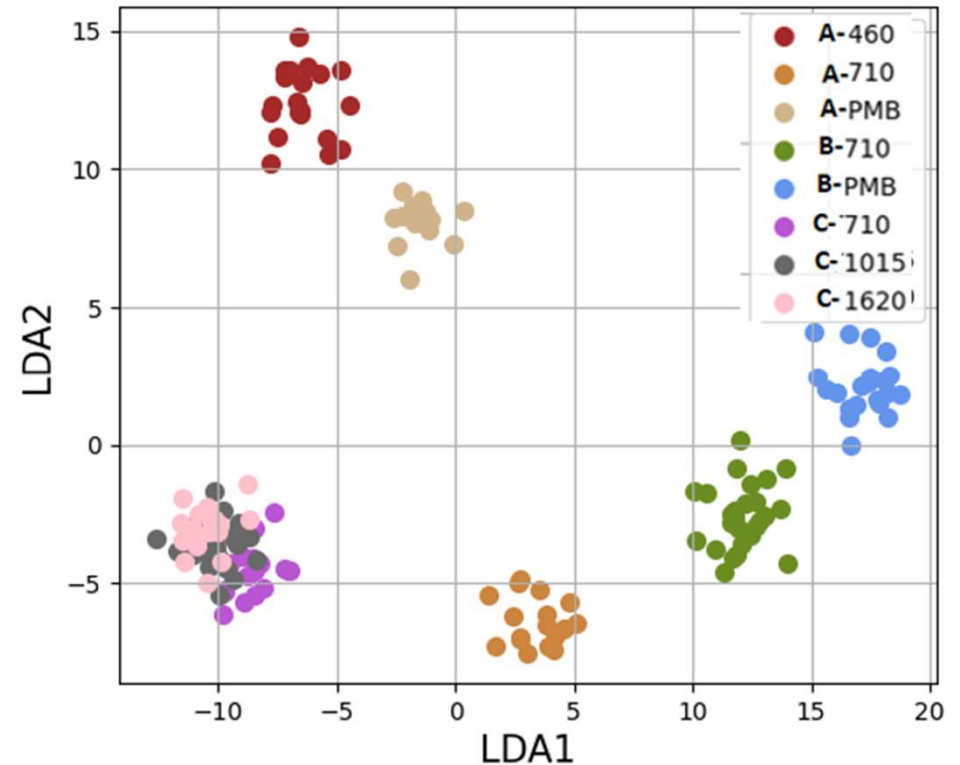
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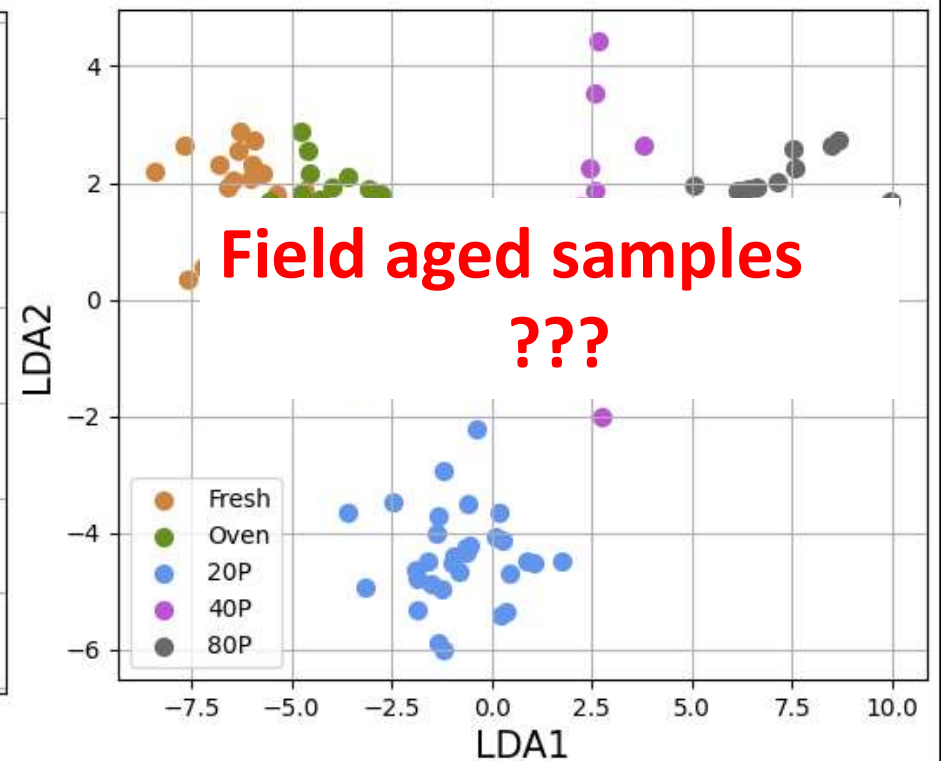
FTIR data analysis - classification
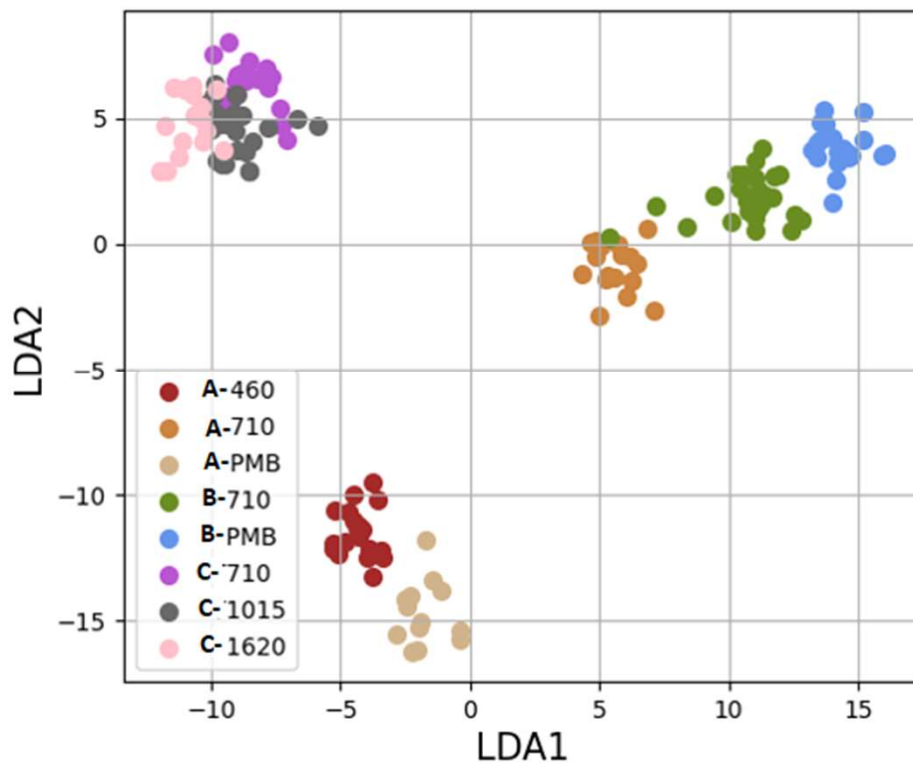
Bitumen ageing
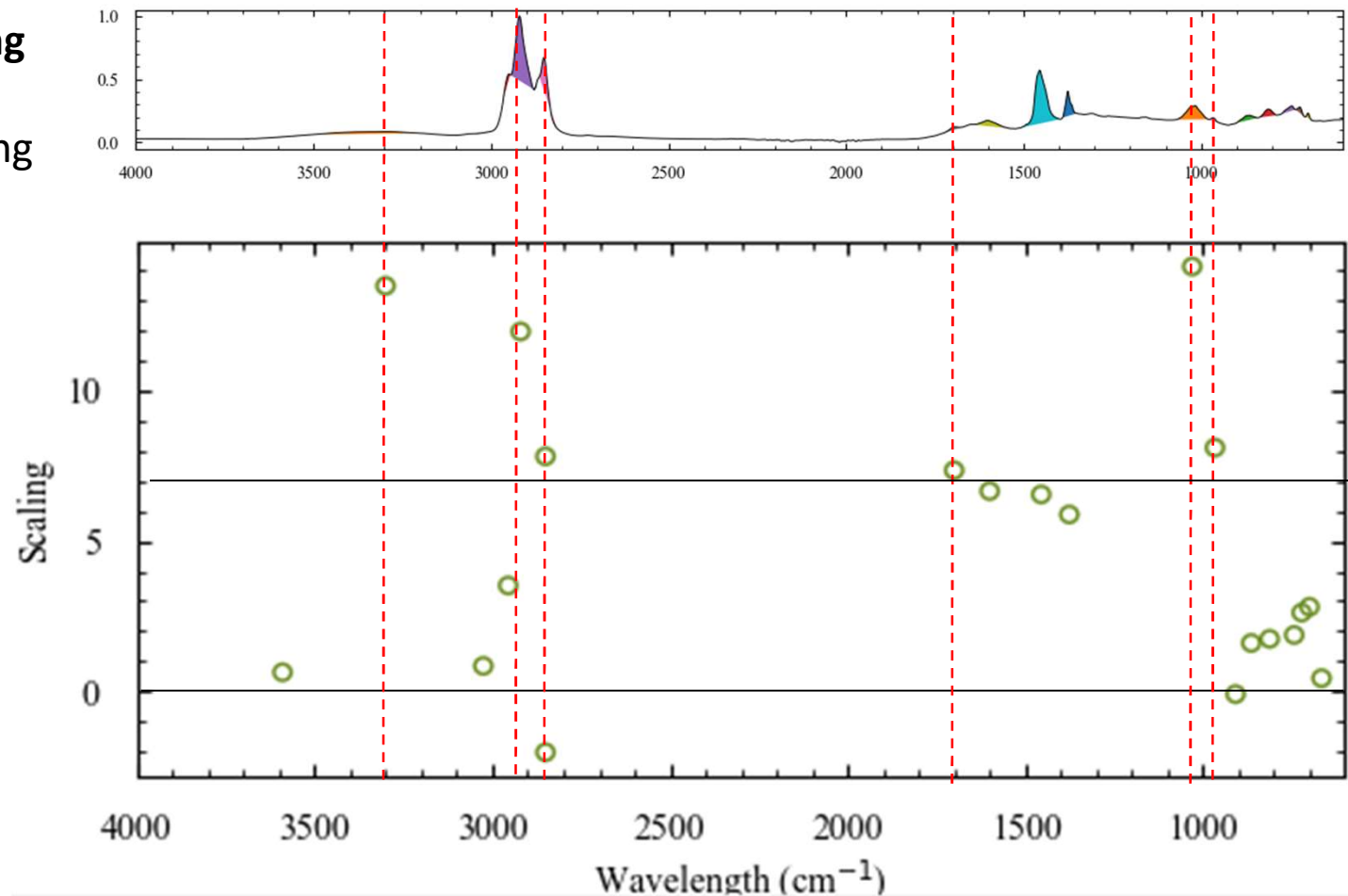

LDA, using peak data

LDA, using all spectra information
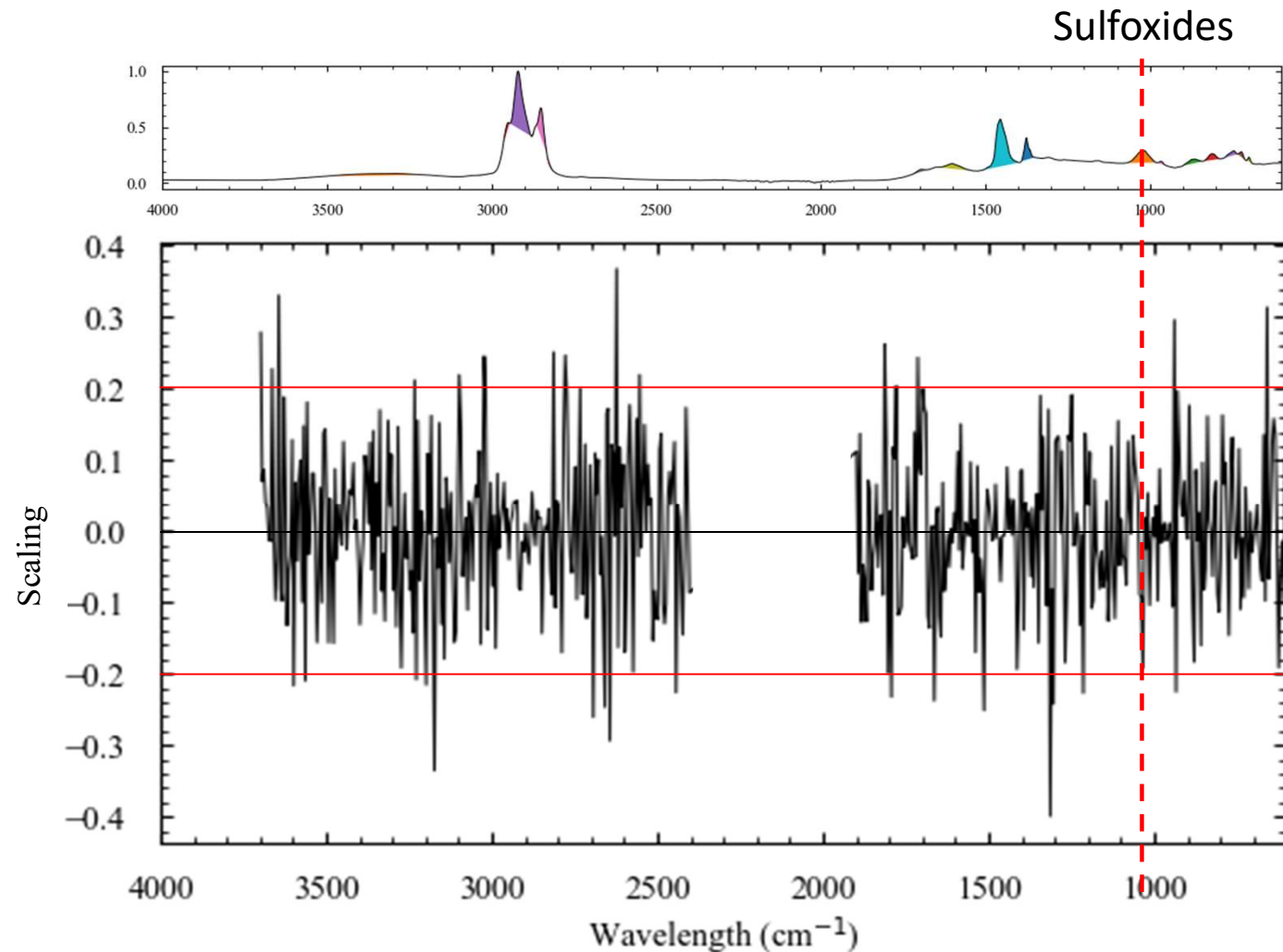
FTIR data analysis - classification

Bitumen ageing

Scaling of ageing level, LDA1

FTIR data analysis - classification

Bitumen ageing

Scaling of ageing level, LDA2

L. Ma, A. Varveri, R. Jing, S. Erkens (2022). Chemical characterization of bitumen type and ageing state based on FTIR spectroscopy and discriminant analysis integrated with variable selection methods. Under review in *Construction and Building Materials*.
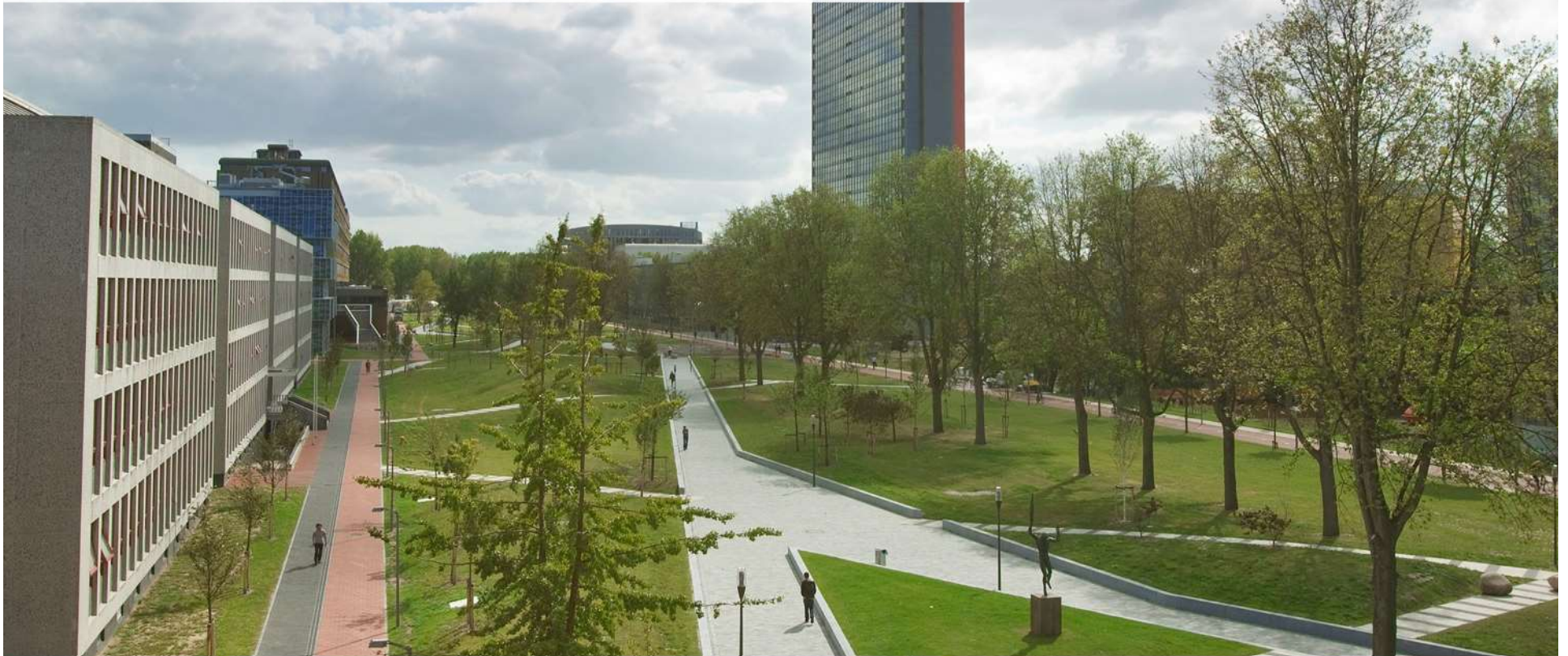
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