Statens vegvesen

Oppfølging av biogene tilsetninger fra en byggherres perspektiv

Performance Evaluation of Bio-binders

(Fatigue)

NaBin 2025

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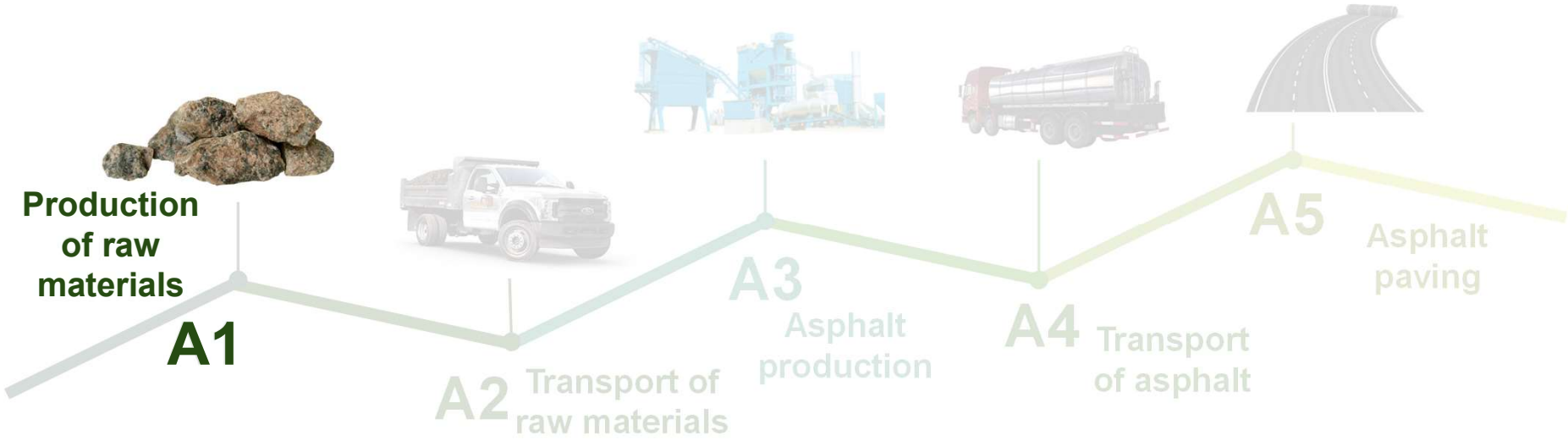
15 October 2025

Foto: Ali Mirhosseini

EPD – Environmental Product Declaration

- A document showing the environmental impacts (CO2 emission) for the product (asphalt).
- The A and C modules in an EPD represent the environmental impacts during the product's production **(A)** and its end-of-life phase **(C)**



Reduction in A1 by using …

- Recycled Asphalt Pavement (RAP)
- Bio-based additives in asphalt binder (replacement for neat binder, additive while blending with RAP etc.)

- How much bio-oil is there..?
- How has it blended with bitumen?
- Interactions with recycled asphalt..?
- What happens if we recycle and add bio-oil again..?

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FTIR

C-14

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MS-GC

H-NMR

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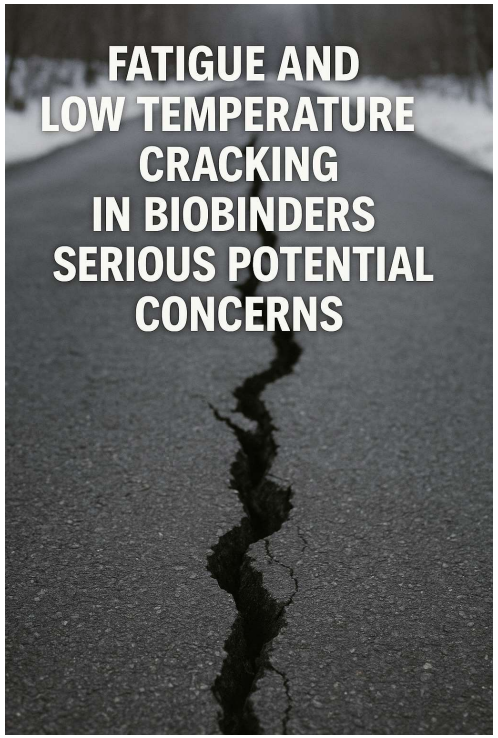


Superpave asphalt binder tests

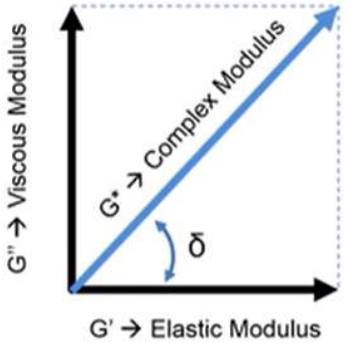
- Rotational Viscosity
- Dynamic Shear Rheometer (DSR) – Unaged
- DSR after RTFO (G*/sin δ)
- DSR on PAV-aged Binder (G*·sin δ)
- Bending Beam Rheometer (BBR) (Creep stiffness (S) and relaxation rate (m-value))
- Direct Tension Test (DTT)
- Rolling Thin Film Oven (RTFO) Aging
- Pressure Aging Vessel (PAV)

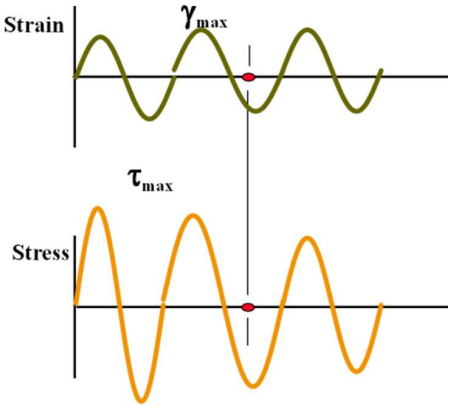
Photos: AI

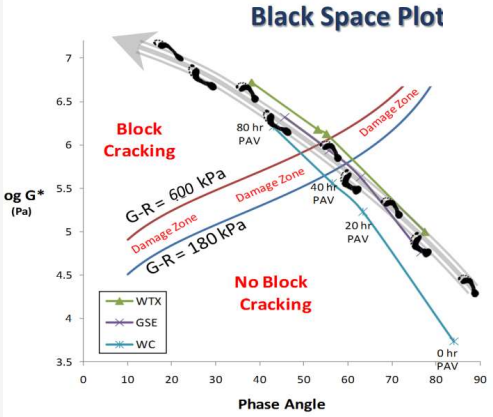
Asphalt Binder Fatigue Tests

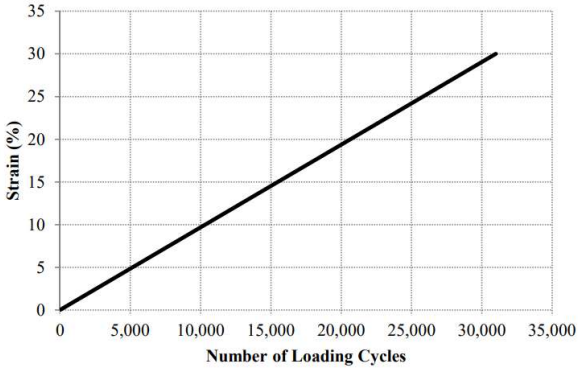
- Superpave specification (G*·sin δ)
  (based on small strain rheology, does not consider damage resistance, failure to capture the impact of modifiers)
- Time Sweep (NCHRP)
  was regarded as the most representative for fatigue, time-consuming nature/ small applied strains
- G-R parameter (G*·cos2 δ/ sin δ)
  single strain and fixed frequency, making them inadequate to address the entire range of temperatures and loads

- **Linear Amplitude Sweep (LAS)**









ViscoElastic Continuum Damage (VECD)

- Relies on constitutive modellingto determine the deviation of damages test results from undamaged properties
- Deviation from initial undamaged properties with respect to number of cycles used to calculate damage
- (This method has been used for asphalt mixtures since 1980s).

- The Linear Amplitude Sweep according to AASHTO TP101 was introduced as a measure of damage resistance.
- Most effective performance-based test of binder fatigue resistance

LAS

1. Frequency Sweep

Employing an applied load of **0.1% strain** over a range of frequencies from **0.2–30 Hz**

$$G'(\omega) = |G^*|(\omega) \times \cos \delta(\omega)$$

$$\log G'(\omega) = m(\log \omega) + b$$

$$\alpha = 1/m$$

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2. Amplitude Sweep

Oscillatory shear in strain-control mode at a frequency of **10 Hz**.
Loading is increased linearly from **zero to 30%** over the course of 3,100 cycles of loading

$$D(t) \cong \sum^{N} [\pi \gamma_0^2 (C_{i-1} - C_i)]^{\frac{\alpha}{1+\alpha}} (t_i - t_{i-1})^{\frac{1}{1+\alpha}}$$

$$C(t) = \frac{|G^*|(t)}{|G^*|_{initial}}$$

$$\log(C_0 - C(t)) = \log(C_1) + C_2 \cdot \log(D(t))$$

$$C_{(t)} = C_0 - C_1 (D)^{C2}$$

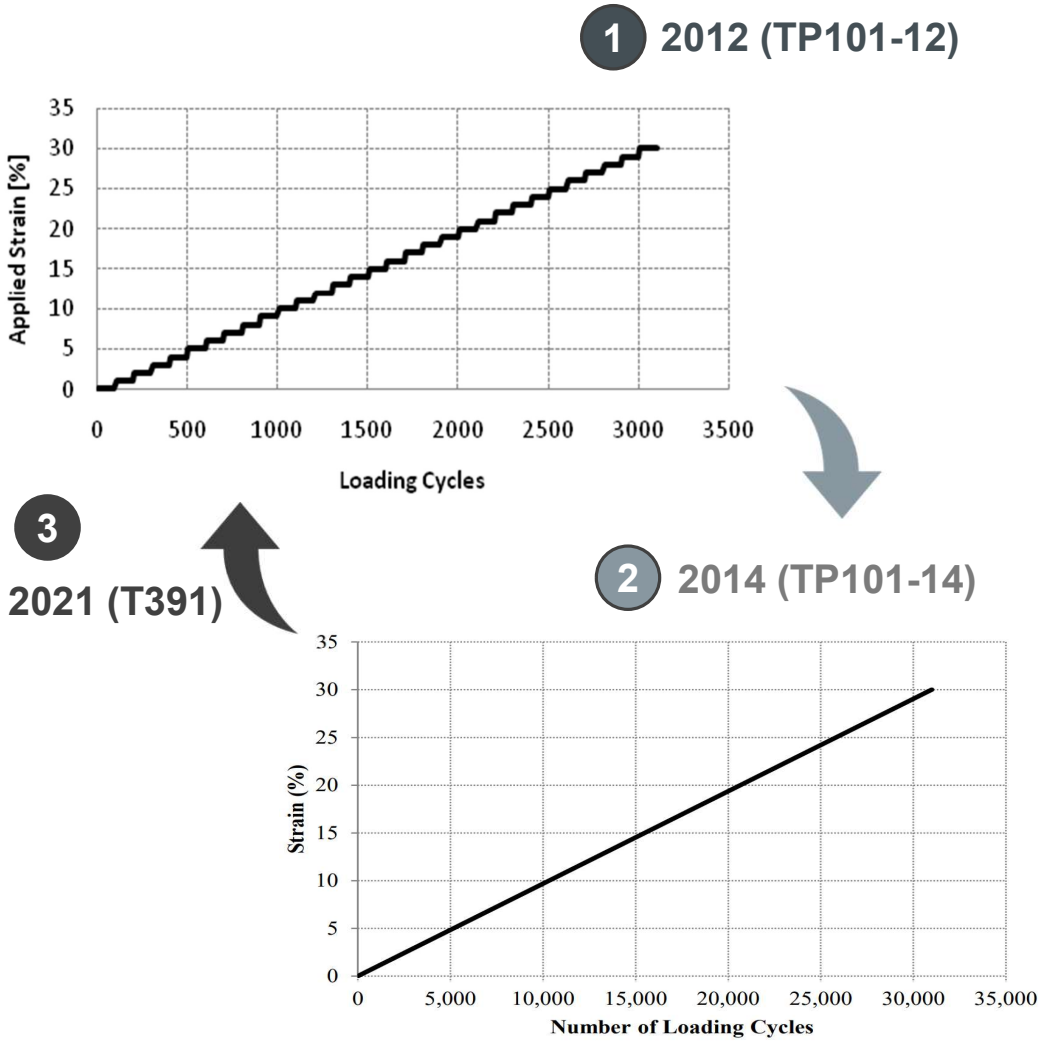
$|G^*|$ = Complex shear modulus, MPa

t = testing time, second

See more:
AASHTO TP101-14

Linear Amplitude Sweep (LAS)

- 2012: The loading scheme in this test was initially, stepwise dissipated energy G*sinδ, damage criterion of 35% (AASHTO TP101-12).
- 2014: The standard was changed to a new version (AASHTO TP101-14) damage criterion: peak of the stress values (reduction in initial $|Gi*|$at peak shear stress)
- 2021: TP 101 changed into a permanent standard AASHTO T391, changes implemented in the TP101-14 were revised back to the original procedure (TP101-12).



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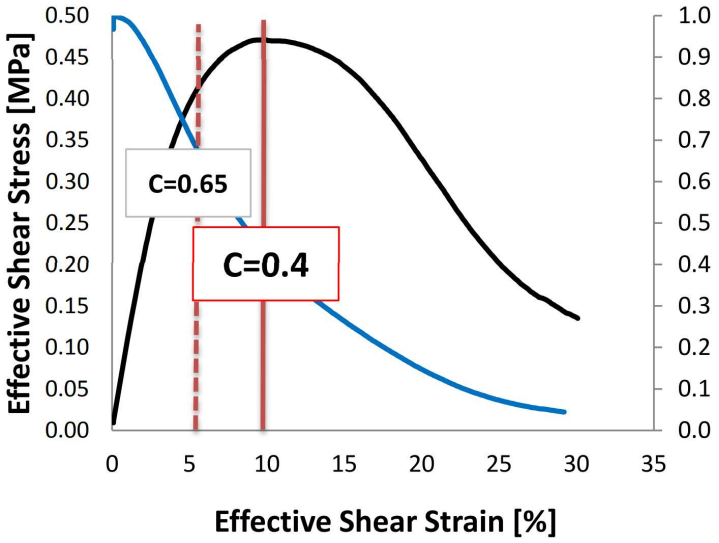
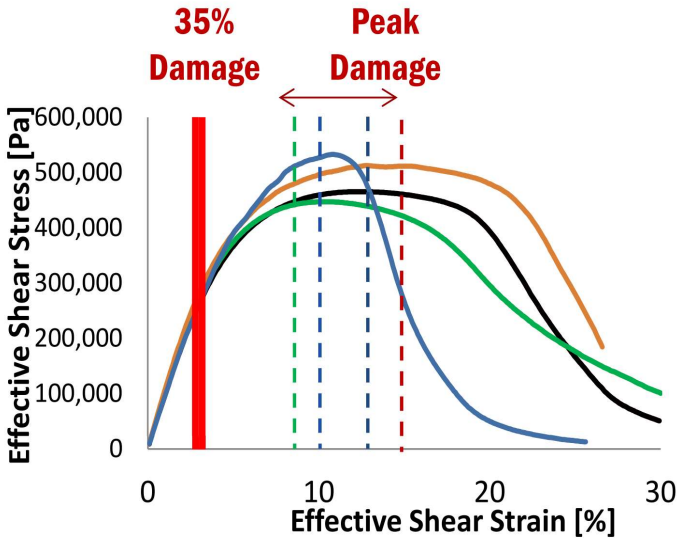
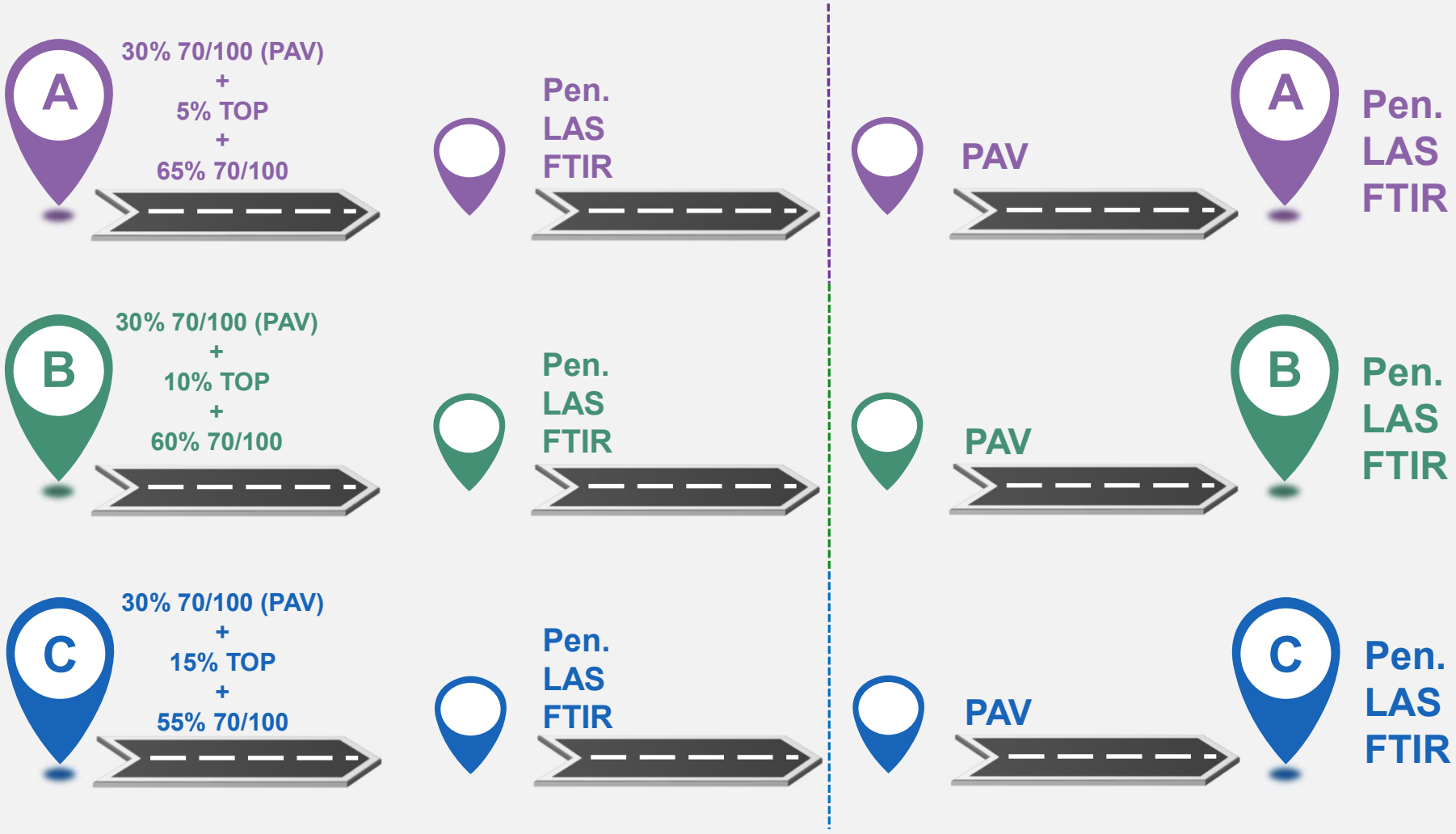
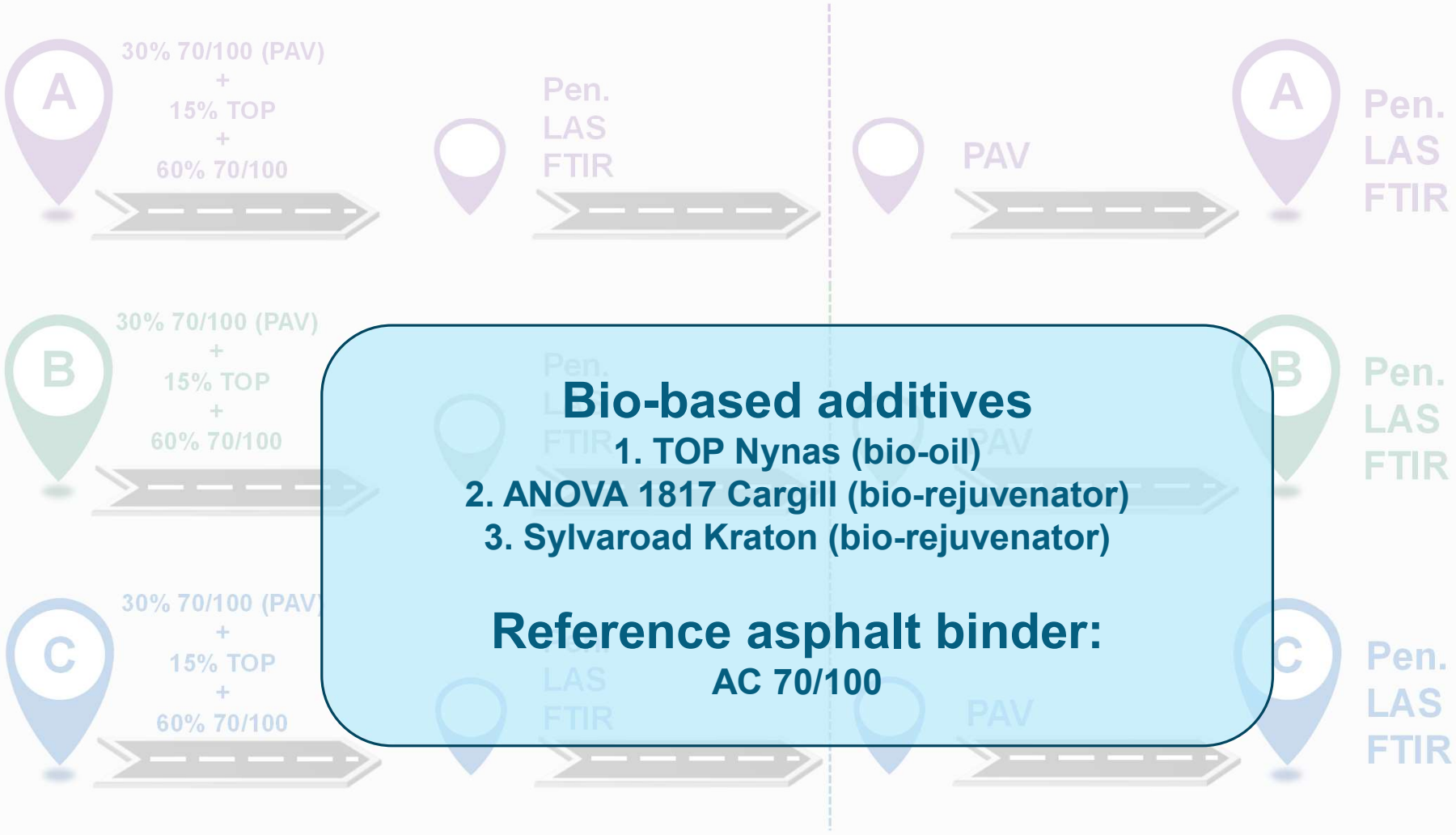




Test plan


A
30% 70/100 (PAV)
+
5% TOP
+
65% 70/100
Pen.
LAS
FTIR
PAV
A
Pen.
LAS
FTIR
B
30% 70/100 (PAV)
+
10% TOP
+
60% 70/100
Pen.
LAS
FTIR
PAV
B
Pen.
LAS
FTIR
C
30% 70/100 (PAV)
+
15% TOP
+
55% 70/100
Pen.
LAS
FTIR
PAV
C
Pen.
LAS
FTIR

Test plan



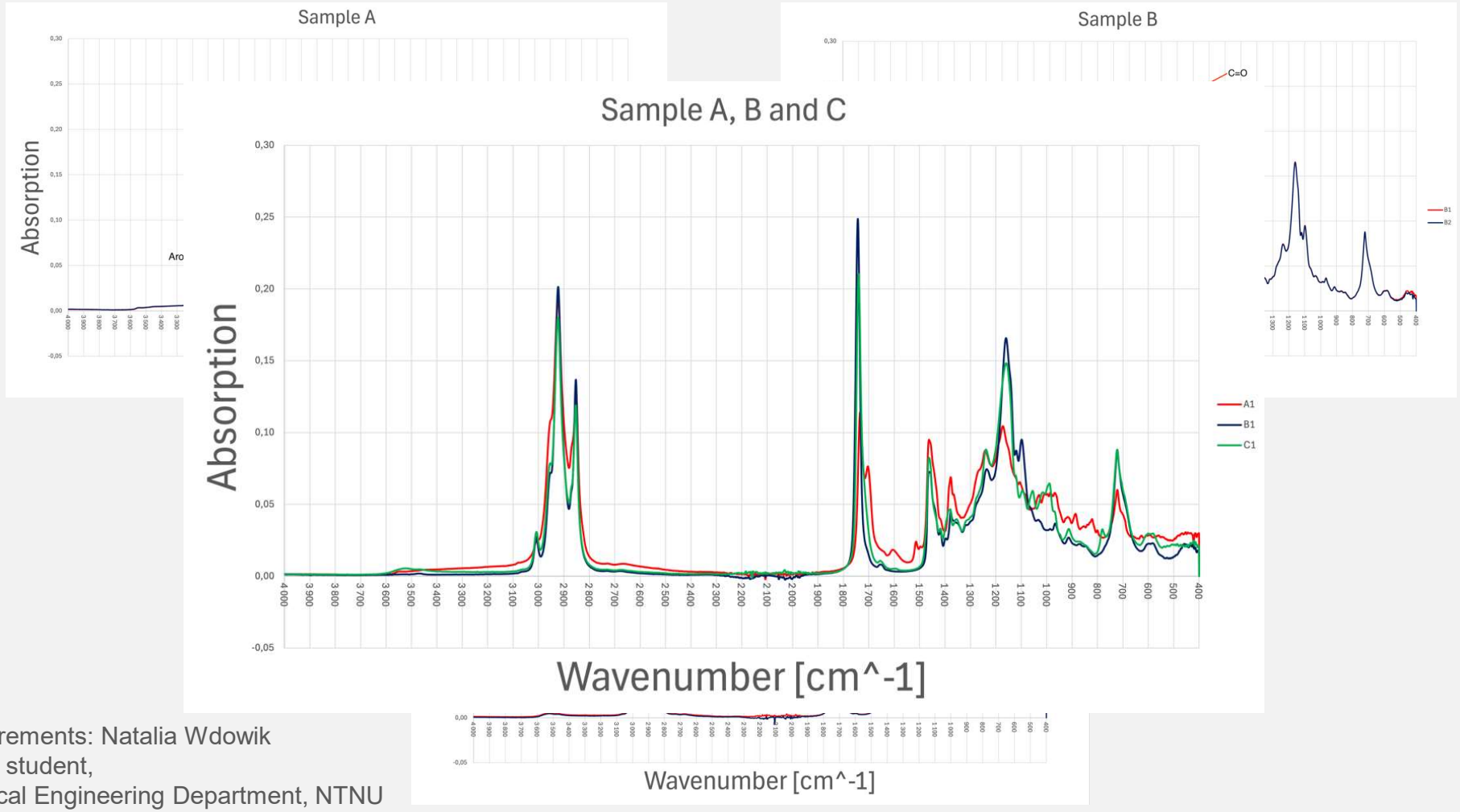
Bio-based additives

1. TOP Nynas (bio-oil)
2. ANOVA 1817 Cargill (bio-rejuvenator)
3. Sylvaroad Kraton (bio-rejuvenator)

Reference asphalt binder:

AC 70/100

Three bio-based additives (anonymous)



Measurements: Natalia Wdowik
Master student,
Chemical Engineering Department, NTNU

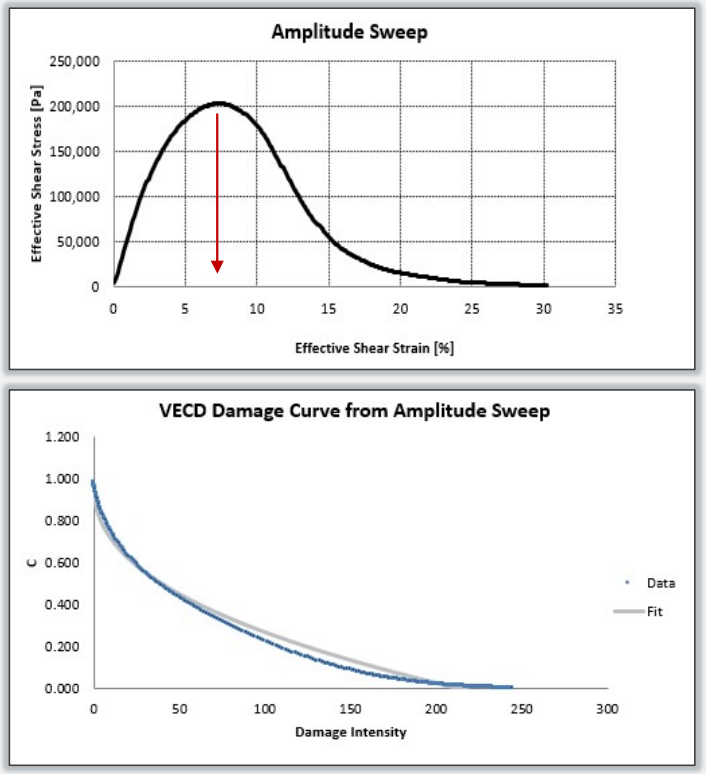
LAS Data Analysis spreadsheet

LAS free publicly available Microsoft excel spreadsheet for analysis of LAS test data can be found on University of Wisconsin-Madison website:

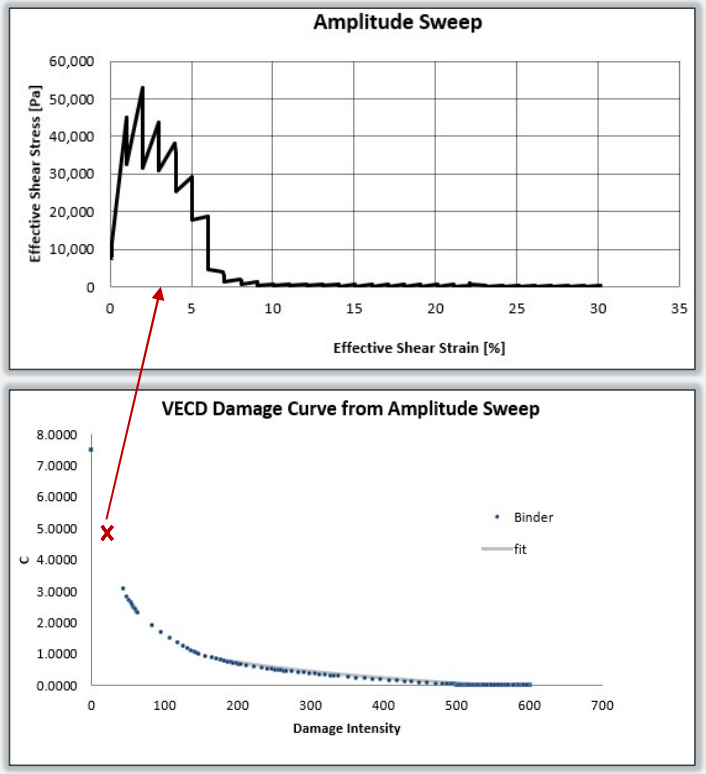
LAS Data Analysis Spreadsheet

Trial tests (AC70/100)

Statens vegvesen, Central Laboratory, Trondheim



(TP101-14)



(T391), manually programmed

Conclusions

- Bio-binders are entering the market at a large scale, driven by their potential to reduce CO_2 emissions and conserve non-renewable raw materials.
- A systematic evaluation of these materials is essential to ensure both performance and sustainability.
- Different bio-oils will undoubtedly perform differently, especially over the long term.
- Low-temperature cracking and fatigue cracking are two key potential failure modes that must be carefully monitored for biogenic binders.
- The LAS test shows great potential for assessing fatigue life and damage characteristics of bio-binders.

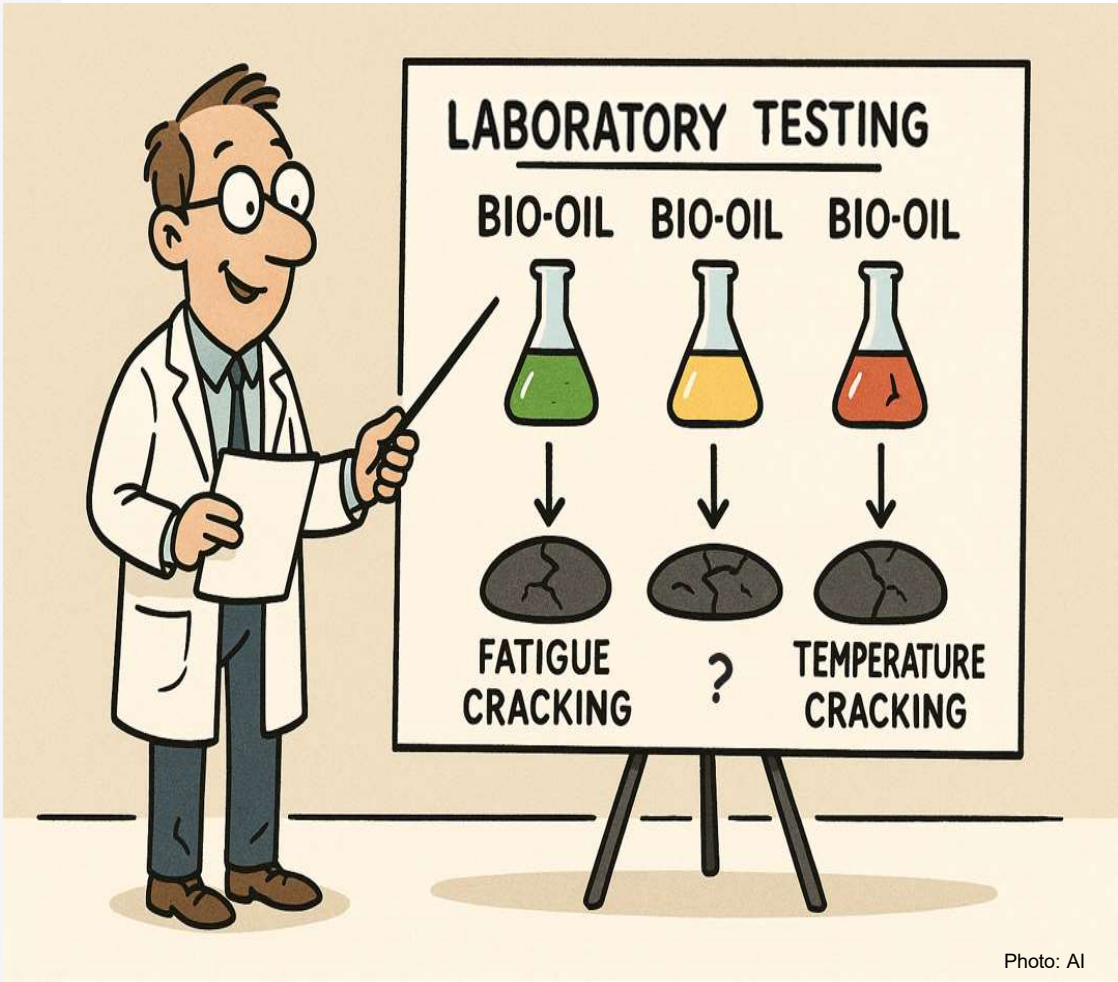


Photo: AI

Thank you

From bio-based binders to fatigue performance —
every test brings us one step closer to
greener, longer-lasting roads.

Ali Mirhosseini, PhD
Norwegian Public Roads Administration