Hrvatsko asfaltersko društvo

Croatian asphalt association

Novi indikatori ponašanja bitumena – studija opravdanosti

New bitumen performance indicators – A feasability study

Bernard Eckmann, Eurovia

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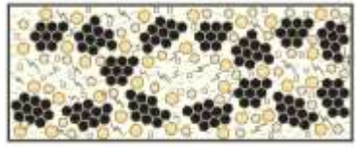
NEW BITUMEN PERFORMANCE INDICATORS
BACKGROUND & OBJECTIVES

- **BACKGROUND**
  - Search for performance related binder properties
  - Opportunity : three 70/100 pen. grade bitumen samples
    - Same penetration
    - Markedly different in composition
- **OBJECTIVES**
  - Evaluate the ability of different test methods to differentiate these binders
    - Conventional / Rheological tests (DSR, BBR)
    - Failure or large strains (Fraass, ABCD and LAS test)
    - Incidence of short (RTFOT) and long-term (PAV) ageing

NEW BITUMEN PERFORMANCE INDICATORS
THREE BITUMEN SAMPLES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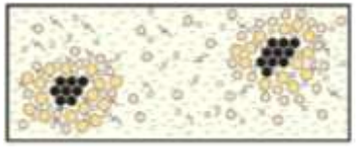
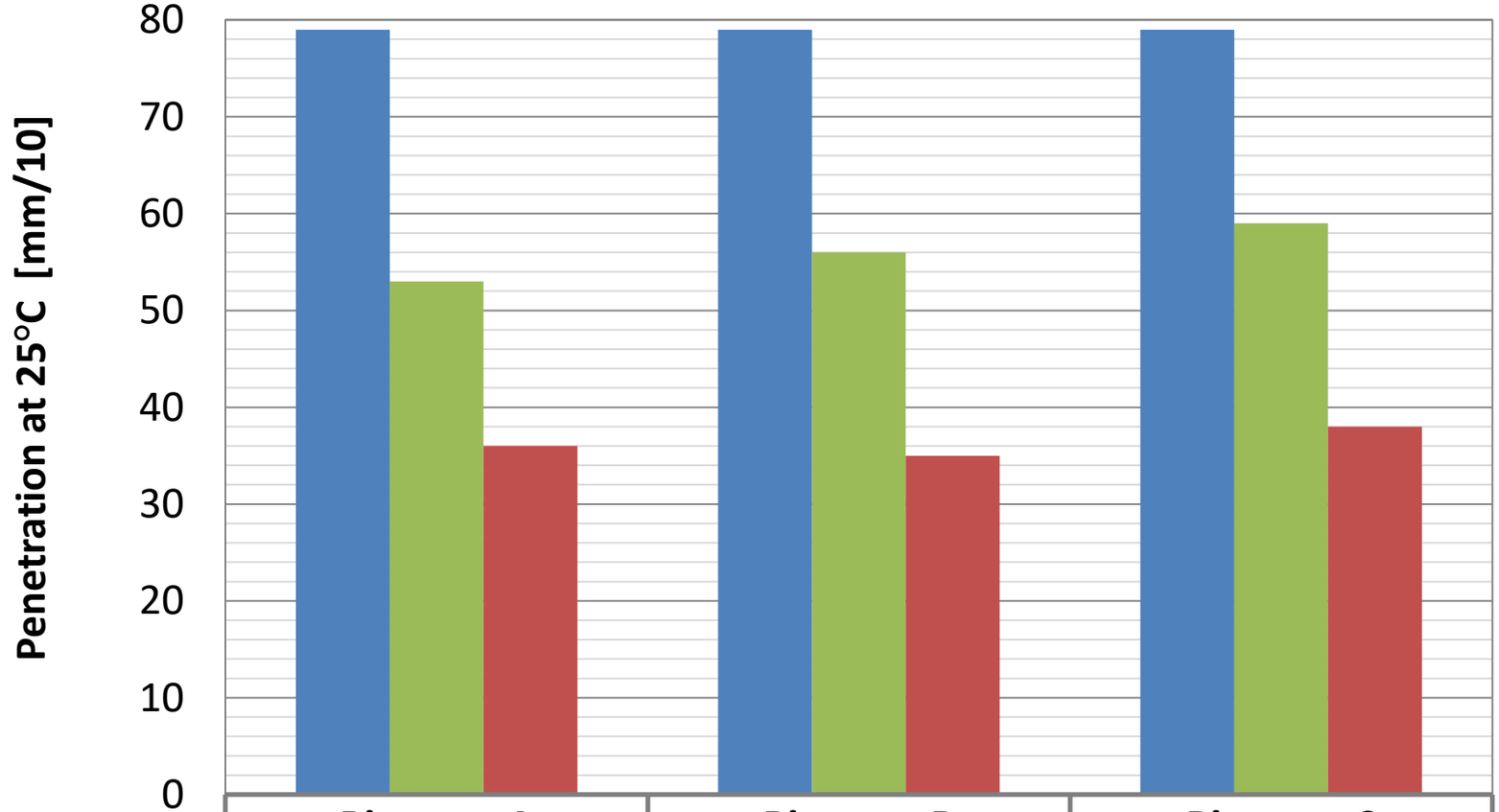


Characteristic	Unit	A GEL	B SOL-GEL	C SOL
Asphaltenes	% (m/m)	12,0	8,5	7,0
Resins	% (m/m)	16,0	15,5	13,0
Aromatics	% (m/m)	64,5	70,0	79,0
Saturates	% (m/m)	7,5	6,0	1,0
Colloïdal Stability Index (Asph. + Sat.)/(Arom. + Resins)	-	**0,24**	**0,17**	**0,09**
Penetration at 25°C	mm/10	**79**	**79**	**79**
Ring&Ball Softening Point	°C	48,4	45,6	44,4
Pfeiffer Penetration Index	-	-0,47	-1,28	-1,65
Fraass brittleness temperature	°C	-24	-19	-13
Dynamic viscosity at 140°C	mPa.s	335	274	245

NEW BITUMEN PERFORMANCE INDICATORS CONVENTIONAL TEST METHODS

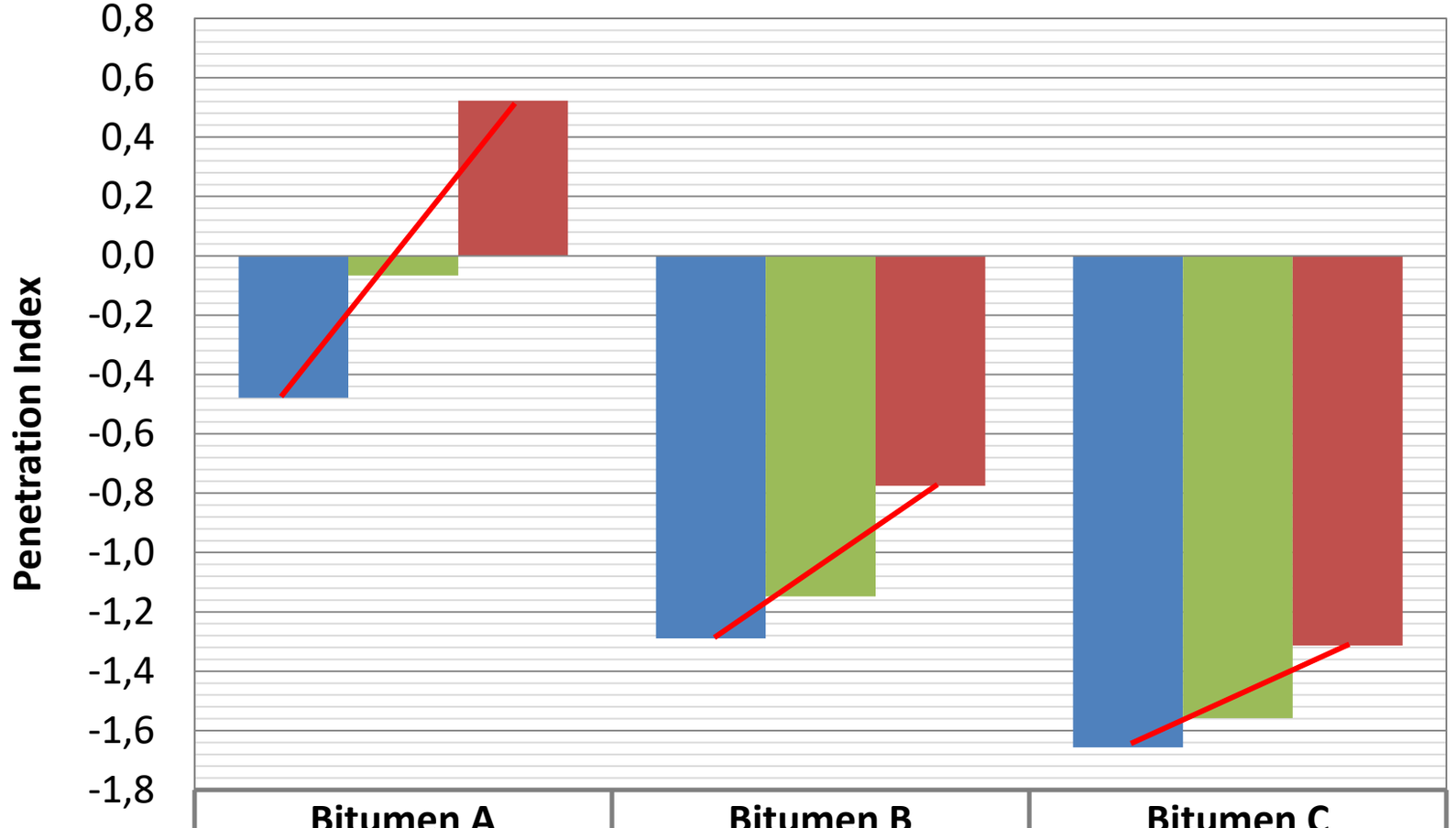
Penetration - Evolution with ageing



	Bitumen A	Bitumen B	Bitumen C
Fresh bitumen	79	79	79
After RTFOT	53	56	59
After RTFOT + PAV	36	35	38

NEW BITUMEN PERFORMANCE INDICATORS CONVENTIONAL TEST METHODS

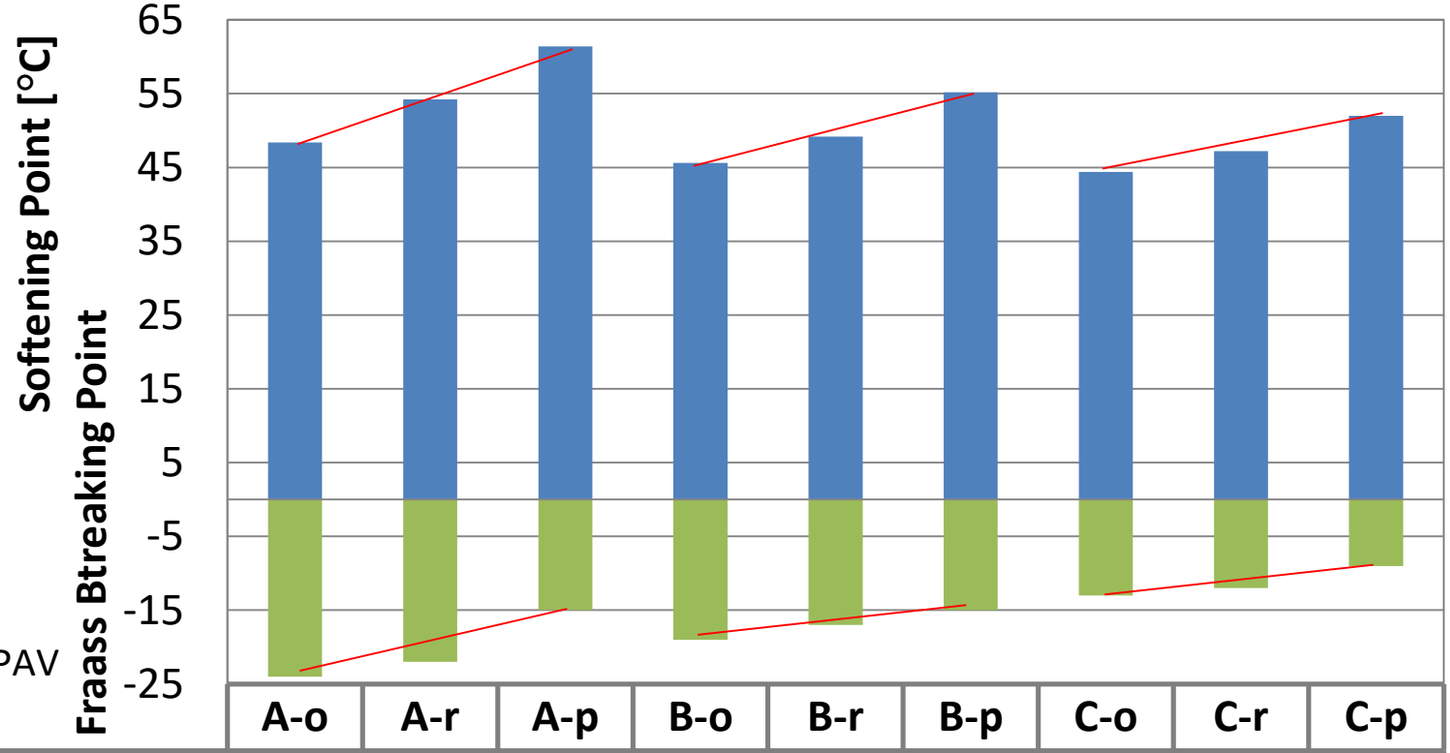
Penetration Index - Evolution with ageing



	Bitumen A	Bitumen B	Bitumen C
Fresh bitumen	-0,479	-1,289	-1,657
After RTFOT	-0,067	-1,148	-1,558
After RTFOT + PAV	0,523	-0,775	-1,313

NEW BITUMEN PERFORMANCE INDICATORS CONVENTIONAL TEST METHODS

Fraass Breaking Point and Softening Point - Evolution with ageing

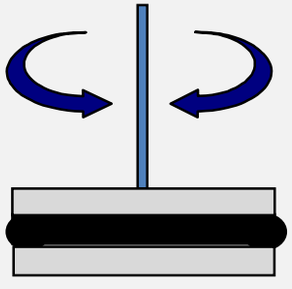


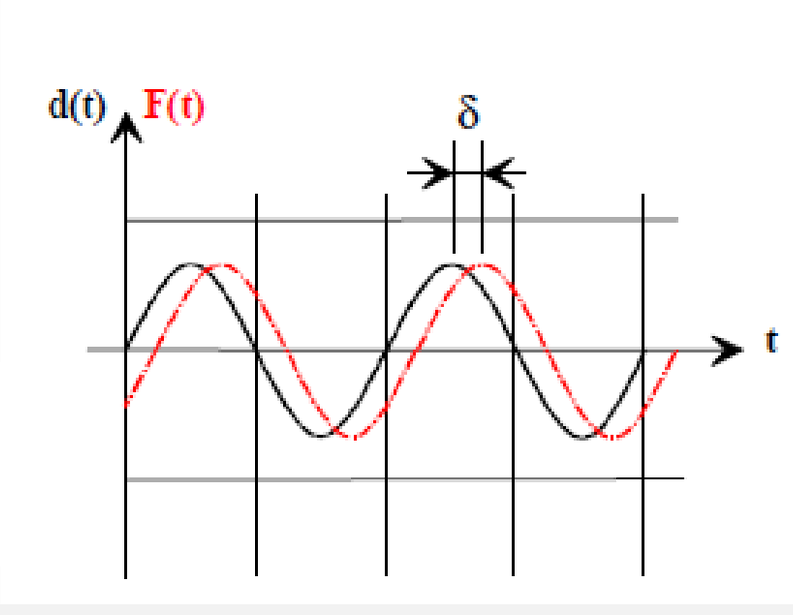
o = fresh
r = after RTFOT
p = after RTFOT + PAV

	A-o	A-r	A-p	B-o	B-r	B-p	C-o	C-r	C-p
Delta Softening Point [°C]	0	5,8	13	0	3,6	9,6	0	2,8	7,6
Delta Fraass [°C]	0	2	9	0	2	4	0	1	4
Softening Point [°C]	48,4	54,2	61,4	45,6	49,2	55,2	44,4	47,2	52,0
Fraass breaking point [°C]	-24	-22	-15	-19	-17	-15	-13	-12	-9

NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS

DSR (DYNAMIC SHEAR RHEOMETER)

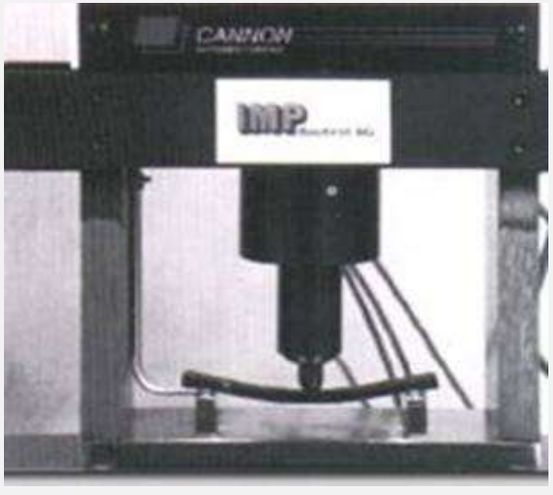


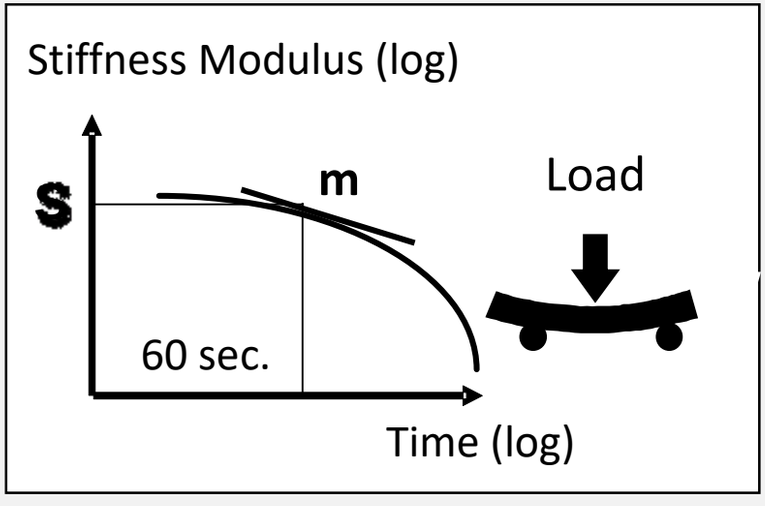


- Stiffness (G*) in relation to temperature and frequency
- Characterization of the visco-elastic nature of bitumen - Phase angle (δ) in relation to temperature and frequency
- Linear domain (small deformations) – Time/Temperature superposition principle

NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS

BBR (BENDING BEAM RHEOMETER)





- Creep stiffness under constant load at low temperatures

Two characteristics are usually considered:

- **S** = stiffness at a loading time of 60 s
- **m** = (-) slope of the creep curve at 60 s

NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS

THE SHRP PARAMETERS (PG GRADING)

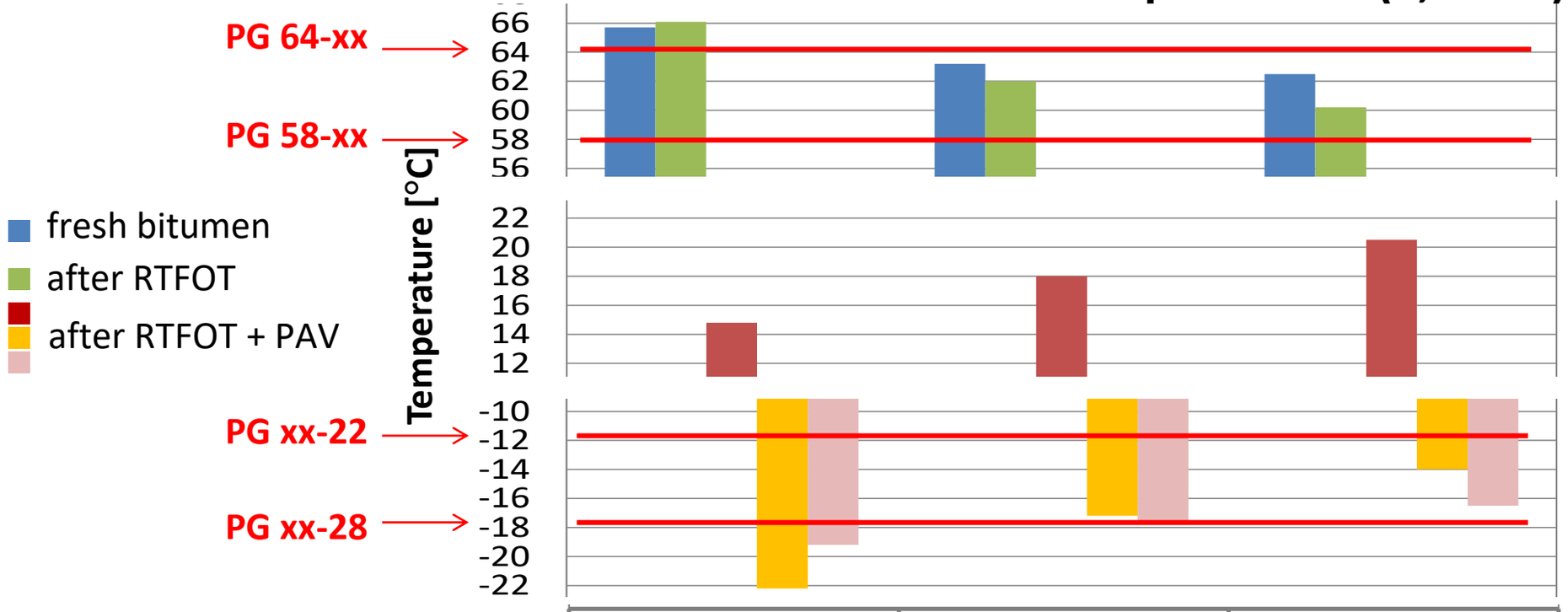
- At high service temperatures (test frequency of 1,59 Hz)
  - On original binder : Temp. at which $G^*/\sin\delta$ = 1.0 kPa
  - On RTFOT aged binder : Temp. at which $G^*/\sin\delta$ = 2,2 kPa

  These 2 temp. determine the high temp. PG grade
- At low temperatures on RTFOT + PAV aged binder
  - Temp. at which S = 300 Mpa
  - Temp. at which m = 0,3

  These 2 temp. determine the low temp. PG grade
- At an intermediate temp. on RTFOT + PAV aged binder
  - Temp. at which $G^*\sin\delta$ = 5 000 kPa (1,59 Hz)
  - Verification against fatigue cracking (?)

NEW BITUMEN PERFORMANCE INDICATORS
SUPERPAVE PARAMETERS

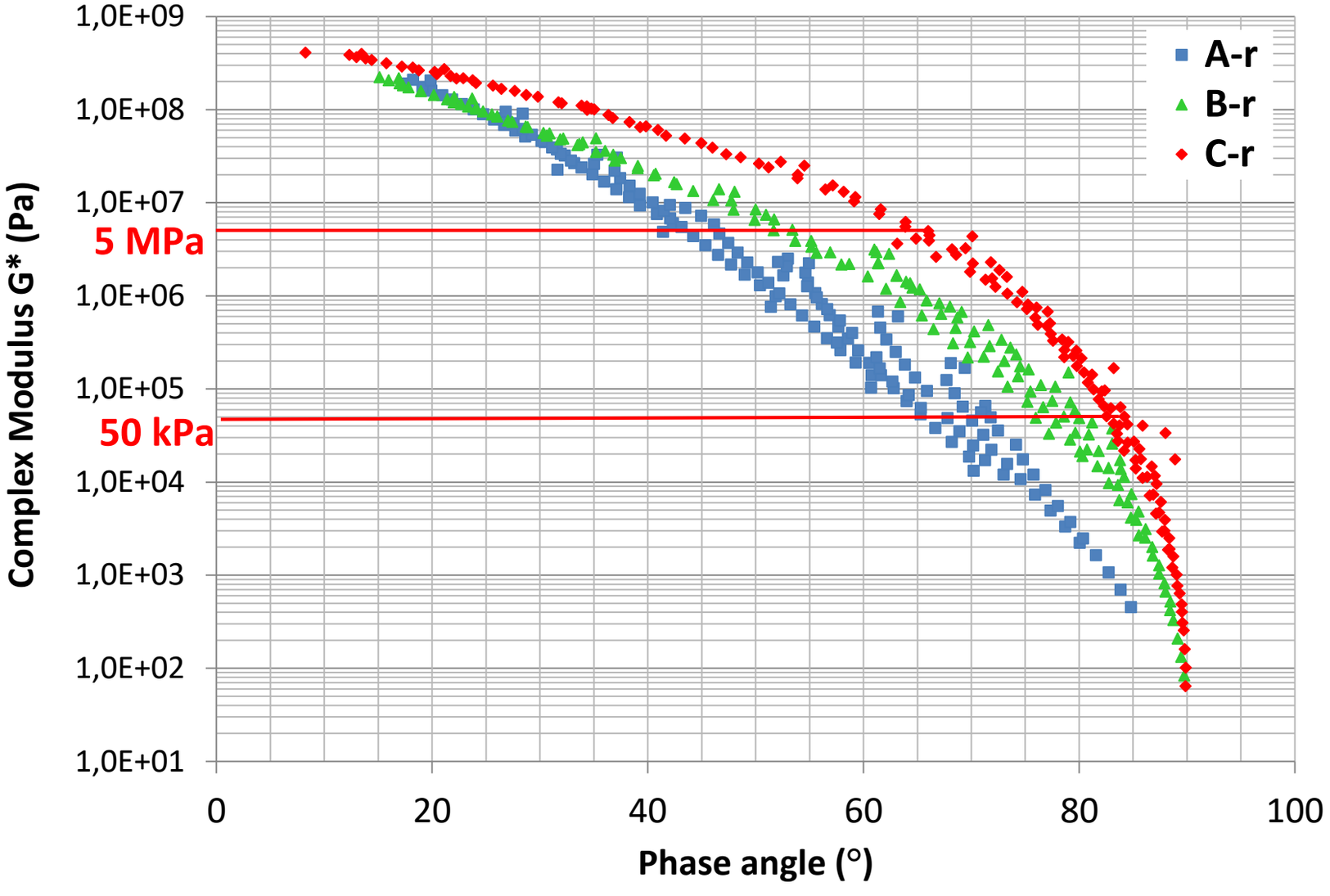
DSR data - SHRP PG temperatures (1,59 Hz)



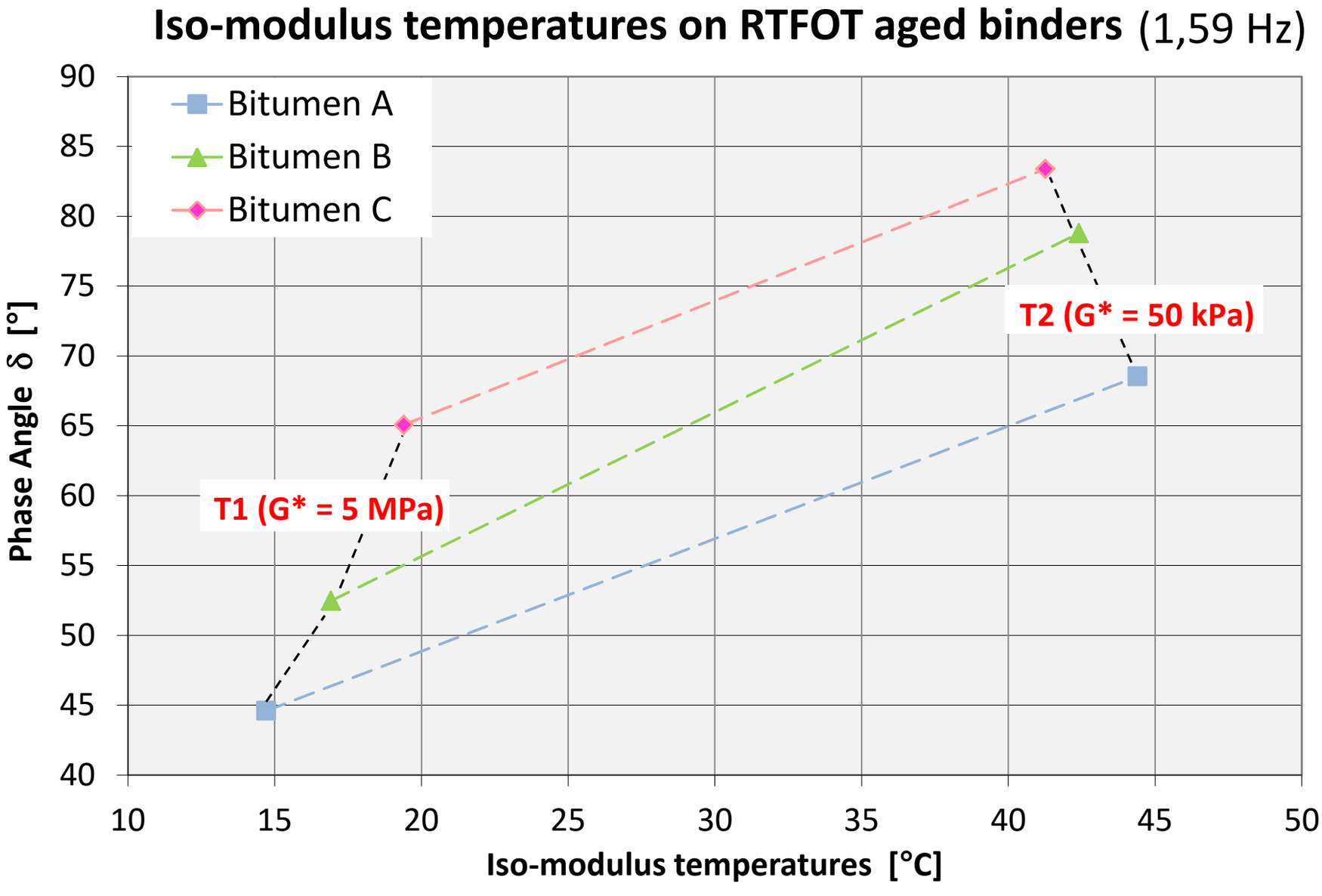
	Bitumen A	Bitumen B	Bitumen C
T @ G*/sinδ = 1.0 kPa [°C]	65,7	63,2	62,5
T @ G*/sinδ = 2.2 kPa [°C]	66,1	62,0	60,2
T @ G*·sinδ = 5000 kPa [°C]	14,8	18,0	20,5
T @ S = 300 MPa	-22,2	-17,2	-14,0
T @ m = 0,3	-19,2	-17,6	-16,5

NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS - DSR

DSR data - Black diagram after RTFOT

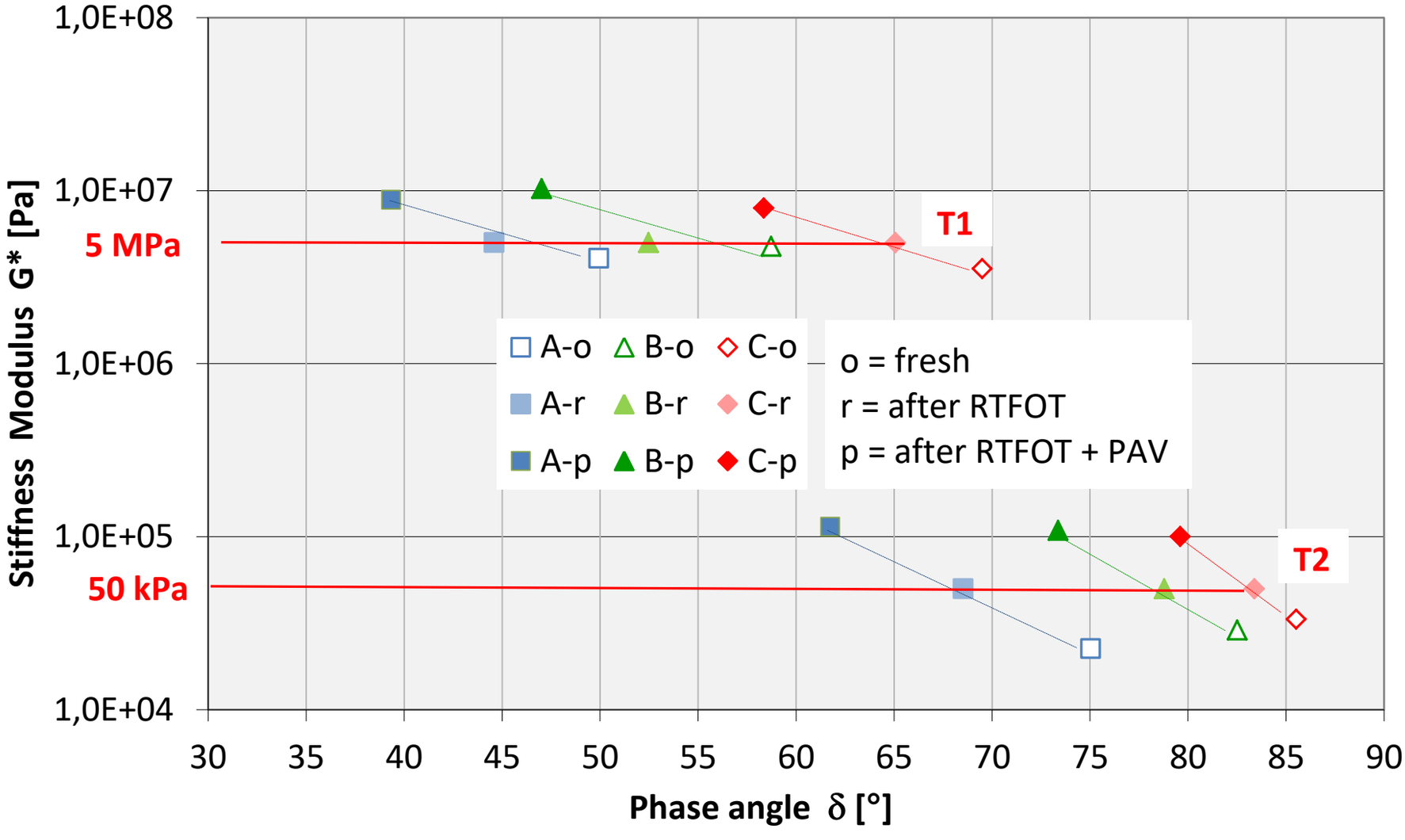


NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS - DSR



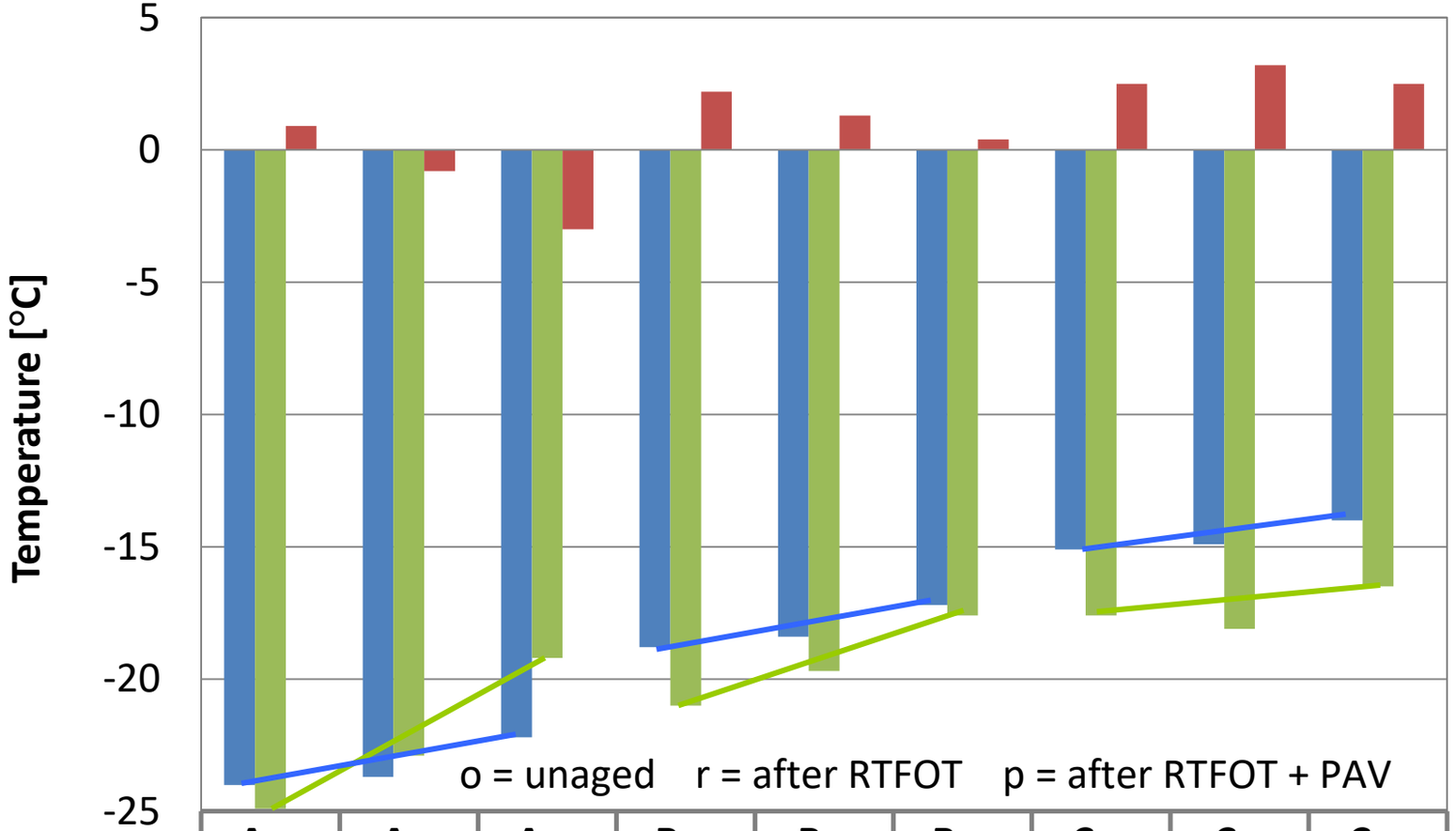
NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS - DSR

Evolution of G* and δ with ageing at T1 and T2 (1,59 Hz)



NEW BITUMEN PERFORMANCE INDICATORS « RHEOLOGICAL » TESTS - BBR

BBR Critical Temperatures - Evolution with ageing



	A-o	A-r	A-p	B-o	B-r	B-p	C-o	C-r	C-p
T @ S = 300 MPa [°C]	-24,0	-23,7	-22,2	-18,8	-18,4	-17,2	-15,1	-14,9	-14,0
T @ m = 0.300 [°C]	-24,9	-22,9	-19,2	-21,0	-19,7	-17,6	-17,6	-18,1	-16,5
TS - Tm [°C]	0,9	-0,8	-3	2,2	1,3	0,4	2,5	3,2	2,5

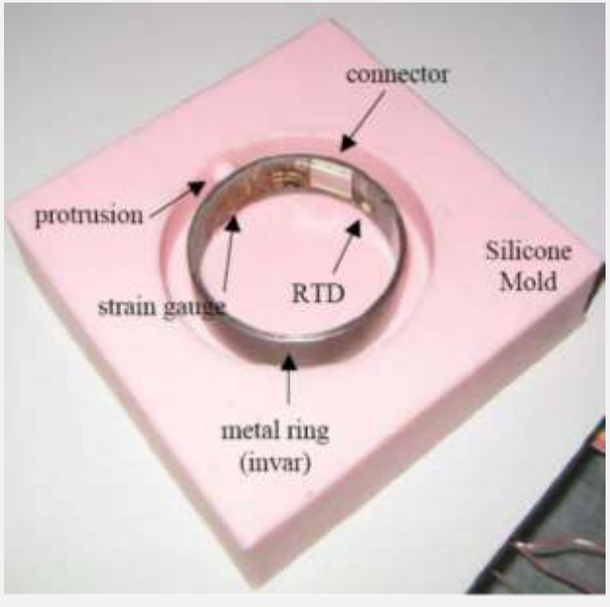
NEW BITUMEN PERFORMANCE INDICATORS FIRST SUMMARY

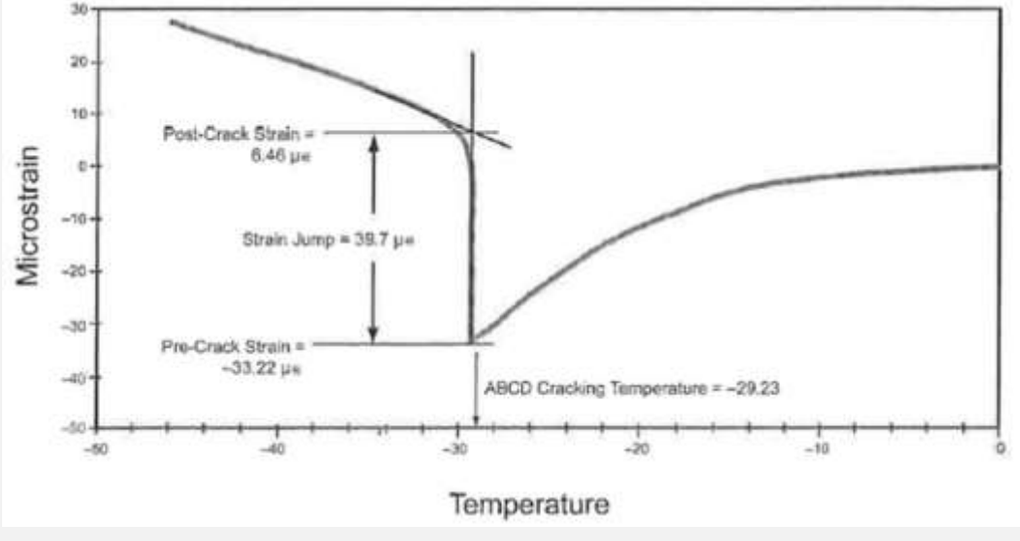
- **CONVENTIONAL TESTS**
  - Soft. Point, Pen. Index and Fraass are sensitive to bitumen structure
  - Except for Penetration, the same applies for the evolution with ageing (more pronounced for the more structured bitumen)

- **« RHEOLOGICAL » TESTS**
  - SUPERPAVE parameters provide a good insight
  - Iso-modulus temperatures at 5 MPa and 50 kPa, and even more so the associated values of δ, do well differentiate
  - But the evolutions with ageing at the iso-modulus temp. do not seem to be strongly affected by bitumen structure
  - $T_{S=300MPa}$ and $T_{m=0,3}$ are sensitive to bitumen structure but different evolutions with ageing are only shown by the $T_{m=0,3}$ value

NEW BITUMEN PERFORMANCE INDICATORS
THE «ABCD» LOW TEMP. FAILURE TEST

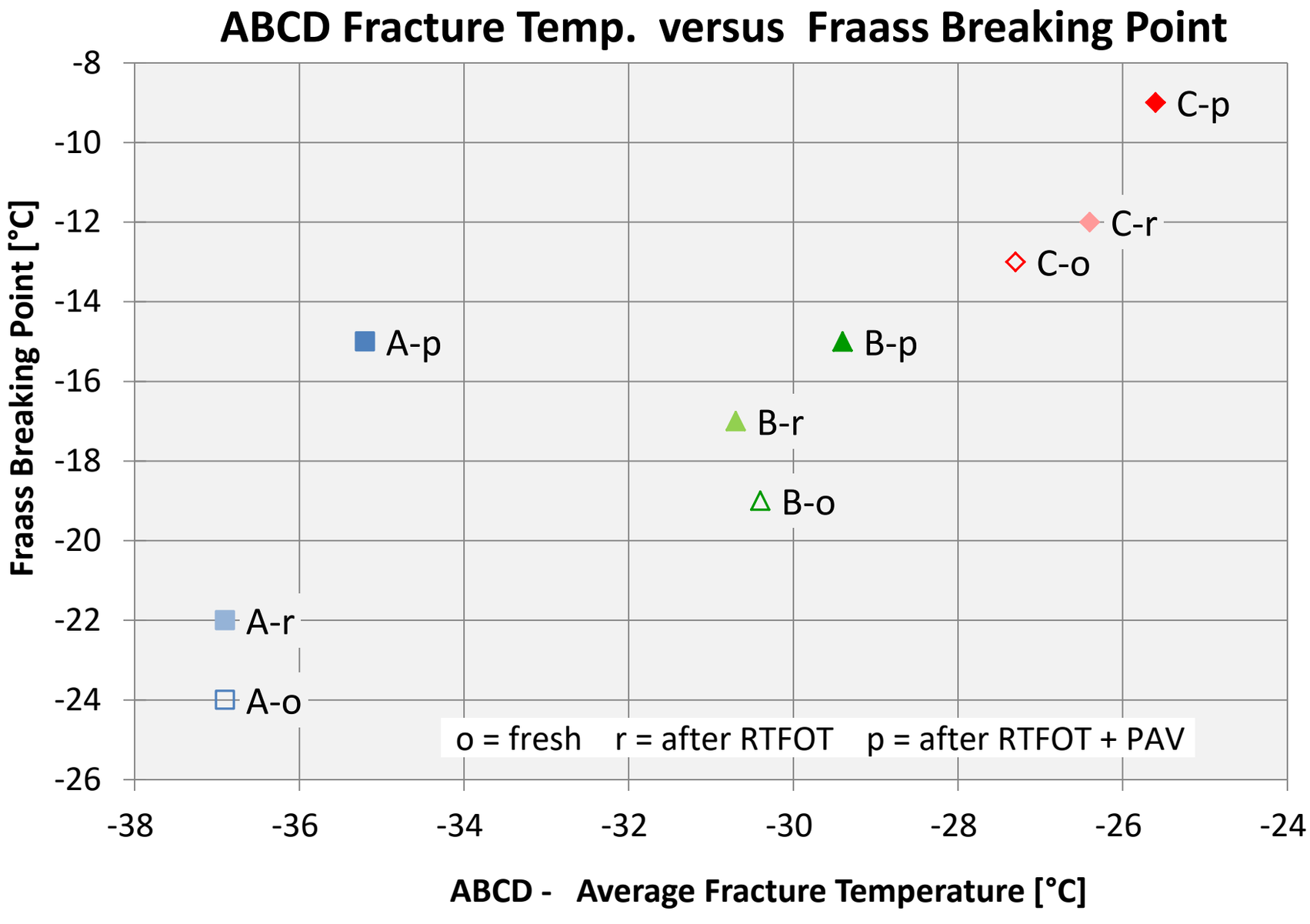
- **ABCD (ASPHALT BINDER CRACKING DEVICE)** (AASHTO TP92-11)



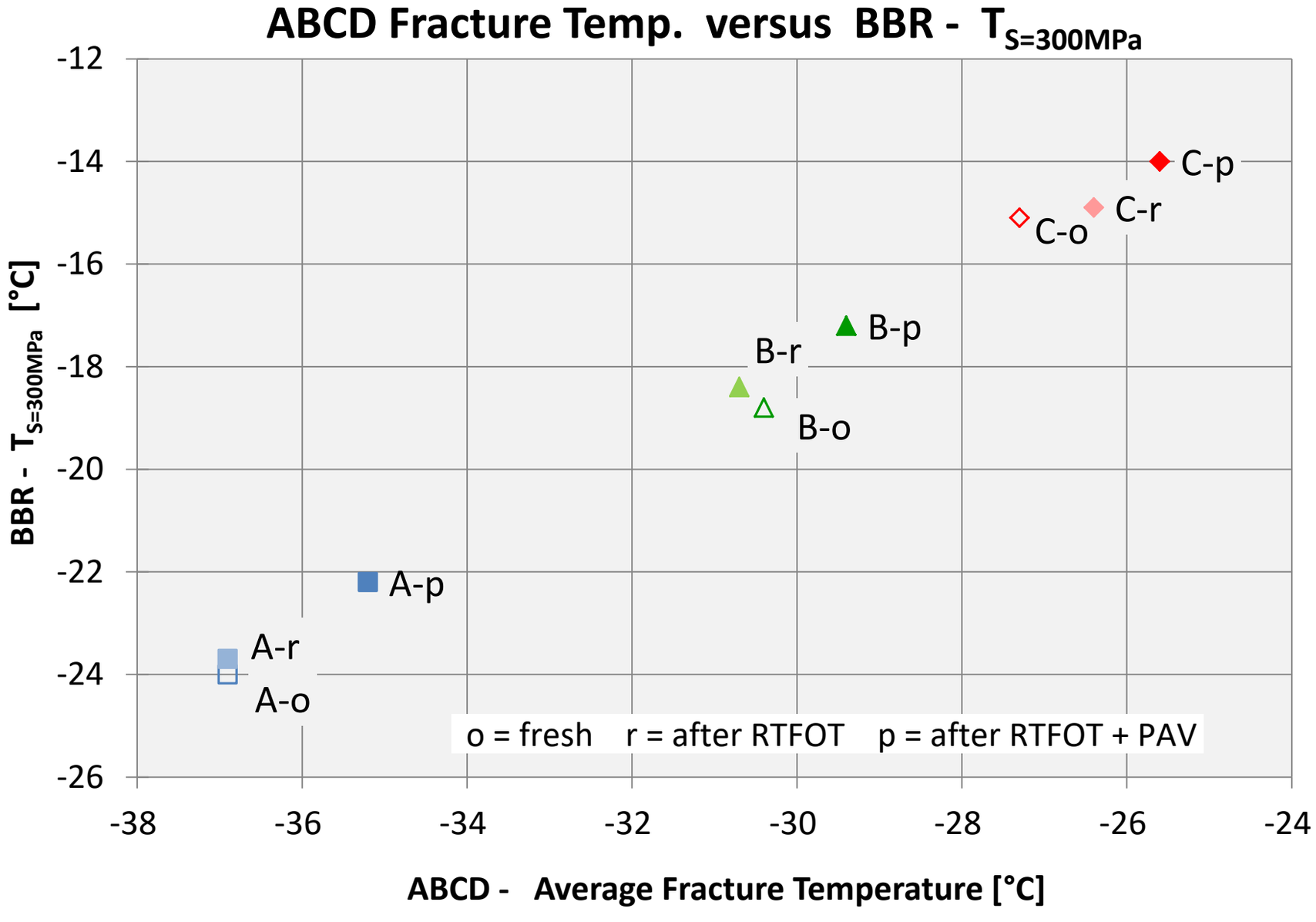


- Contraction of a bitumen ring is restricted by an Invar steel ring
- Cooling rate of 10°C/hr starting at +5°C

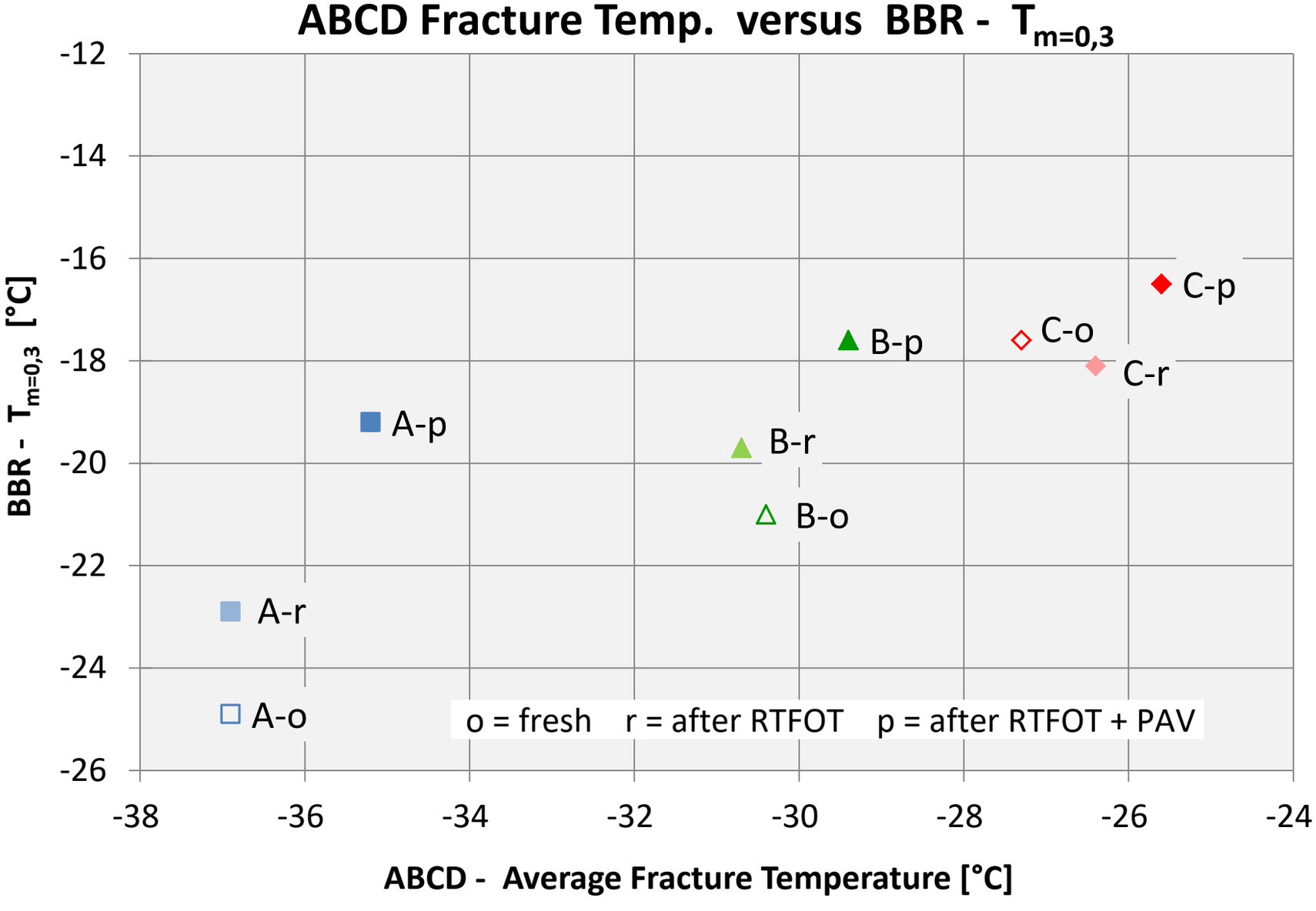
NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS



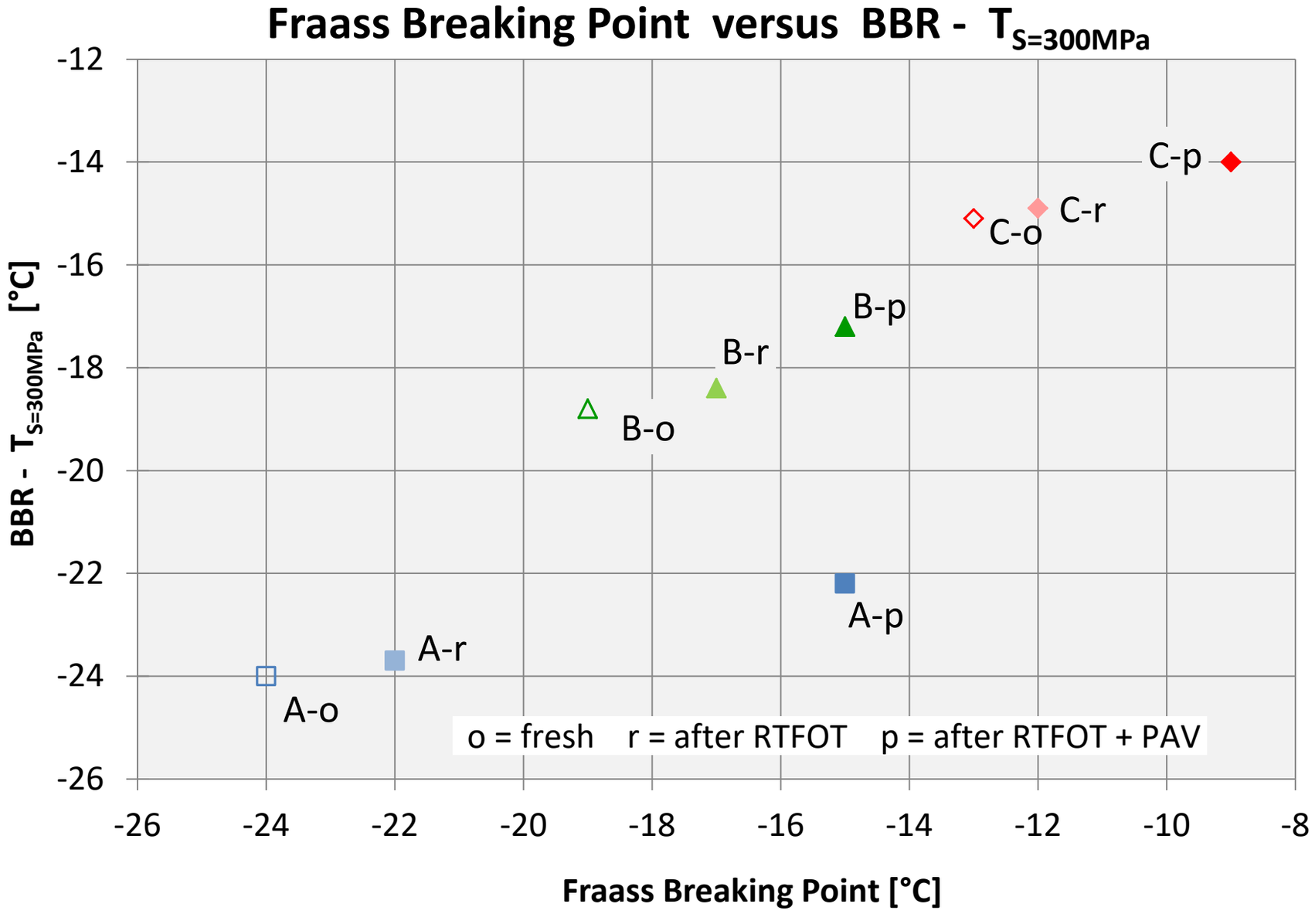
NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS



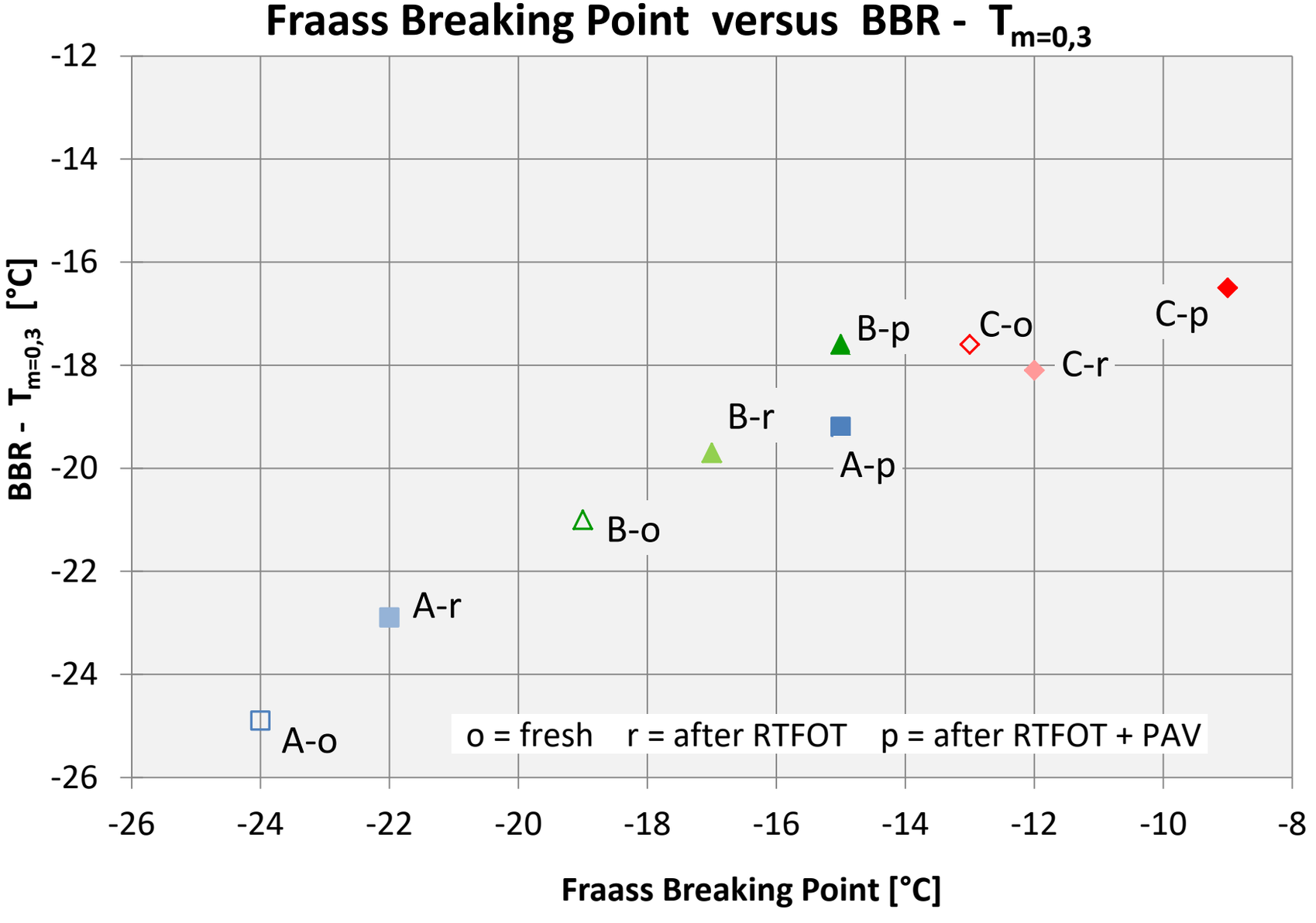
NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS



NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS



NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS



NEW BITUMEN PERFORMANCE INDICATORS
LOW TEMP. FAILURE TESTS

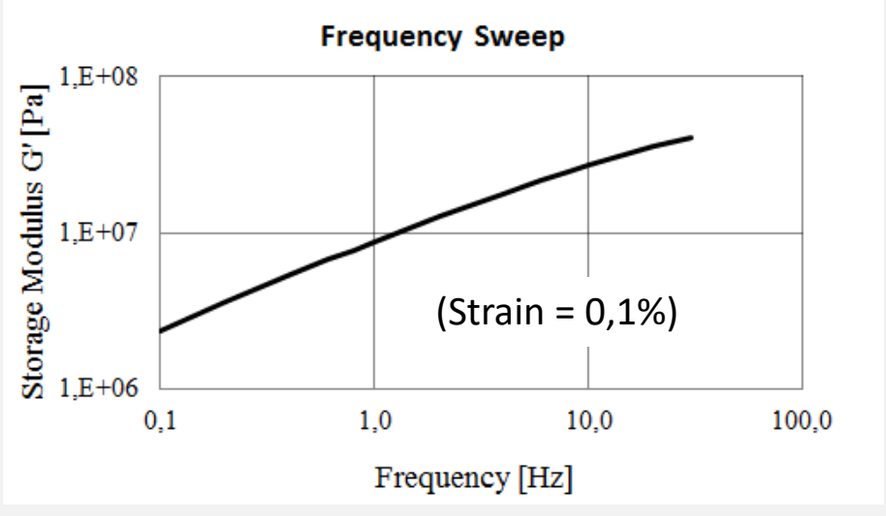
- **ABCD VS FRAASS BREAKING POINT**
  - ABCD test differentiates well the 3 bitumen but does not show large evolutions with ageing
  - ABCD fracture temp. are significantly lower than Fraass values
  - ABCD test (cooling rate of 10°C/h) much less severe than Fraass procedure (repeated flexions at a cooling rate of 1°C/min)

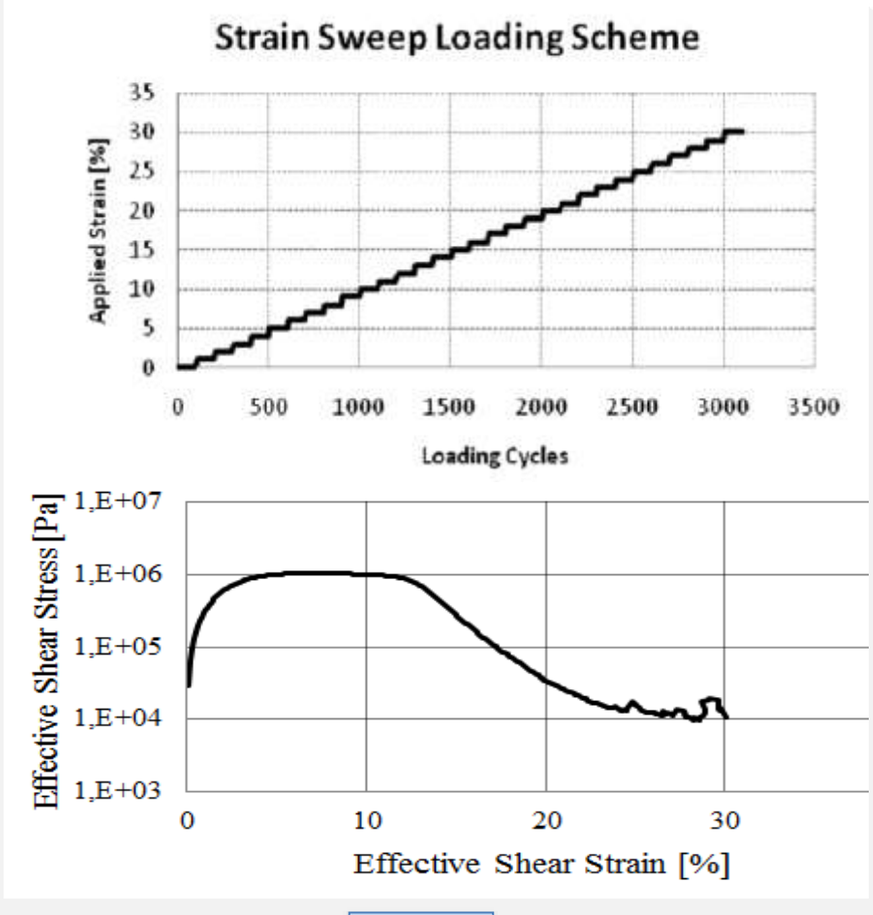
- **CORRELATION TO BBR CRITICAL TEMPERATURES**
  - ABCD test is primarely impacted by stiffness (good correlation with $T_{S=300MPa}$) rather than by relaxation ability (correlation with $T_{m=0,3}$ is less good)
  - Relaxation ability seems to have a stronger impact on the Fraass breaking point (good correlation with $T_{m=0,3}$)

NEW BITUMEN PERFORMANCE INDICATORS
DSR – INCREASING LEVELS OF STRAIN

- **LAS (LINEAR AMPLITUDE SWEEP)** (AASHTO TP101-12-UL)
  - Proposed by the University of Wisconsin as a potential predictor for resistance to fatigue
  - Results of DSR frequency and strain sweeps are interpreted via viscoelastic continuum damage (VECD) theory to calculate a theoretical fatigue line.
  - Tests to be run at a sufficiently low temperature (sufficiently high stiffness) to eliminate flow behaviour
  - A stiffness level of 30 MPa at 10 Hz has been adopted
  - Comparisons have been done under iso-modulus conditions

NEW BITUMEN PERFORMANCE INDICATORS
DSR – THE LAS PROCEDURE





Slope

B

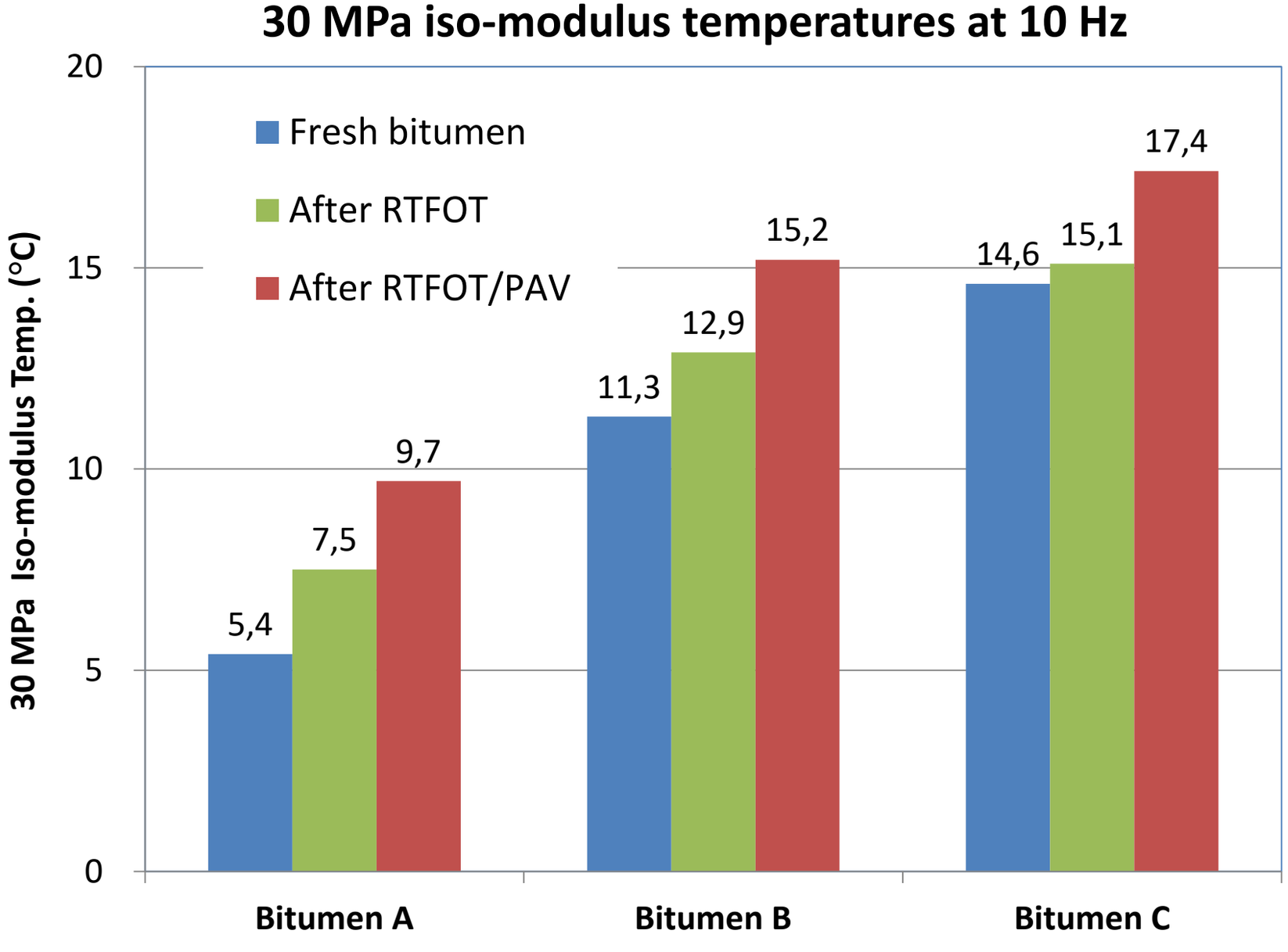
$$N_f = A \cdot (\varepsilon)^B$$

VECD

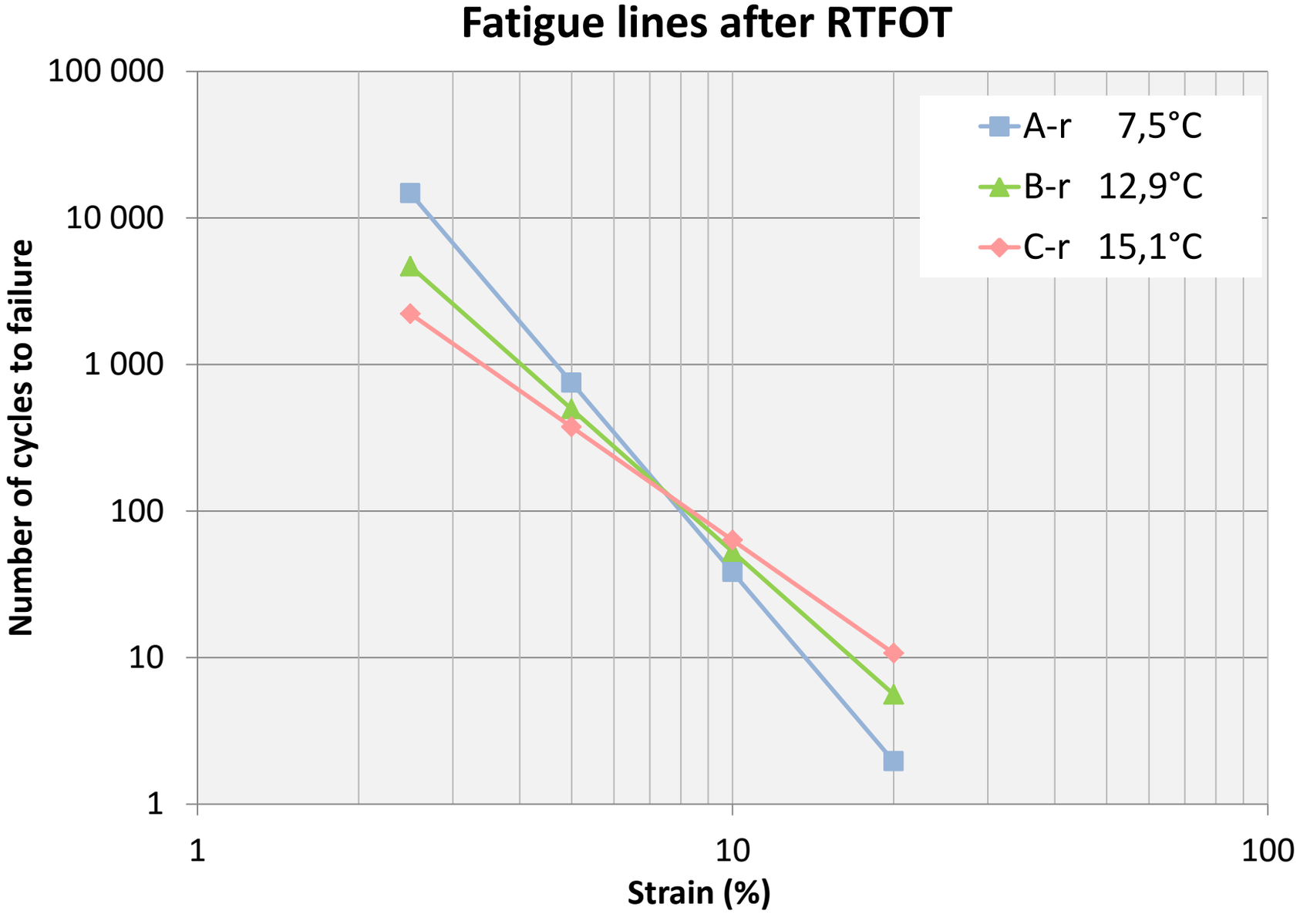
A

After H. Tabatabaee / H. Bahia / C. Hintz, Univ. of Wisconsin

NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST

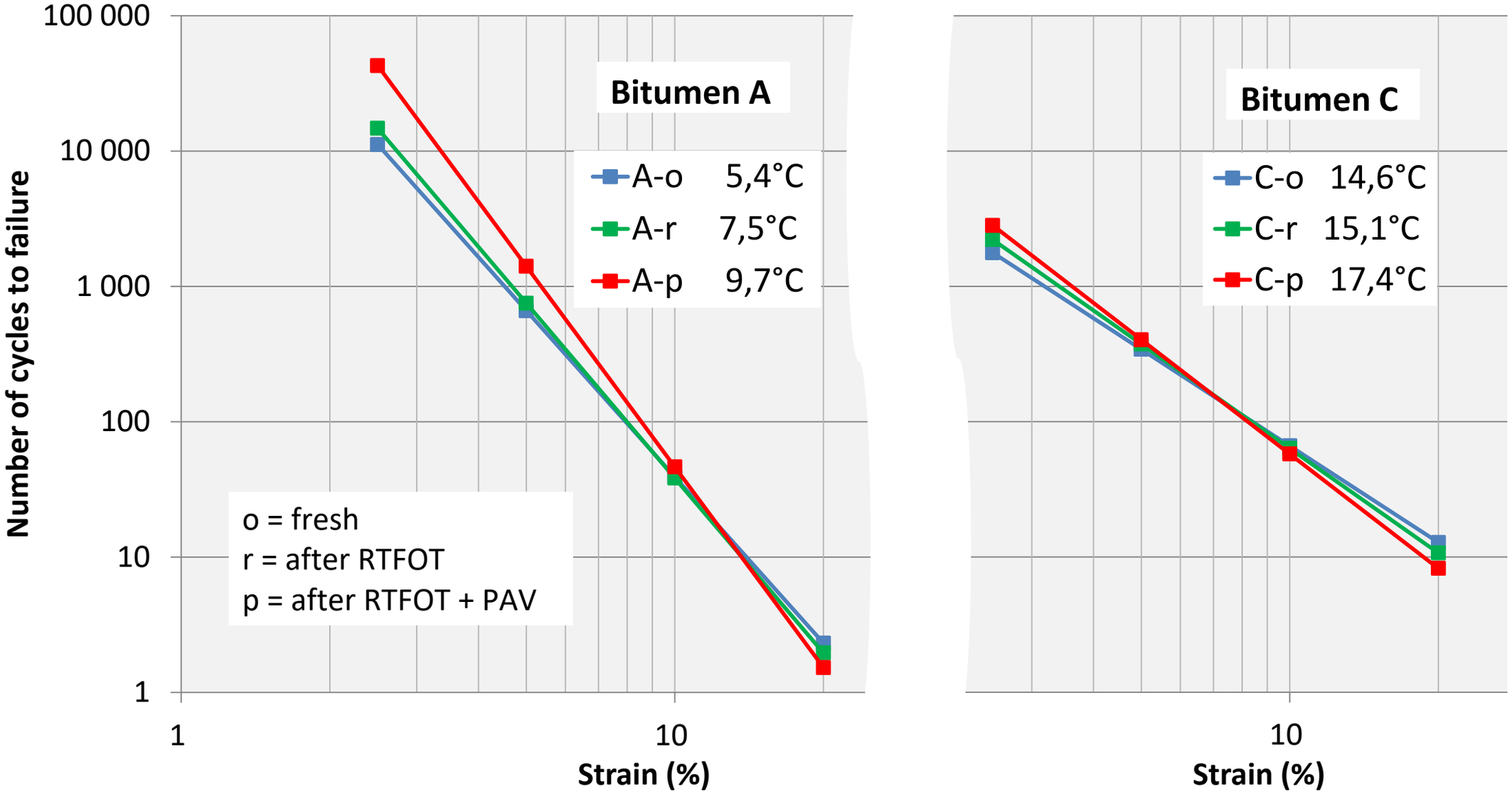


NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST



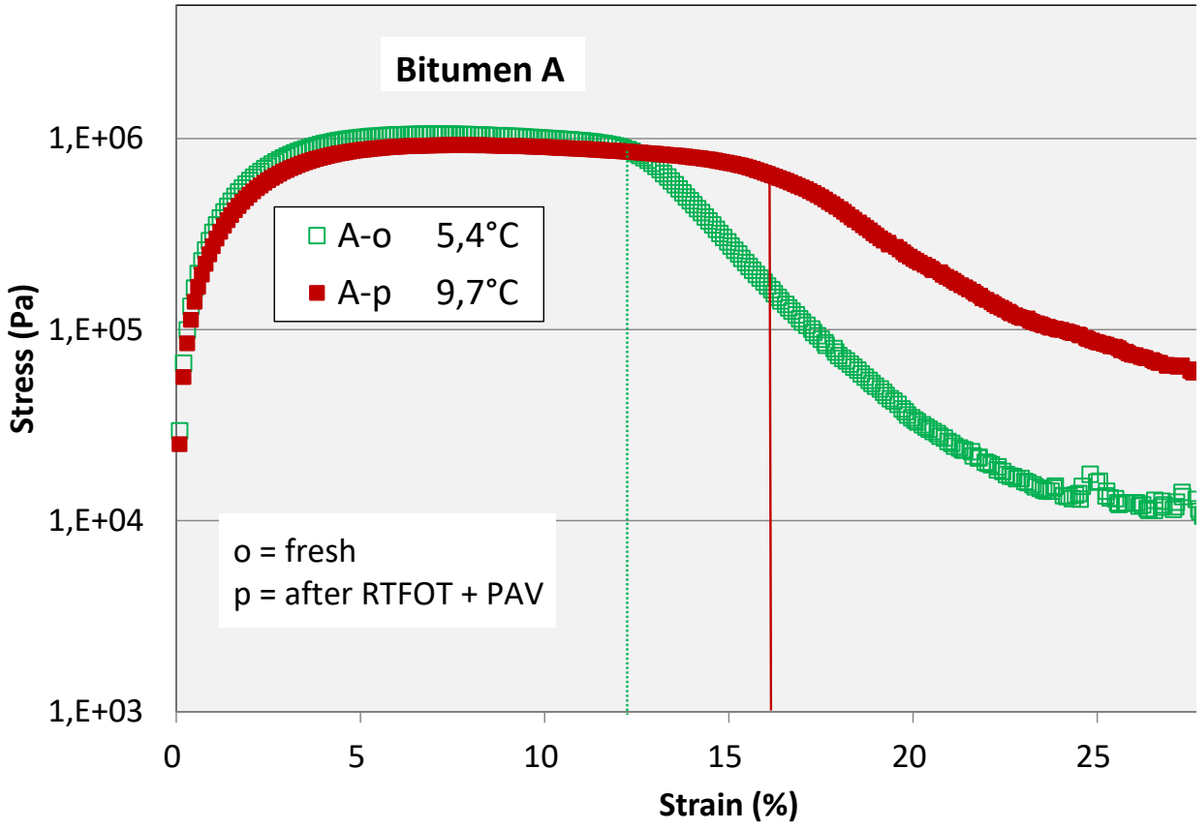
NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST

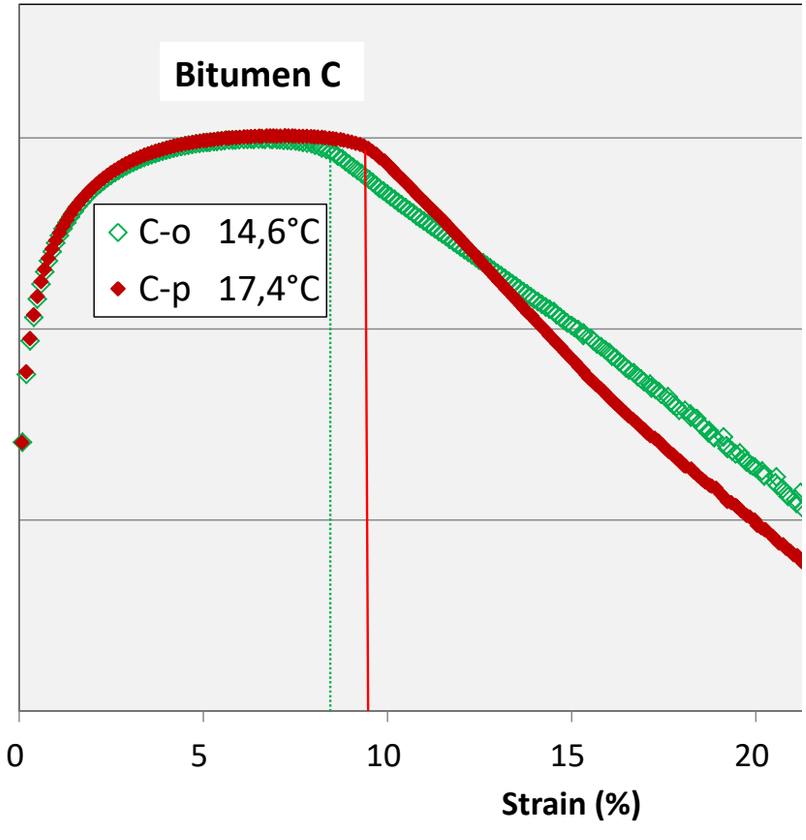
Evolution with ageing



NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST

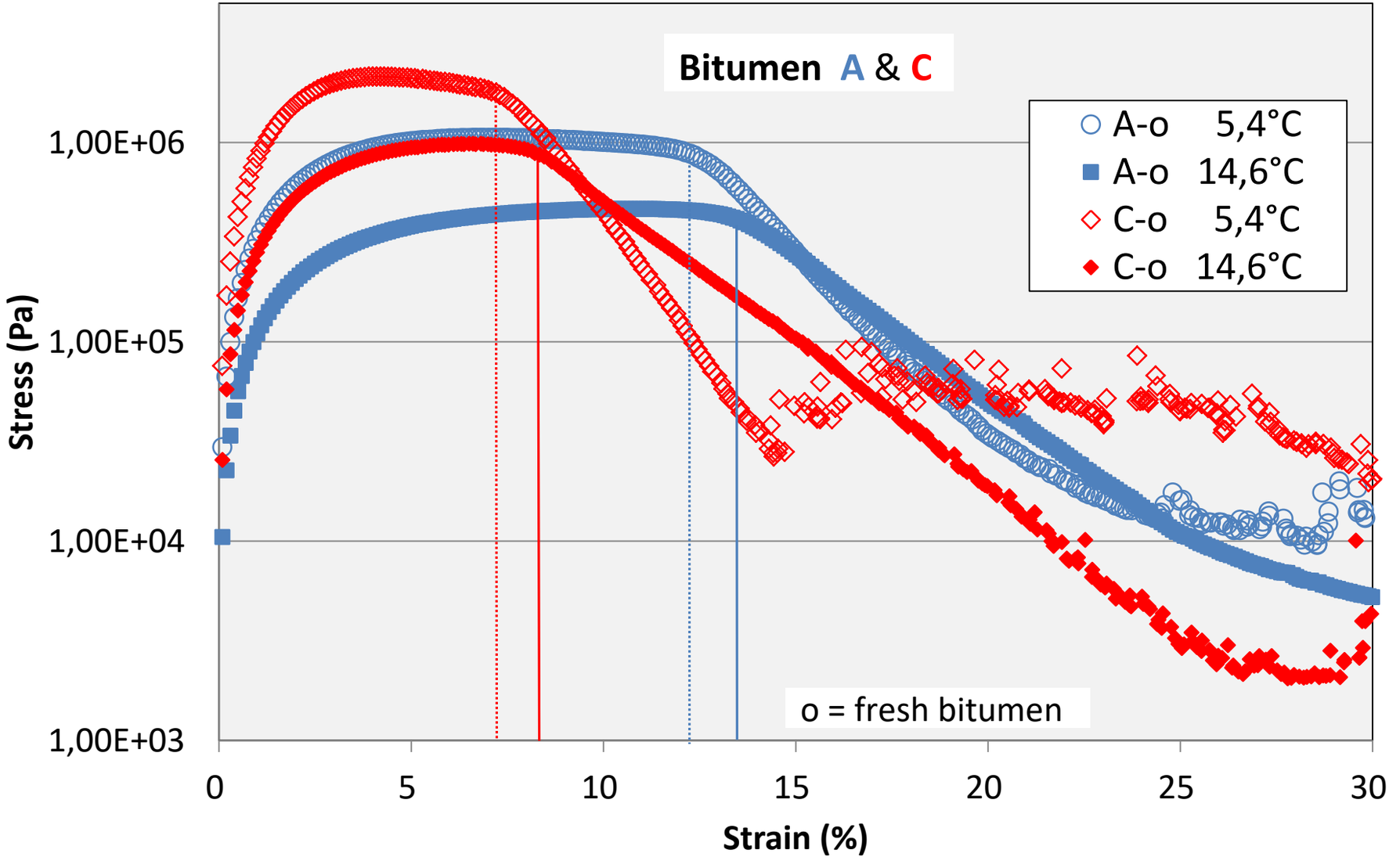
Impact of ageing on the evolution of stress





NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST

Impact of temperature on the evolution of stress



NEW BITUMEN PERFORMANCE INDICATORS
DSR –LAS TEST

- **MAIN OBSERVATIONS**
  - LAS «fatigue lines» show some differences depending on bitumen type (steeper for the most structured bitumen)
  - But they are not very much impacted by ageing (except for A)
- **THIS IS HOWEVER AN « INTRINSIC » BEHAVIOUR**
  - We have been working under **iso-modulus** conditions
  - Most of the differences between binders, as well as the evolution with ageing, have been « captured » by the iso-modulus temperatures (which are significantly different)
- **TO BE CONTINUED**
  - Evolution of stress/strain curves in relation to temperature

NEW BITUMEN PERFORMANCE INDICATORS CONCLUSIONS

- ✓ Conventional tests are still valuable tools for the evaluation of bitumen
- ✓ «Rheological» tests offer the advantage of measuring fundamental properties and should therefore be privileged
- ✓ But bitumen response is highly dependent on the applied loading conditions
- ✓ The real significance of a given Performance Indicator is therefore strongly related to what it actually measures
  - G* and δ : description of visco-elastic behaviour under small strains
  - LAS test : evolution of stress with increasing levels of strain
  - $T_{S=300MPa}$: stiffness, $T_{m=0,3}$: ability to relax stress
- ✓ This needs to be kept in mind when selecting a bitumen for a given end-use

NEW BITUMEN PERFORMANCE INDICATORS
ACKNOWLEDGEMENTS

MANY THANKS TO MY CO-AUTHORS AND THEIR LABORATORY STAFF

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DSR and BBR rheology

Michael Farrar, Jean-Pascal Planche
ABCD and LAS tests

Ref. 6th Eurasphalt & Eurobitume Congress, Prague, 1-3 June 2016, paper # 97

THANK YOU FOR YOUR ATTENTION