

*RILEM inter-laboratory test on
binder rheology test methods
DSR and BBR.*

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*RILEM Technical Committee 182
PEB „Performance Testing and
Evaluation of Bituminous Materials”*

RILEM TC 182 RR Test

- *RILEM Technical Committee 182 PEB
„Performance Testing and Evaluation of
Bituminous Materials”*
- *1993 - 1st Round Robin Test on Binder’s
Rheology*
- *1998 - 2nd Round Robin Test on Binder’s
Rheology*

Objectives

- Evaluation of BBR- and DSR-test procedure
- Determination of repeatability and reproducibility
- Improvement of test procedures for standardization

Binders

- Pure bitumen
- SBS low modified binder
- SBS high modified binder
- EVA modified binder

Testing program

		BBR	DSR
Phase I	original binder	X	X
Phase II	after RTFOT	X	X
	after RTFOT and PAV	X	X

Contributing laboratories

	Laboratory	DSR	BBR	RTFOT	PAV
A1	Univ. Vienna	•	•	•	•
B1	BRRC	•	•	•	•
B2	Fina Research	•	•	•	•
CH1	EMPA	•	•	•	•
E1	CEDEX	•	•	•	•
E2	REPSOL	•	•	•	•
E3	Centro de Investigacion Elpidio Sanchez Marcos	•	•	•	•
F1	Esso Asphalt Research Laboratories	•	•	•	•
F2	ELF	•	•	•	•
F3	LCPC	• • •	•	•	•
GB1	SWK Pavement Engineering	•		•	•
H1	AKMI (Veszprem)	•	•	•	•
NL1	DWW	•		•	•
S1	Royal Institute of Technology	•	•	•	•
S2	NYNAS	•	•	•	•
US1	U.W. Madison	•	•	•	•

Overview of test methods and testing conditions

- Handling procedure for binders, emphasis on:
 - temperatures for reheating
 - homogenisation
 - sampling
- Ageing procedures:
 - RTFOT-ageing according to EN12607-1
 - PAV-ageing according to AASHTO-standard at 100°C

Overview of test methods and testing conditions

■ BBR

- Testing procedure for calibration and testing: draft ASTM
- 3 temperatures per binder
- 3 repetitions per temperature

Overview of test methods and testing conditions

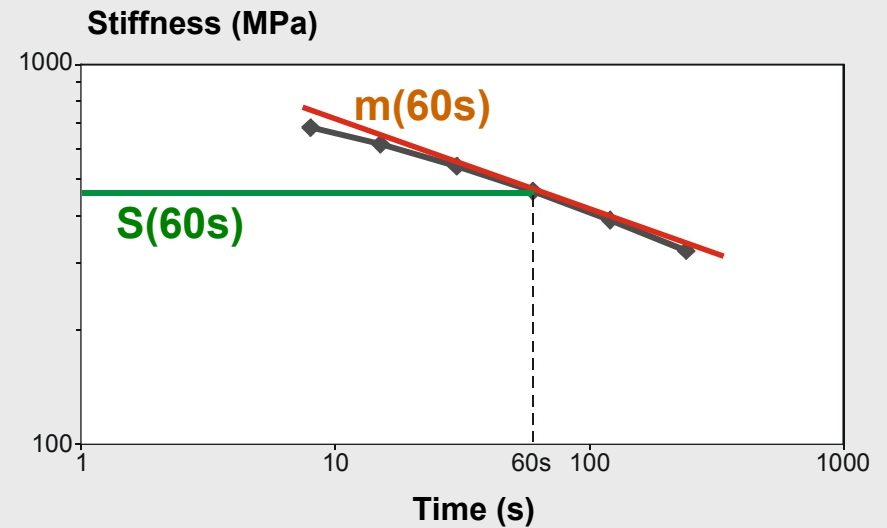
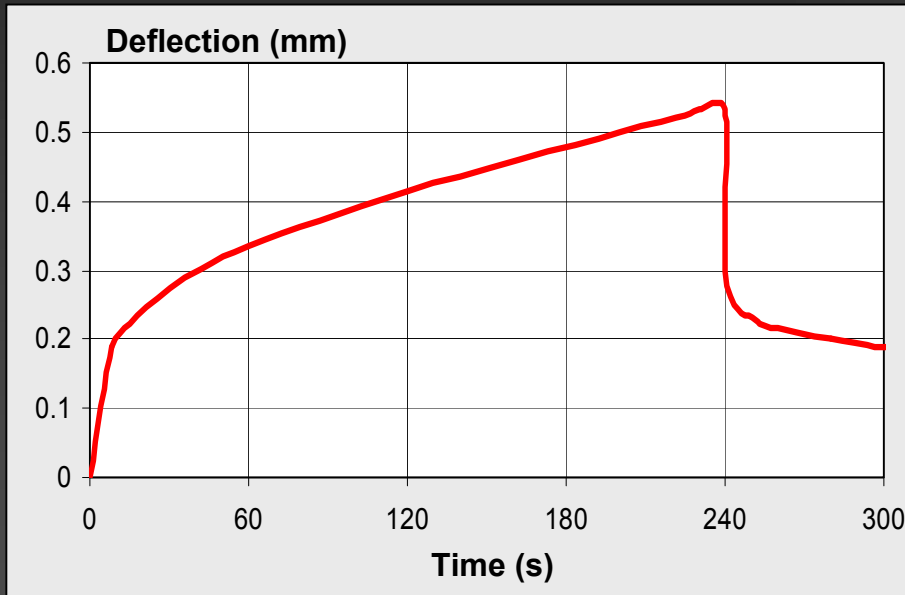
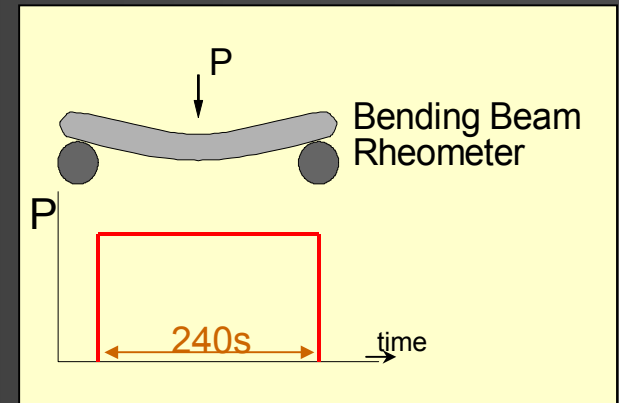
■ Dynamic Rheometers

- measurements of G^* and δ
- temperature: (- 24, -18, -12, -6, 2,) 10, 16, 22, 28, 34, 40, 46, 52, 58, 64, 70, 76°C
- frequency: 0.1, 1.6, 5, 10, 20, 50 Hz
- 3 repetitions for one chosen binders
 - Phase I: b1 pure bitumen
 - Phase II: b4 EVA modified bitumen
- 1 measurement on others
- Test procedure for DSR (parallel plates): AASHTO TP5

Overview of test methods and testing conditions

- Ring & Ball Softening Point temperature determination according to EN 1427:
 - before RTFOT
 - after RTFOT
 - after RTFOT + PAV

BBR-results: principle

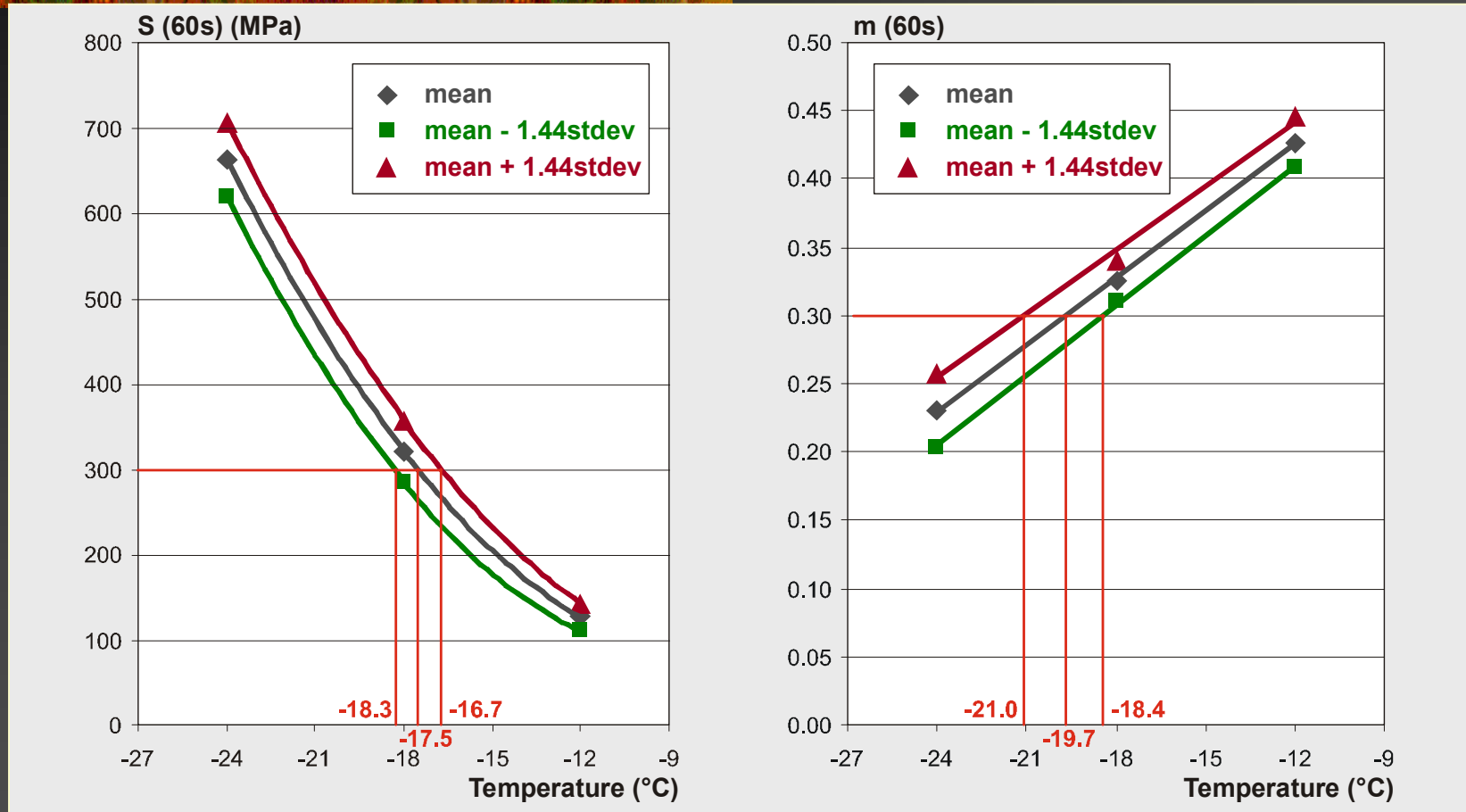


BBR Precision

(after elimination of outliers)

- Mean values of Coefficient of Variation for all temperatures
- All binders, original, RFTO or RTFO+PAV aged
- Repeatability
 - S(60) 2 – 3%
 - m(60) 1 – 2%
- Reproducibility
 - S(60) 5%
 - m(60) 3 – 5%

BBR Determination of SHRP PG (3 measurements per temperature)

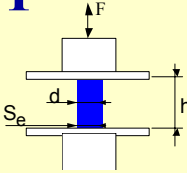
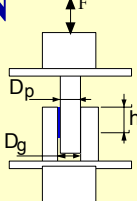
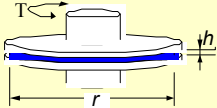
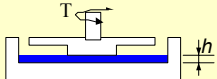
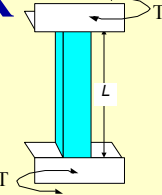


*Precision on critical temperatures according to SHRP: about 1°C
→ better than one PG-class*

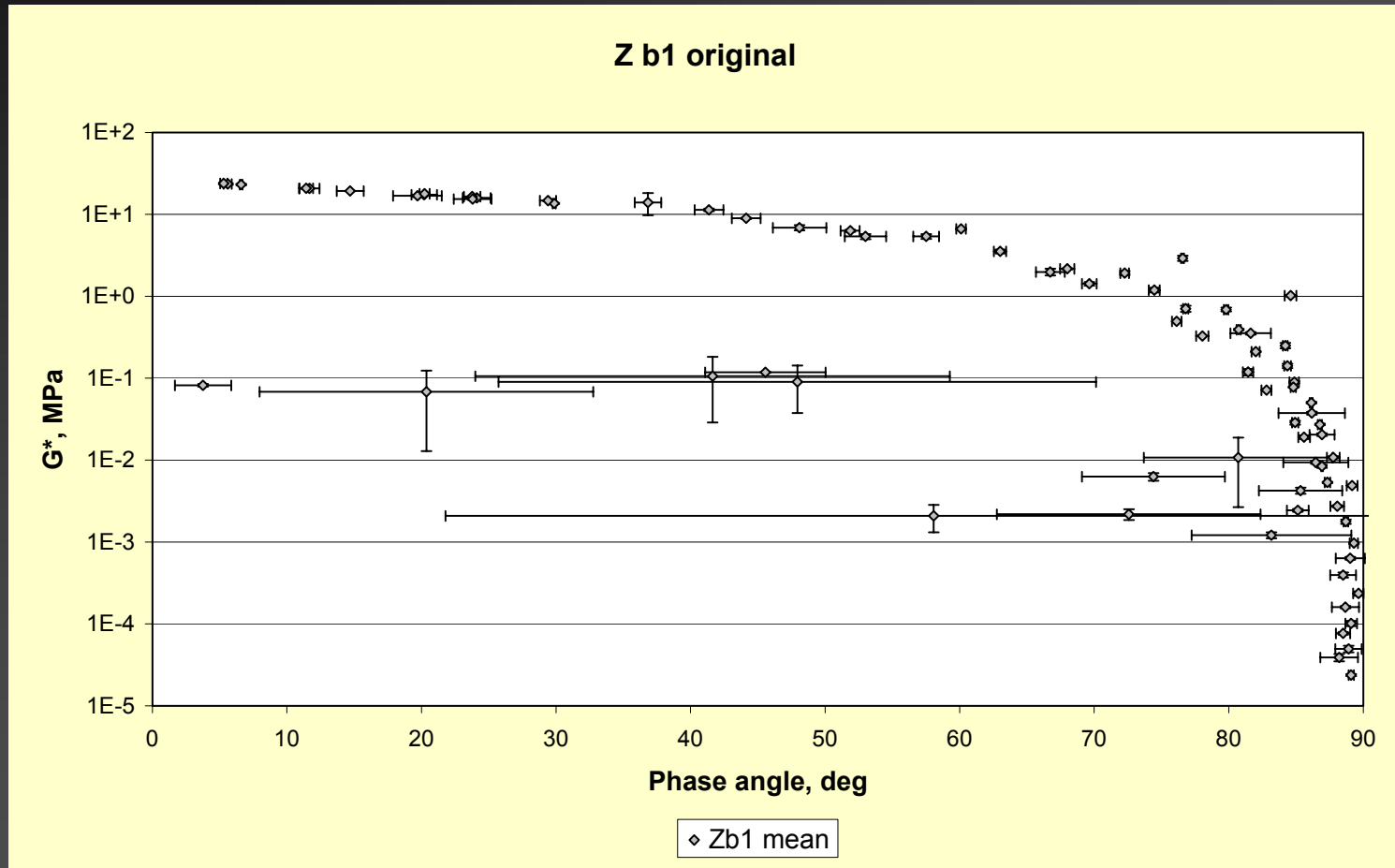


DSR-results

Overview of Dynamic Rheometers

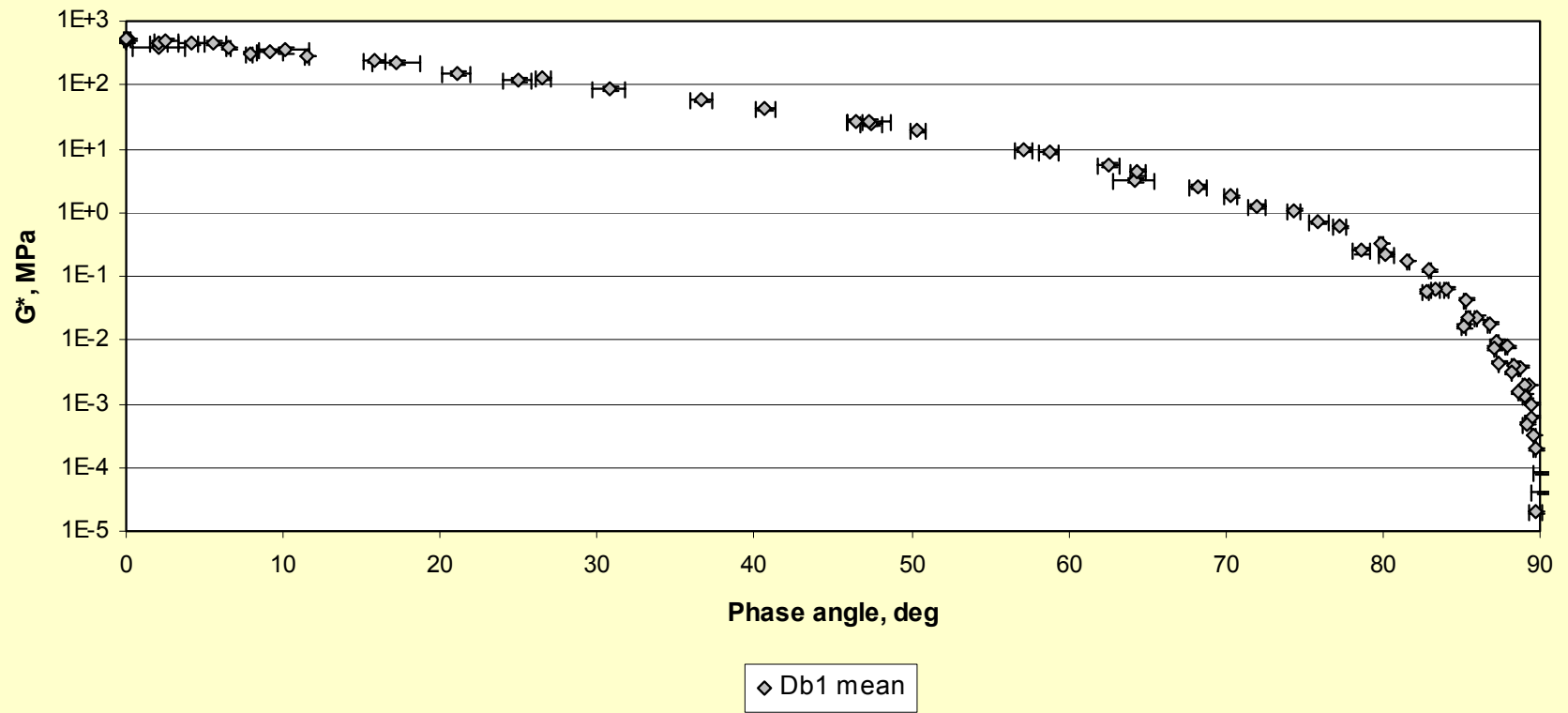
Test geometry	Type of loading	No. of labs
L-TC-CY 	LINEAR Tension - Compression	2
L-SH-AN 	LINEAR Annular Shear	2
R-SH-PP 	Rotational Shear Parallel Plates	15
R-SH-CP 	Rotational Shear Cup & Plate	1
R-TO-PR 	Torsional Shear	1

Black curve



Black curve

D b1 original



Dynamic Rheometers

Reproducibility

- Analysis of two sets of results:
 - all types of equipments/geometries
 - DSR-geometries according to recommendations of AASHTO TP5

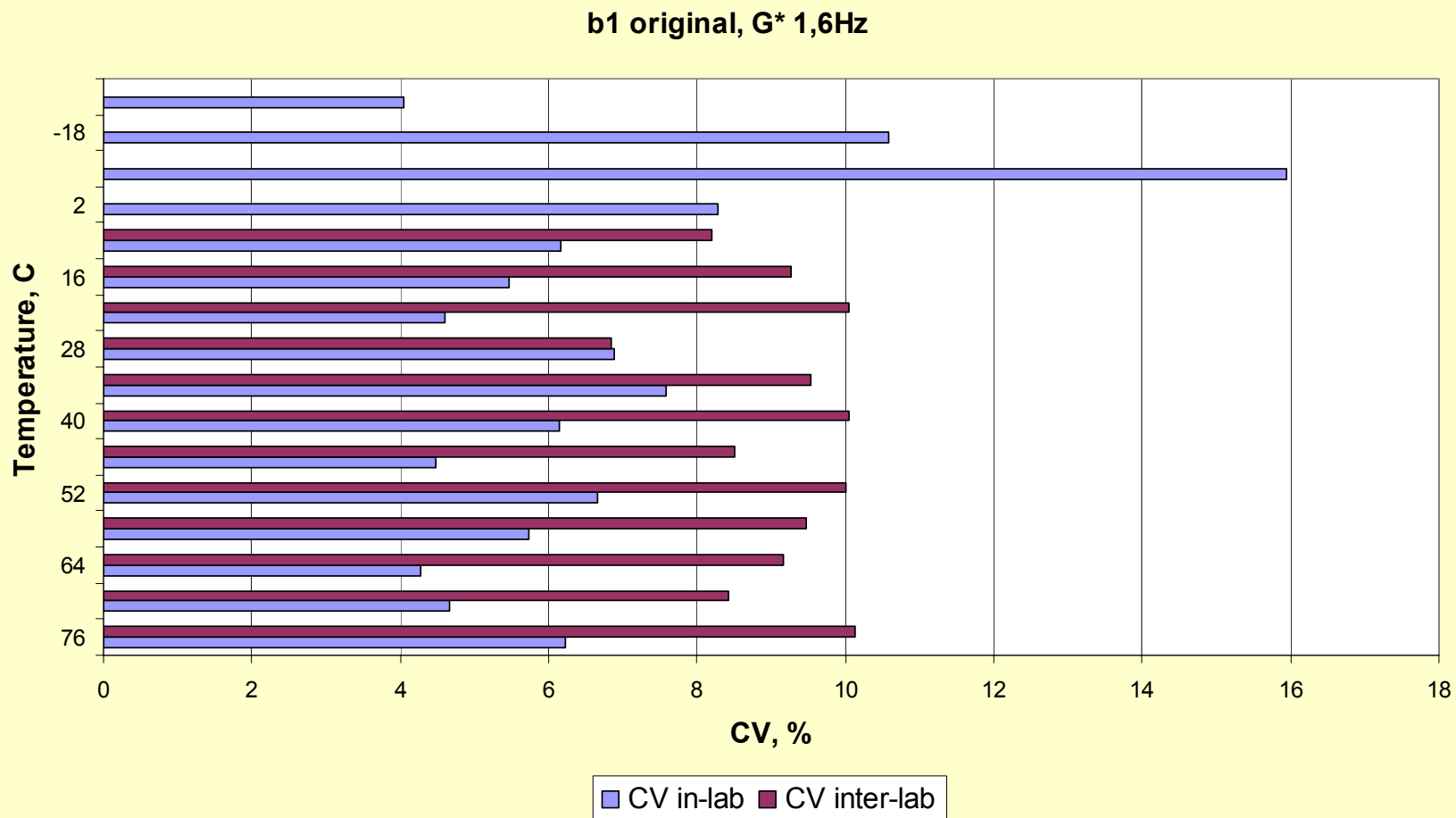
Precision

Inter-laboratory precision in AASHTO TP5

Condition	Coefficient of Variation (1s %), %	Acceptable range of two results (d2s %), %
Original $G^*/\sin\delta$	10,3	29,1
RTFOT $G^*/\sin\delta$	11,1	31,3
PAV $G^*\sin\delta$	19,8	56,1

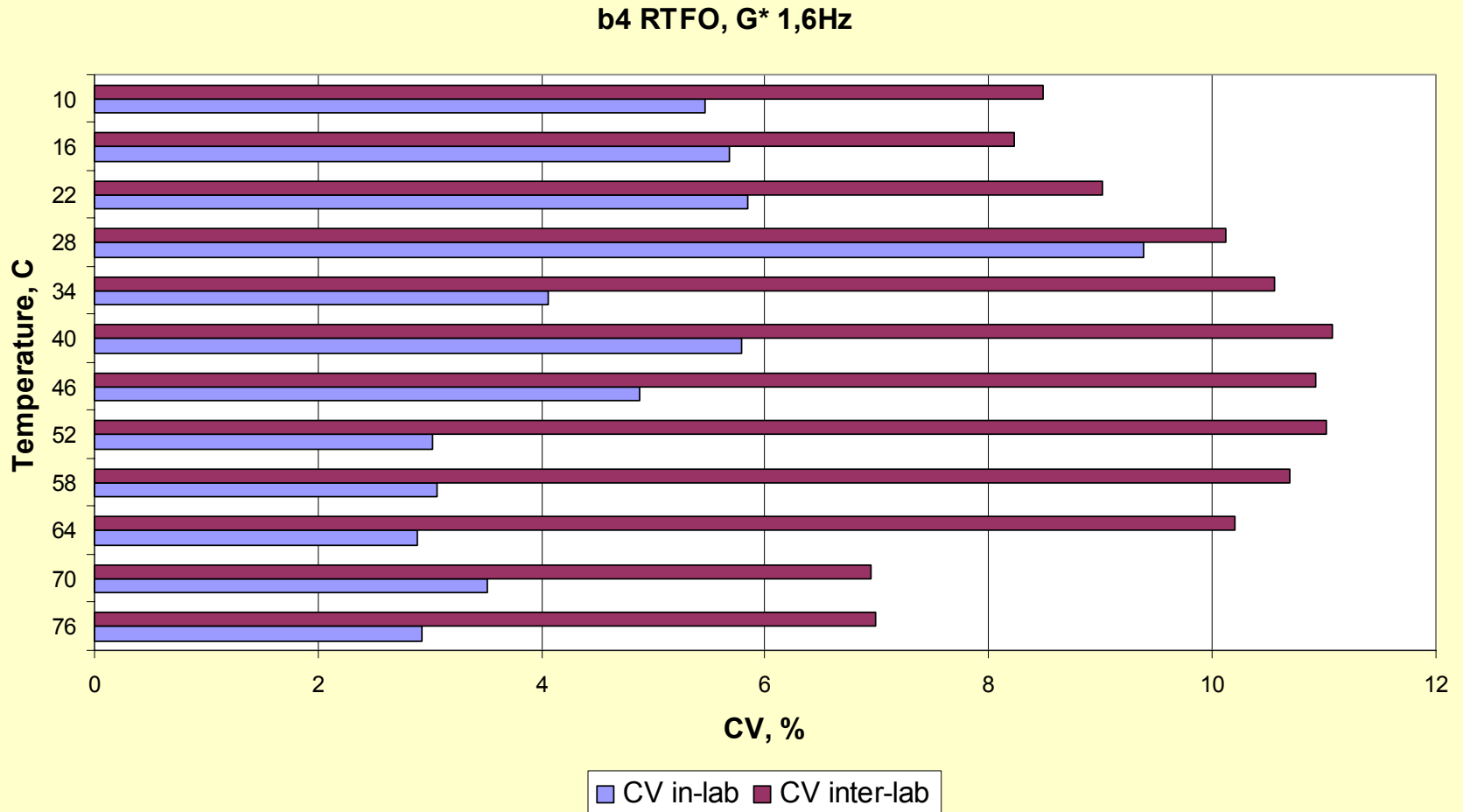
Dynamic Rheometers

Repeatability and Reproducibility



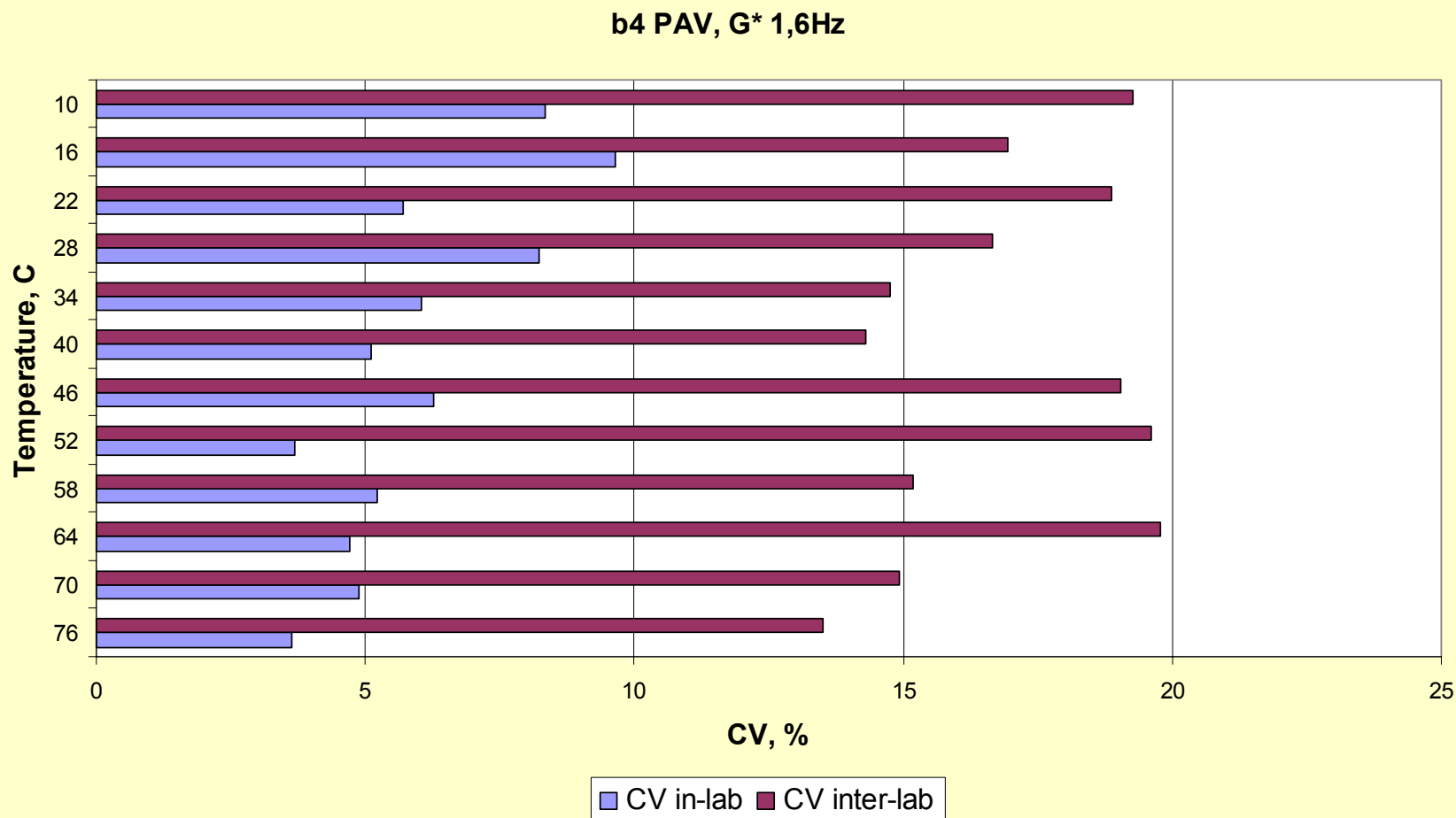
Dynamic Rheometers

Repeatability and Reproducibility



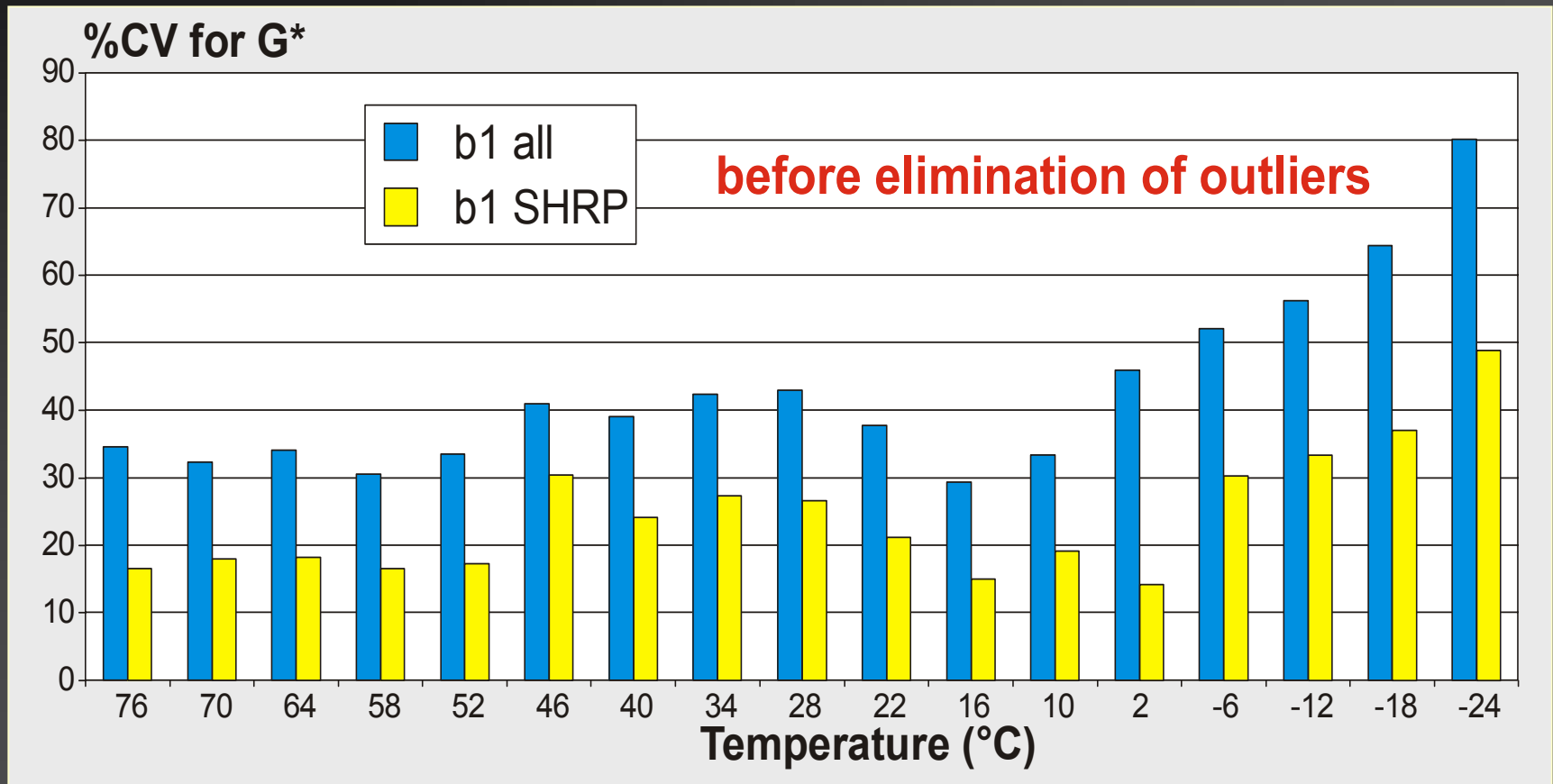
Dynamic Rheometers

Repeatability and Reproducibility



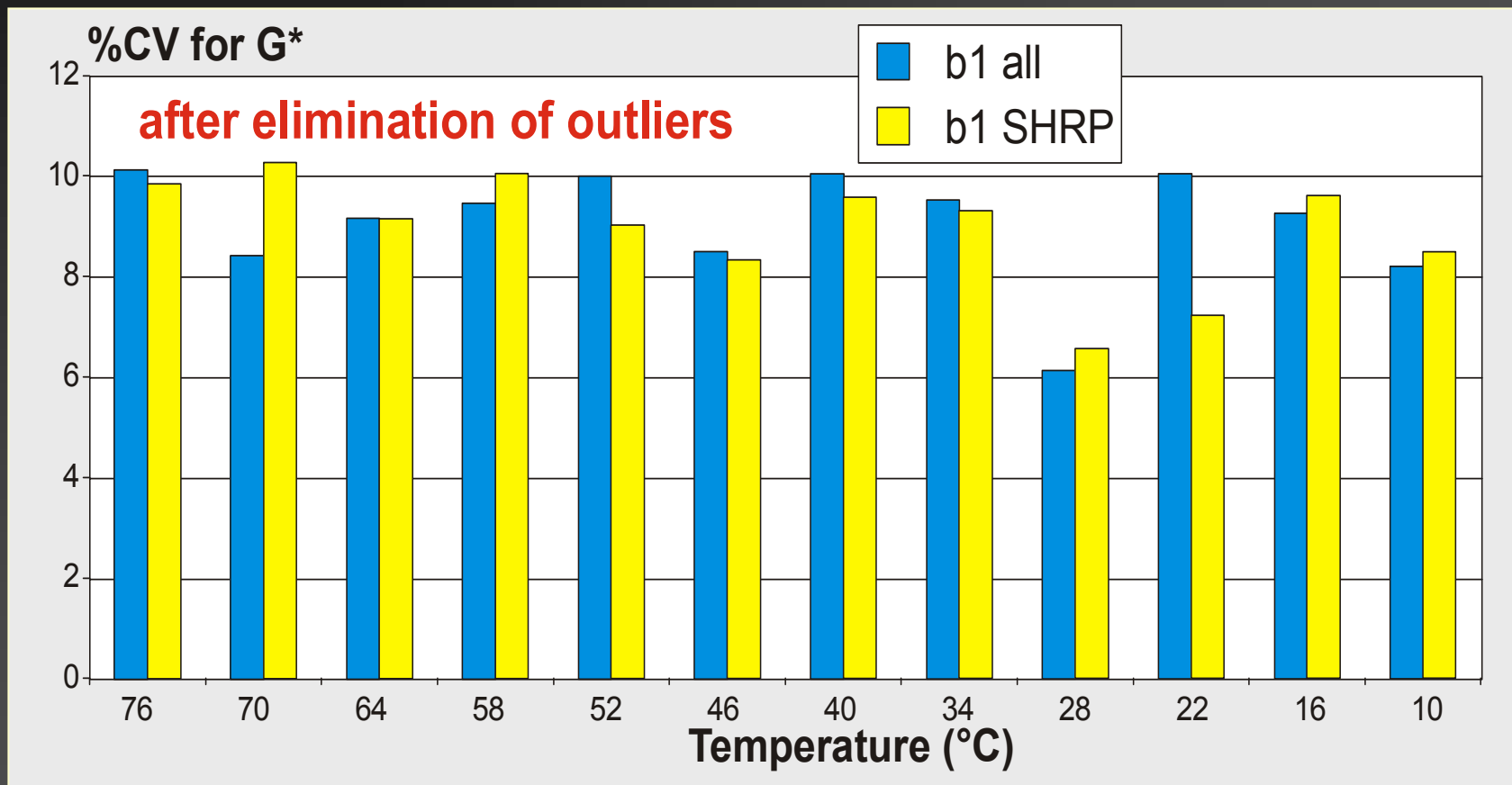
Dynamic Rheometers

Reproducibility



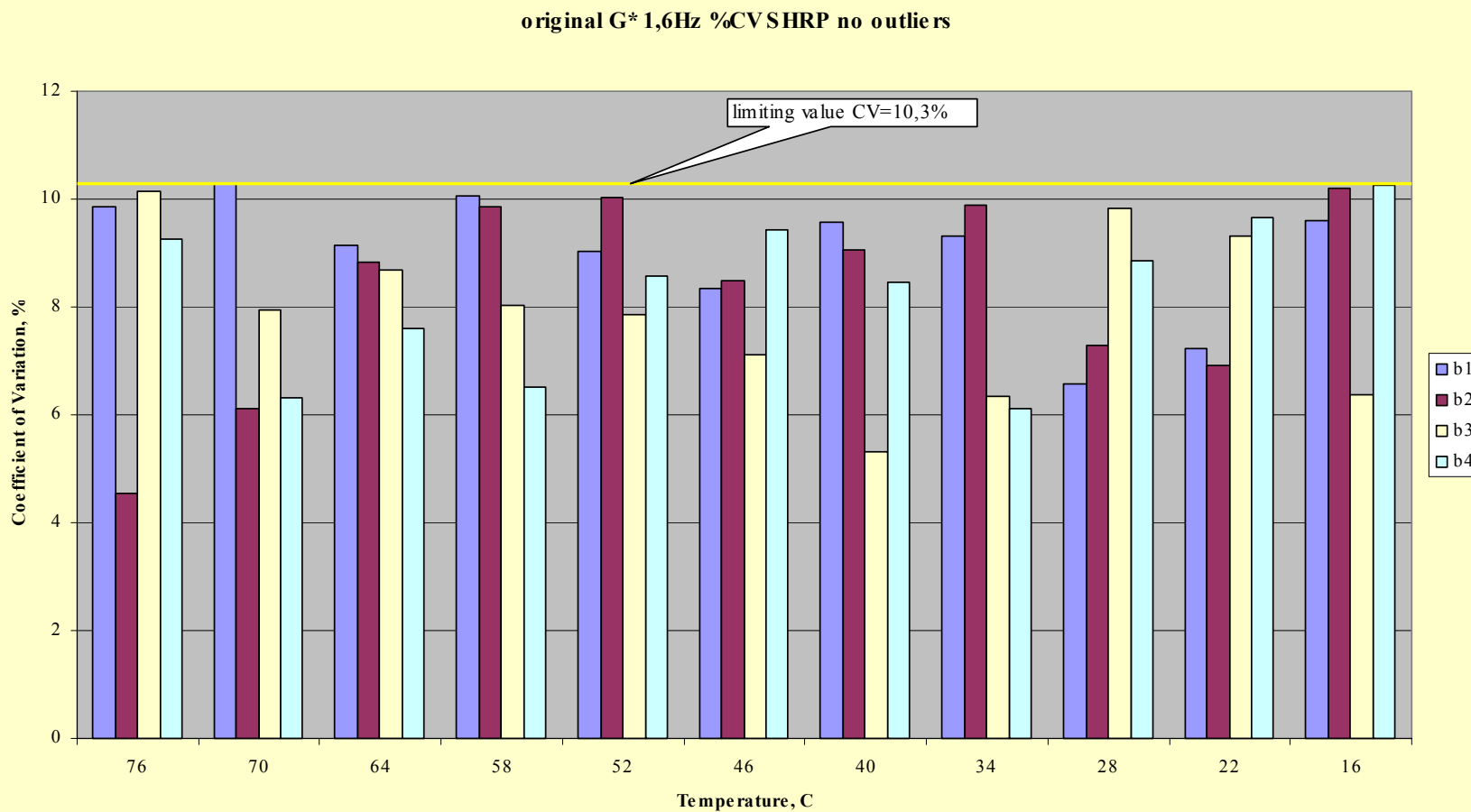
Dynamic Rheometers

Reproducibility



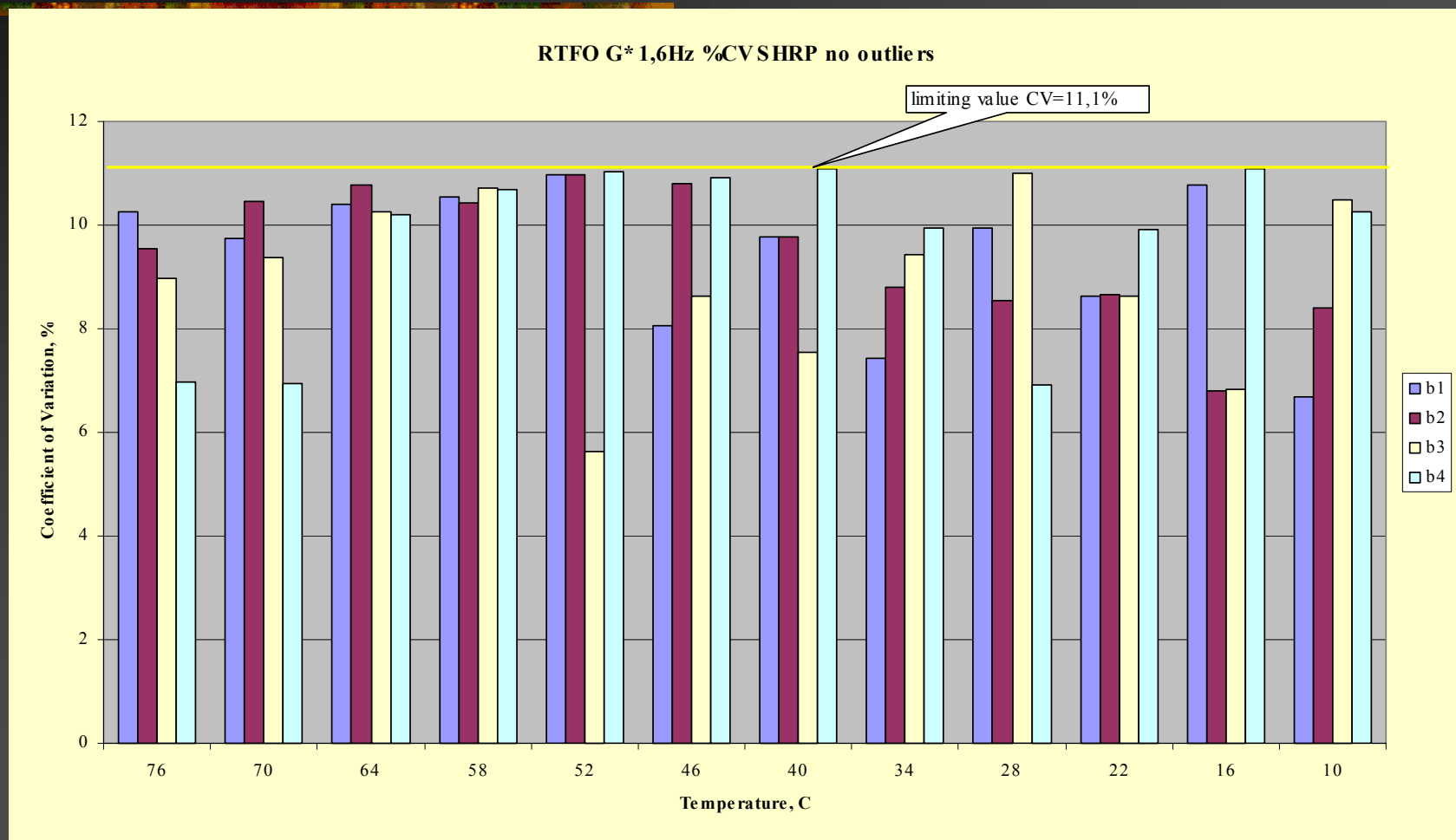
Dynamic Rheometers

Reproducibility



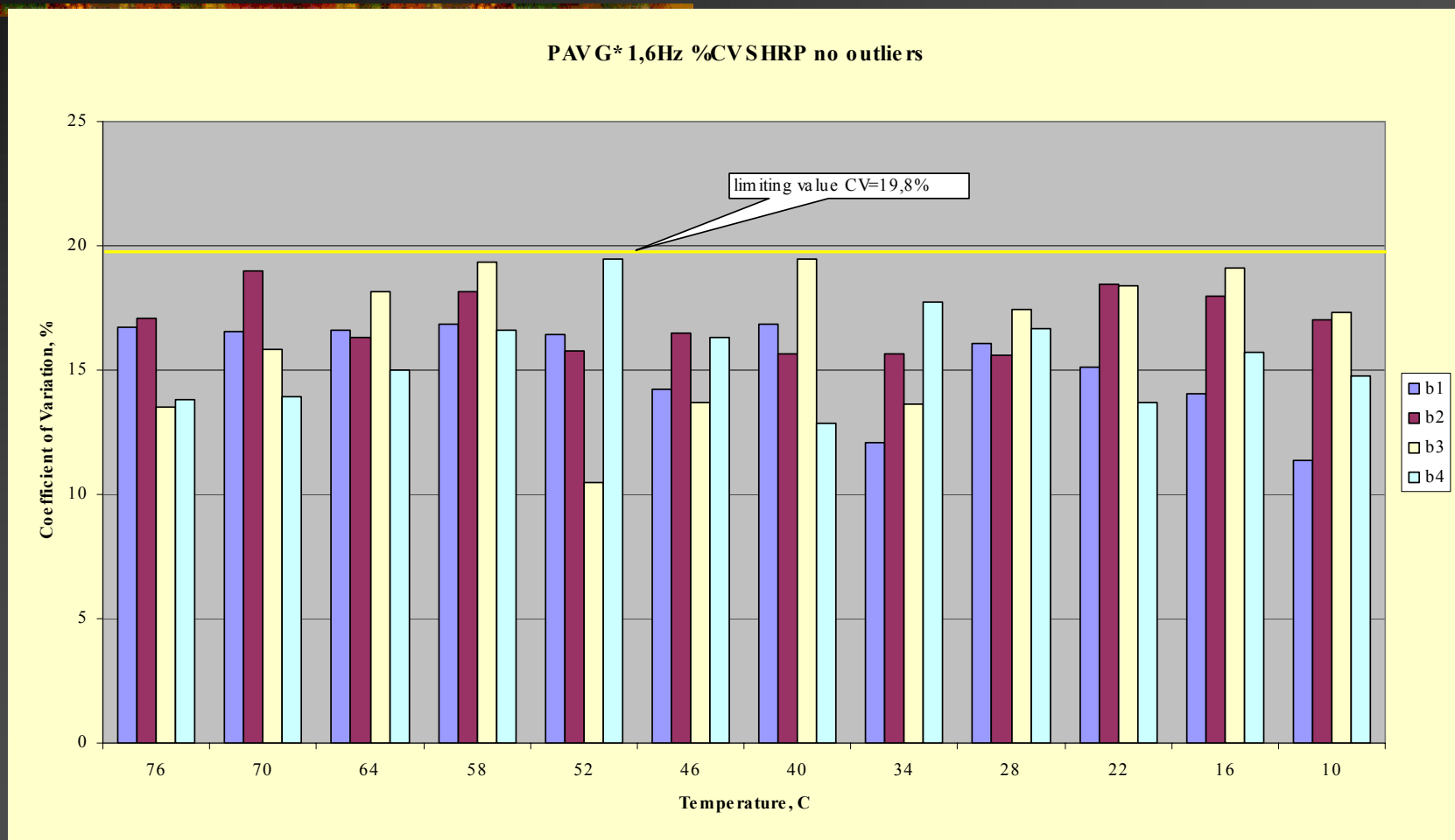
Dynamic Rheometers

Reproducibility



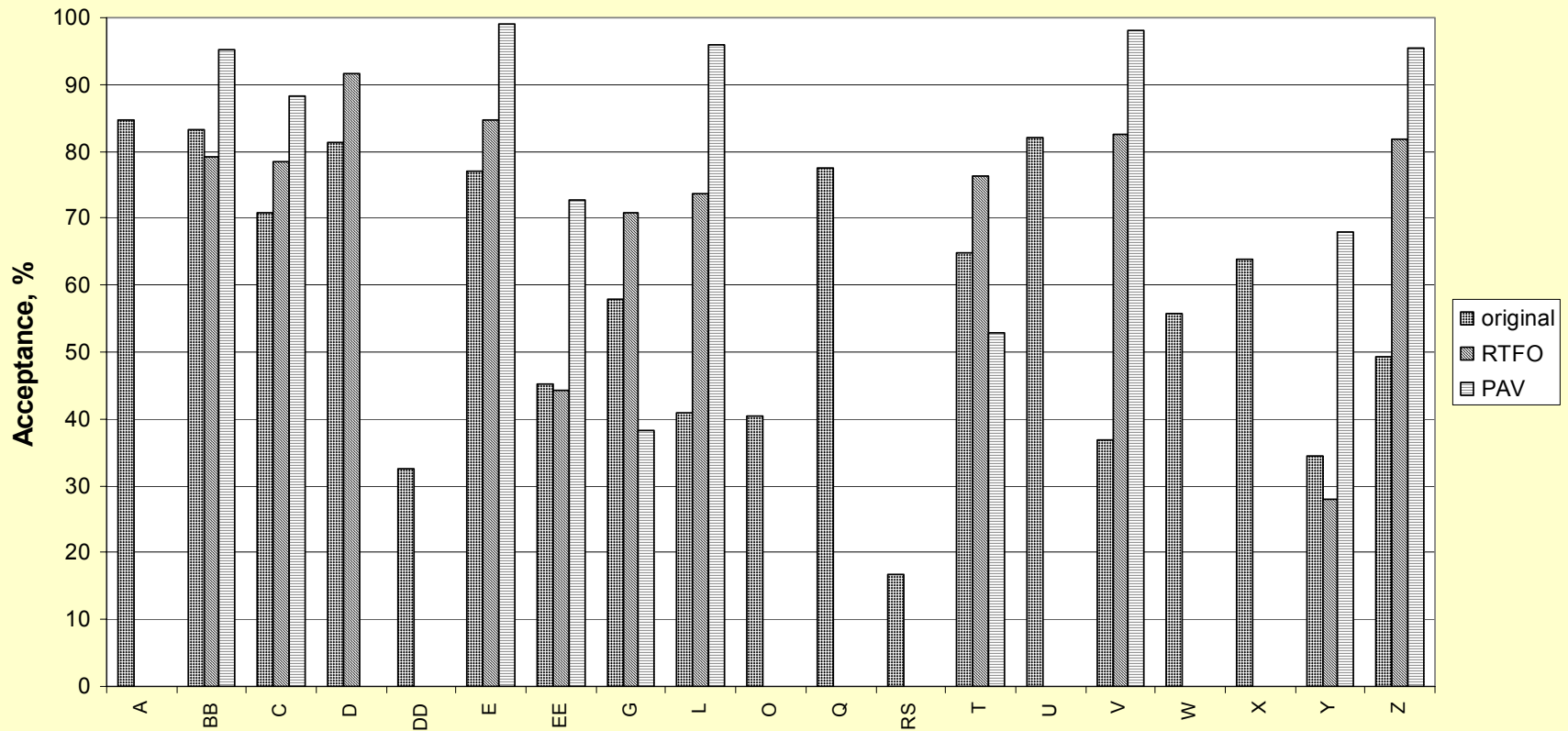
Dynamic Rheometers

Reproducibility



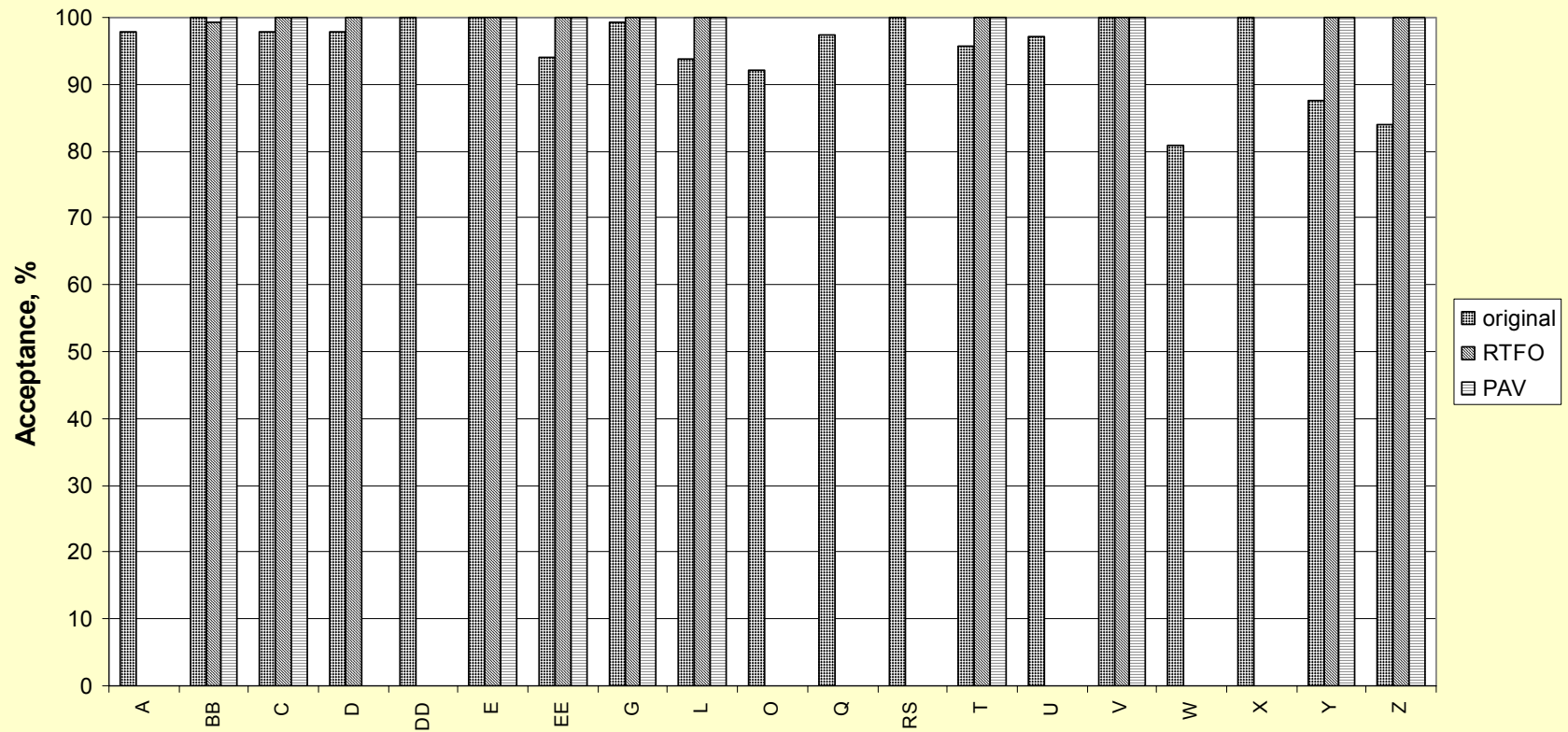
Reliability of laboratories

Acceptance of results, G, all geometries



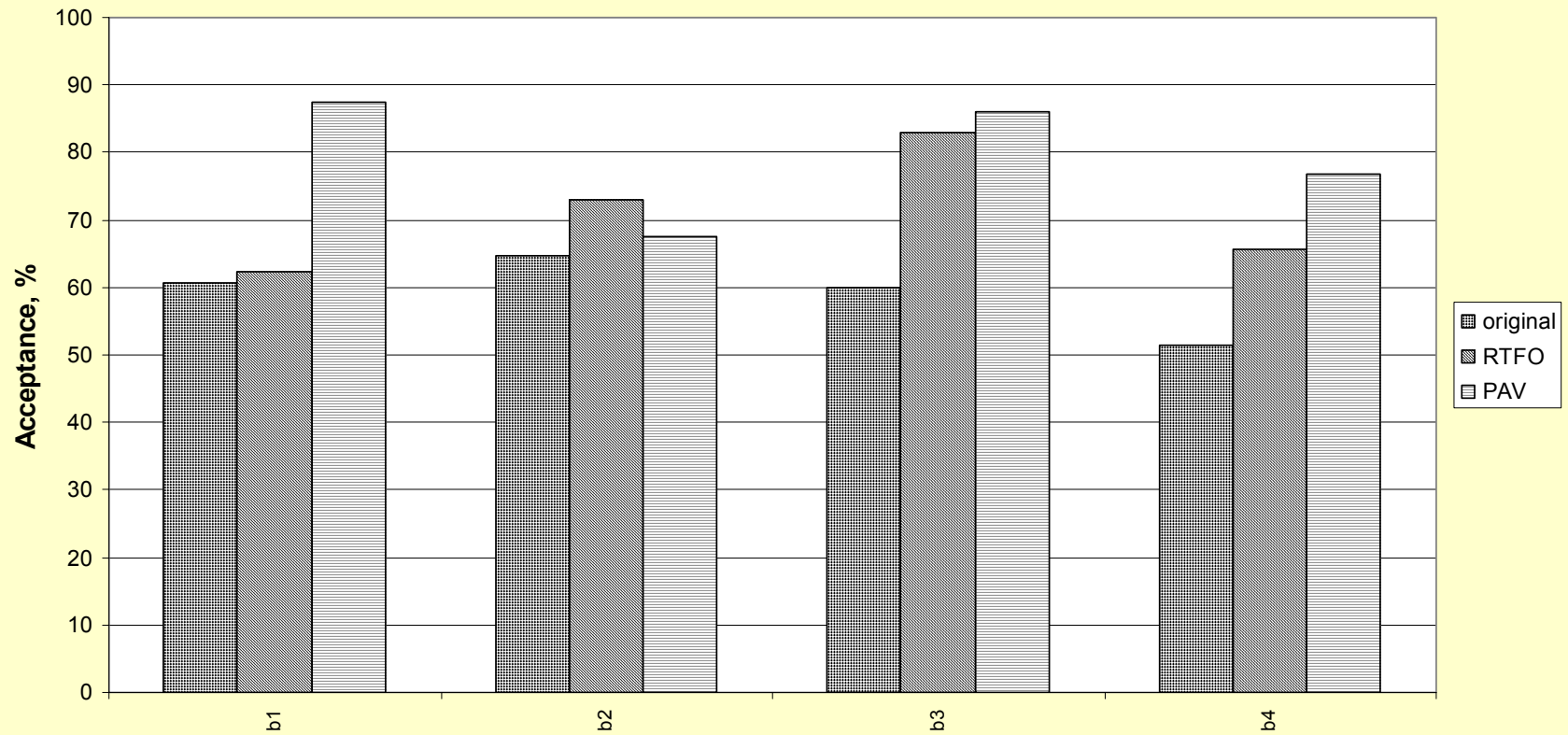
Reliability of laboratories

Acceptance of results, PA, all geometries



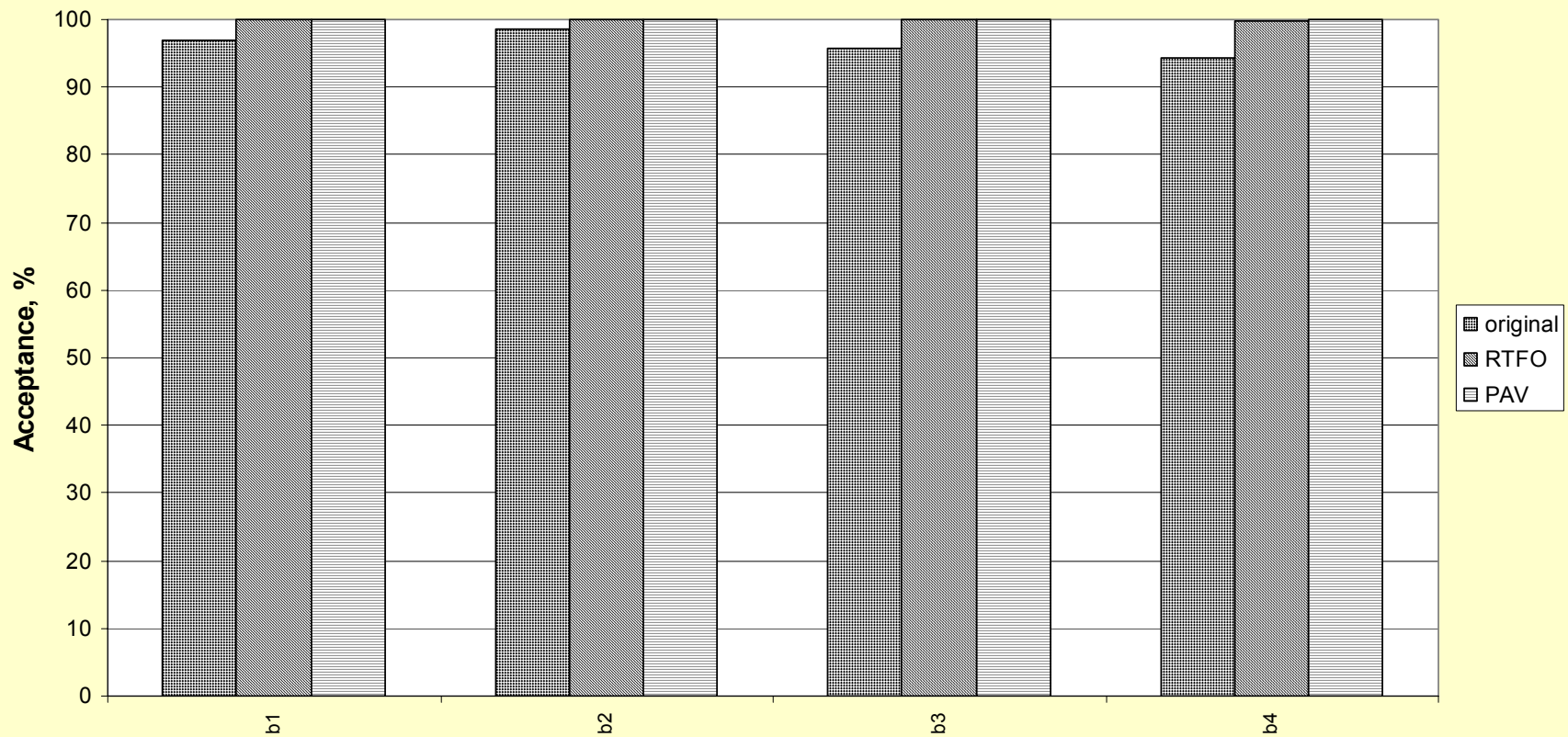
Reliability of results for binders

Acceptance of results, G, all geometries

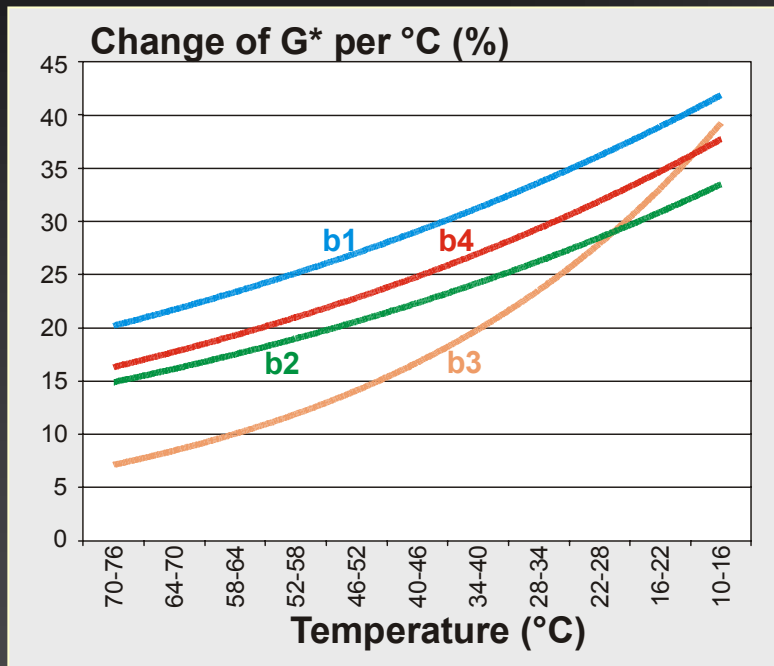


Reliability of results for binders

Acceptance of results, PA, all geometries



Comparison of precision of DR and R&B



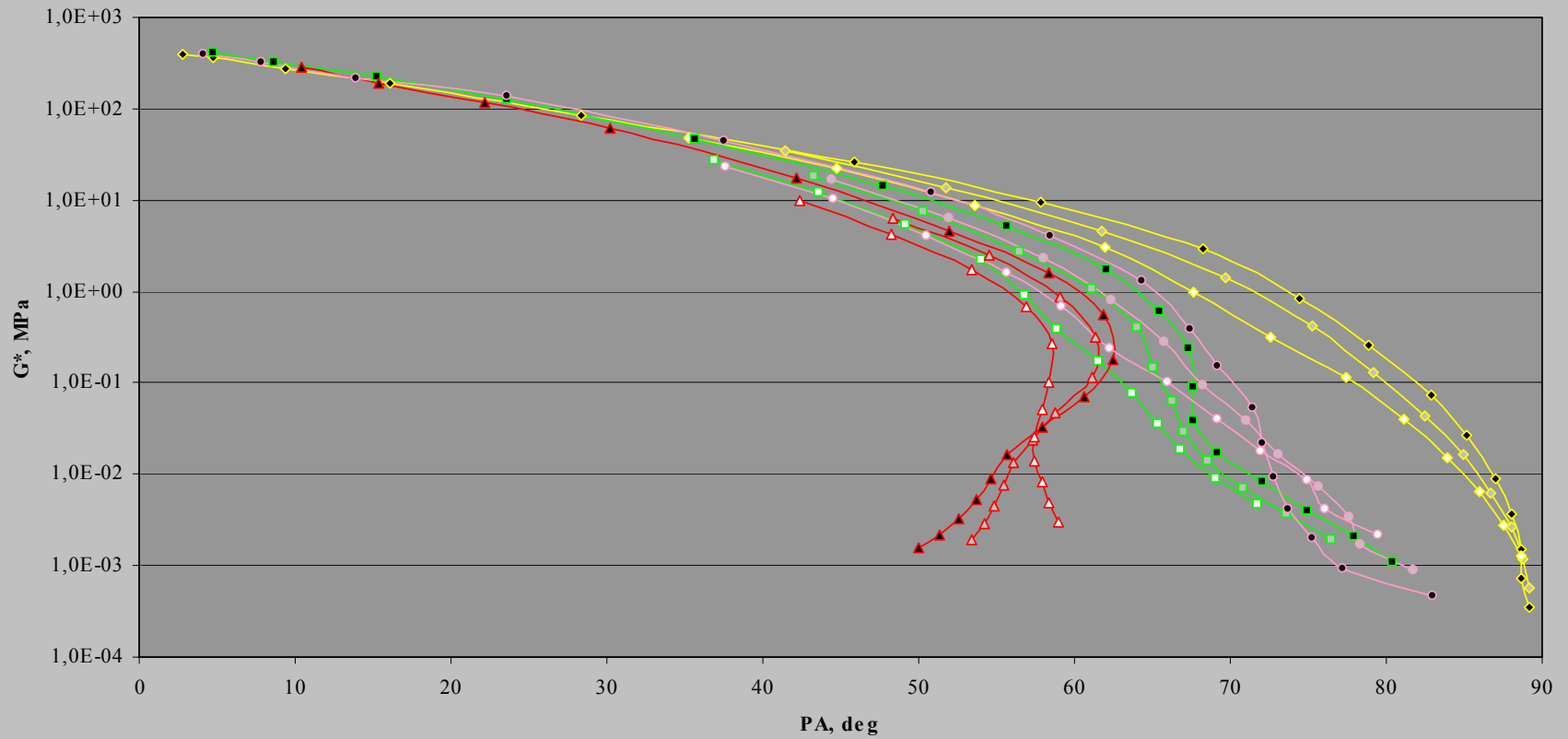
<i>Binder</i>	<i>R&B</i> ($^{\circ}\text{C}$)	<i>St. Dev. ($^{\circ}\text{C}$)</i>	
		<i>RILEM</i> (<i>EN1427</i>)	<i>Mentioned</i> <i>EN 1427</i>
<i>1</i>	49,0	0,6	0,7
<i>2</i>	56,6	1,2	1,3
<i>3</i>	85,7	2,7	2,0
<i>4</i>	61,6	2,0	1,3

G^* varies 10 - 25 % per 1°C

Hence: St.Dev. of 10 % corresponds to less than 1°C

Average

Average Black curve 1,6 Hz SHRP



Legend: b1 orig (yellow diamond), b1 RTFO (yellow circle), b1 PAV (yellow square), b2 orig (green square), b2 RTFO (green circle), b2 PAV (green triangle), b3 orig (red triangle), b3 RTFO (red circle), b3 PAV (red square), b4 orig (black circle), b4 RTFO (black square), b4 PAV (black triangle)



DR Reliability

- Equipment or geometry other than SHRP: higher risk for incorrect results
- Higher acceptance of PA than G^* results
- Higher acceptance of results from DSR and SHRP geometries
- Higher acceptance of results after ageing (more precise recommendations for second phase of test)
- The same reliability of DSR results for plain and polymer modified binders
- The precision on G^* is comparable or even better than the precision on R&B

DR main sources of error

- Non-linearity of material's behaviour (too high strain)
- Improper sample geometry: too big plate radius or too thin gap
- Too high rheometer compliance
- Deviation of temperature from the target value
- Improper sample handling and preparation
 - thermal history
 - heterogeneity
 - steric hardening (too long storage of the sample)
 - deficient or excessive sample volume
 - deficient bond between sample and plates
- Rewriting

Conclusions

(recommendations for CEN standards)

■ BBR:

- Reproducibility standard deviation on S(60s):
5 %
- Reproducibility standard deviation on m(60s):
3 - 5 %
- Performance Grade according to SHRP can
be determined with a precision of about 1°C
(3 measurements per temperature)

Conclusions

(recommendations for CEN standards)

■ DSR:

- For EN-standardization purposes, it is recommended to limit rheometers to SHRP-equipment and geometries. Other equipment/geometries can also lead to correct results, but with higher risks
- For EN-standardization purposes the temperature range should be limited from 10 to 76 °C
- Reproducibility standard deviation on G^* : 10%
- Reproducibility standard deviation on phase angle: 5%

Thank you for
your attention

