Neuburg Siliceous Earth
vs wollastonite and barium sulfate
in peroxide cured FKM

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Experimental	• Formulation and fillers • Mixing and curing • Tests
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Status Quo

Wollastonite

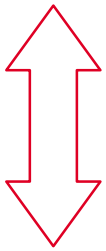
Barium Sulfate

traditionally used fillers
in FKM compounds

Objective

Wollastonite

Barium Sulfate



Neuburg Siliceous Earth

Formulation

		phr
Viton GAL-200S	66 % fluorine, 25 MU (ML 1+10, 121 °C) Terpolymer (HFP+VFD+TFE)	100
Zinkoxyd aktiv	Zinc oxide	3
Diak No. 7	Coactivator TAIC	3
Varox DBPH-50	2,5-dimethyl-2,5-di(tertbutylperoxy)-hexane	2
Filler	-	as indicated

Fillers, Characteristics

Filler	Description	Functionalization
Wollastonite AST	Calcium silicate, d_{50}: 3,5 µm	Amino silane
Wollastonite EST	Calcium silicate, d_{50}: 3,5 µm	Epoxy silane
Barium Sulfate	ppt. barium sulfate, d_{50}: 3 µm	-
Silfit Z 91	Calcined Neuburg Siliceous Earth, d_{50}: 2 µm	-
Aktifit VM	Calcined Neuburg Siliceous Earth, d_{50}: 2 µm	Vinyl
Aktifit PF 111	Calcined Neuburg Siliceous Earth, d_{50}: 2 µm	Alkyl
Aktifit AM	Calcined Neuburg Siliceous Earth, d_{50}: 2 µm	Amino
Aktifit PF 115	Calcined Neuburg Siliceous Earth, d_{50}: 2 µm	Special amino
Aktisil AM	Neuburg Siliceous Earth, d_{50}: 2 µm	Amino
Aktisil Q	Neuburg Siliceous Earth, d_{50}: 4 µm	Methacrylic

Preparation and Curing of the Compound

Mixing	
Open mill	Ø 150 x 300 mm
Batch weight	ca. 1 kg
Temperature	50 °C 30 °C for removing the sheet off the mill
Mixing time	approx. 15 min.

Cure	
Cure	7 min. / 177 °C
Post-cure	2 h / 232 °C

All mentioned mechanical properties are related to post-cured specimens if not indicated differently.

Tests

Standard mechanical tests with post-cured specimens
Hardness, tensile tests, compression set, abrasion resistance

Resistance tests with post-cured specimens	
Hot air	70 h / 232 °C
Engine oil OS206304	168 h / 150 °C
Fuel FAM B (DIN 51604)	70 h / 23 °C
Acetic acid (1M, pH 3)	168 h / 100 °C

Filler Choice

Neuburg Siliceous Earth vs.

Wollastonite AST

Wollastonite EST

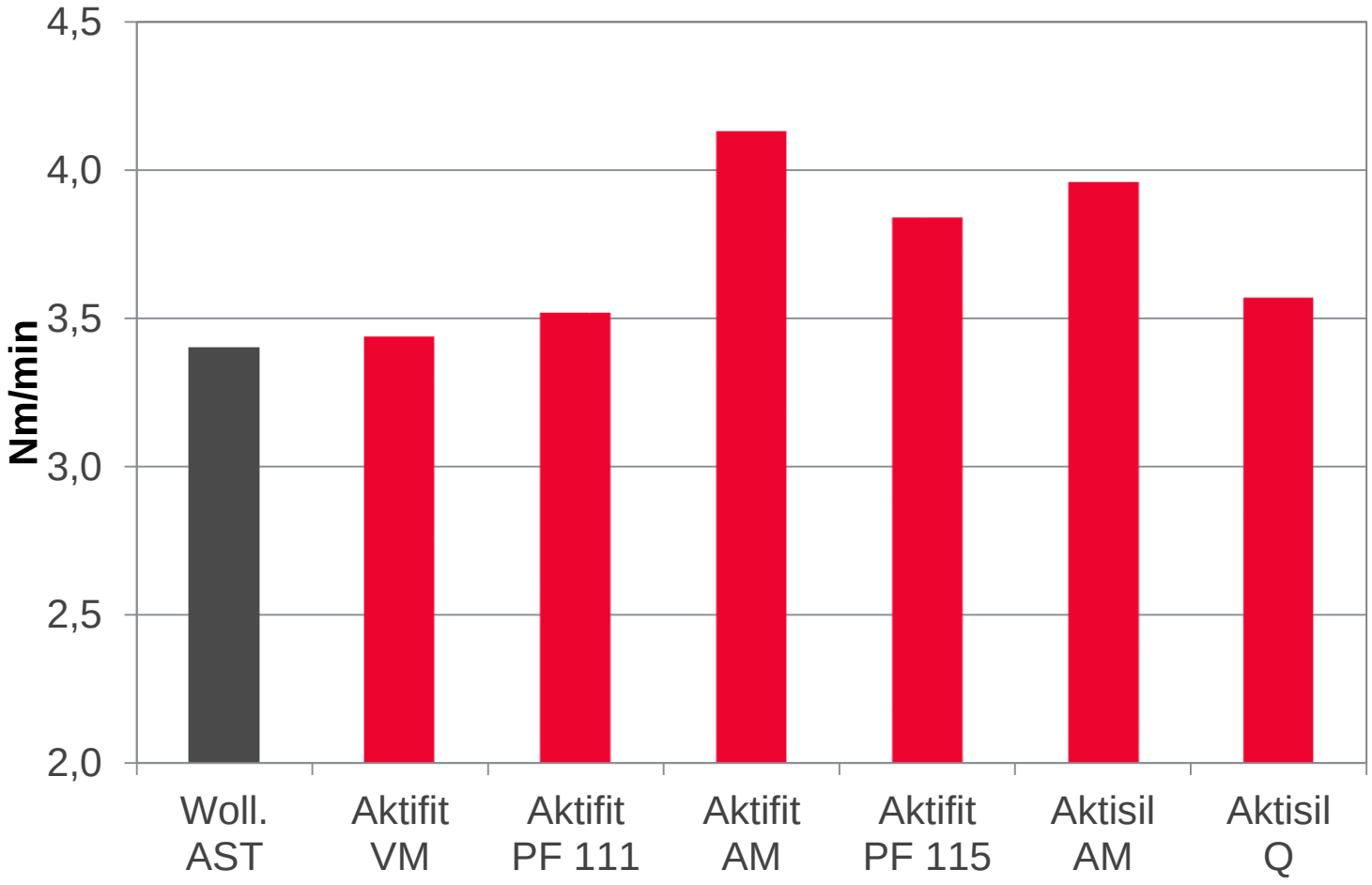
Barium Sulfate

Neuburg Siliceous Earth vs. Wollastonite AST

Hardness
65 Shore A

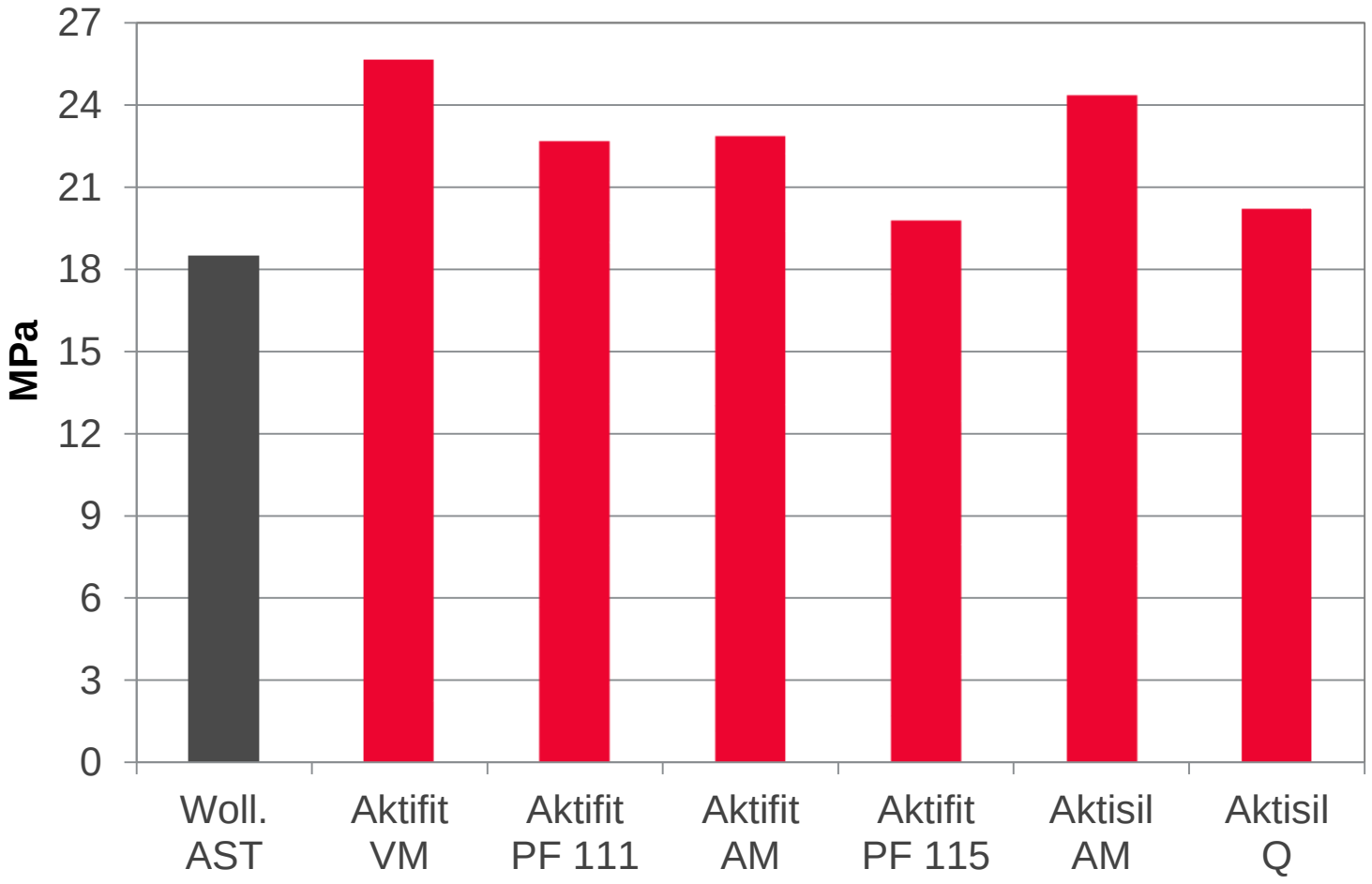
Wollastonite AST
Max. Cure Speed

DIN 53 529, T3 – Göttfert Elastograph, 177 °C, Amplitude 0.2°



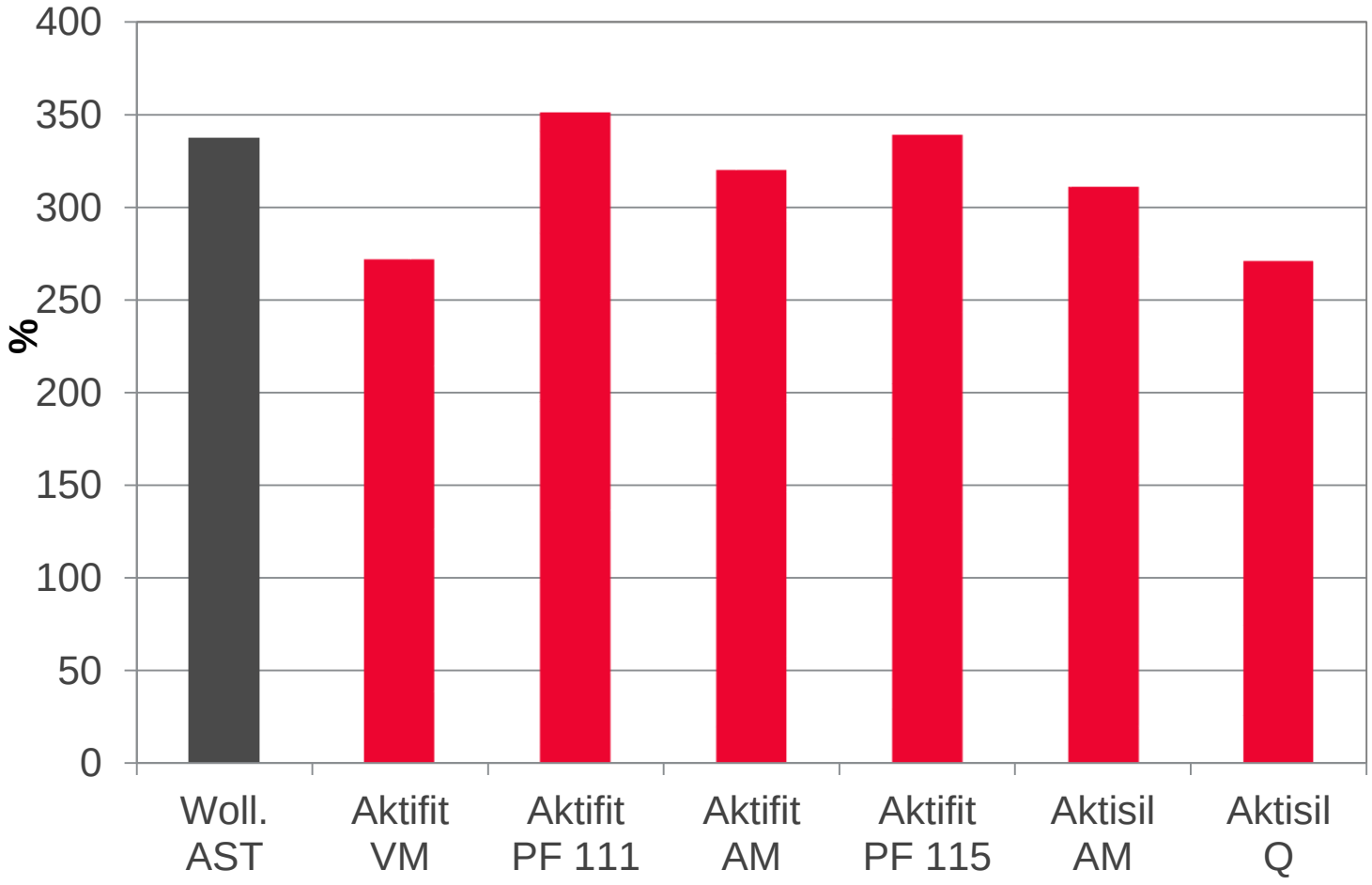
Wollastonite AST
Tensile Strength

DIN 53 504, S2



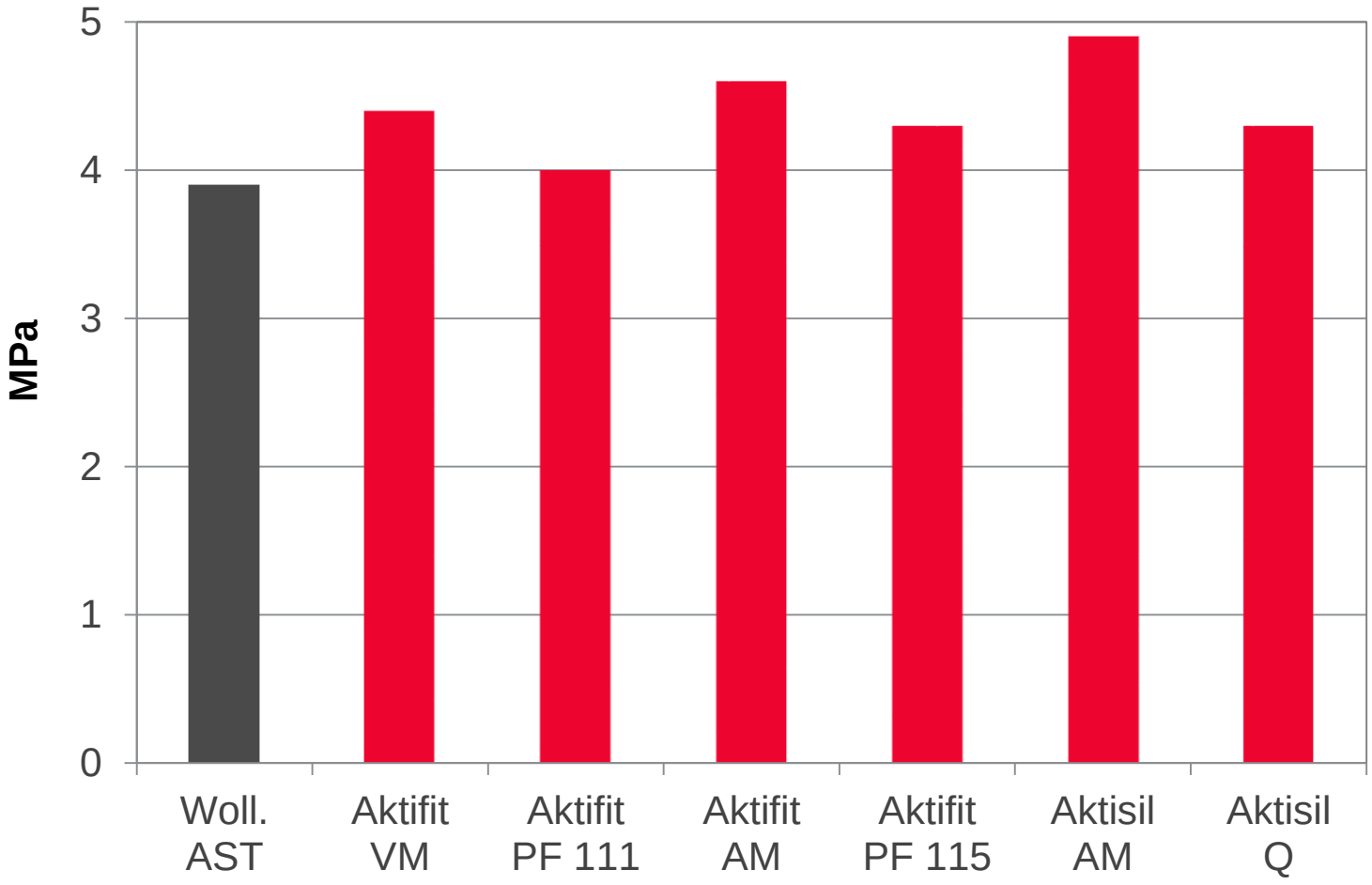
Wollastonite AST
Elongation at Break

DIN 53 504, S2



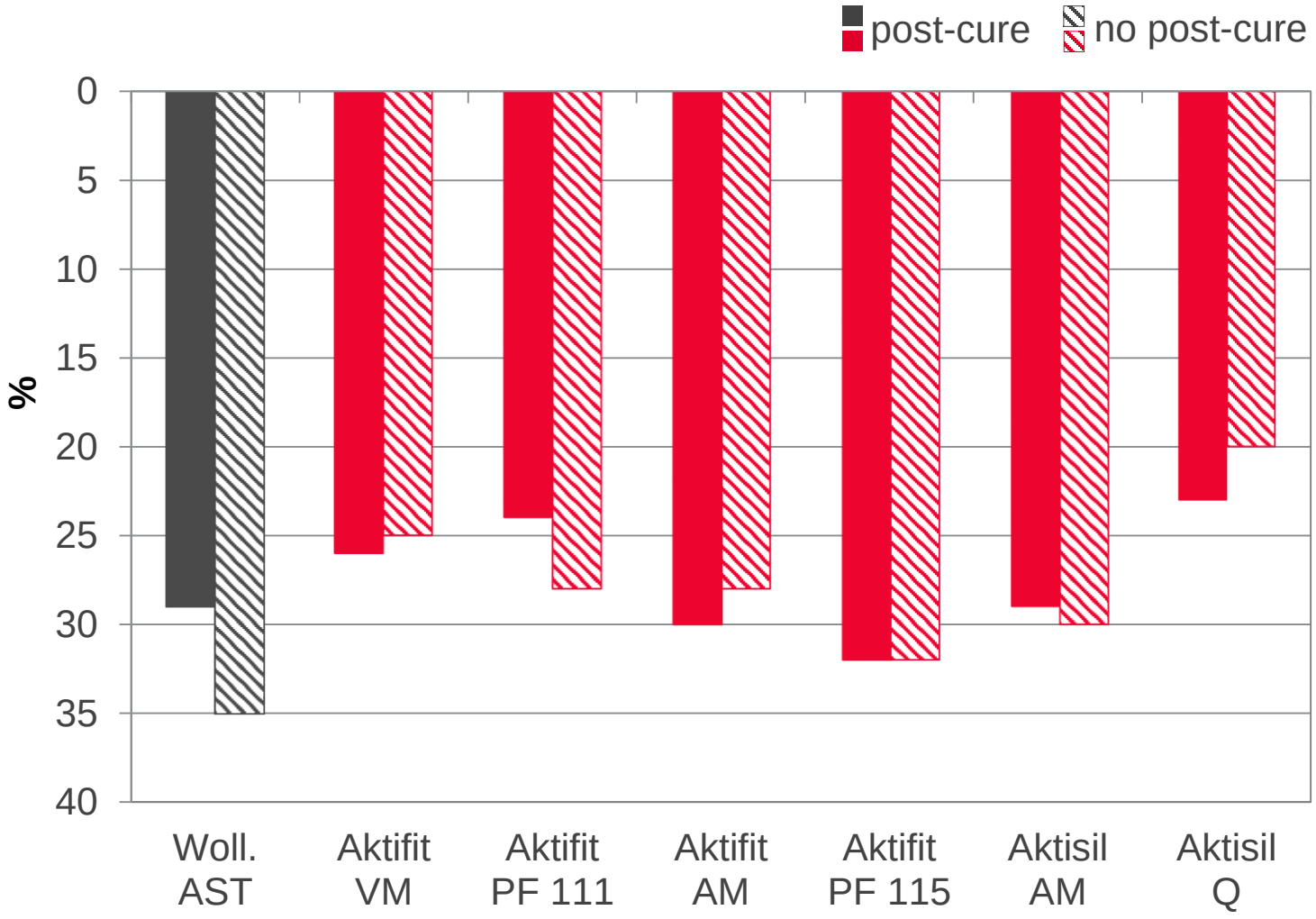
Wollastonite AST
Modulus 100 %

DIN 53 504, S2



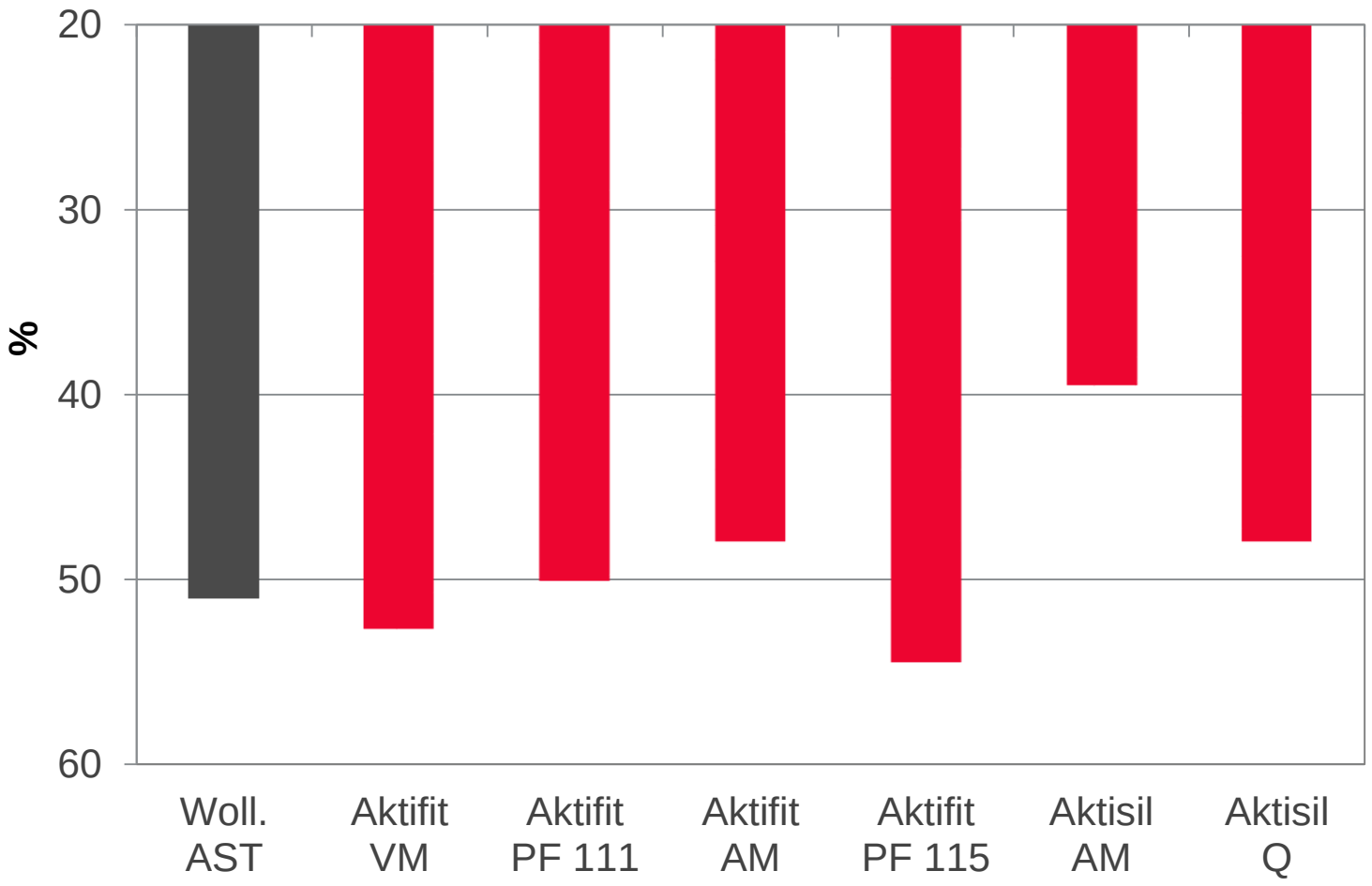
Wollastonite AST
Compression Set ISO

DIN ISO 815-1 B, 25 % defl., 70 h / 232 °C



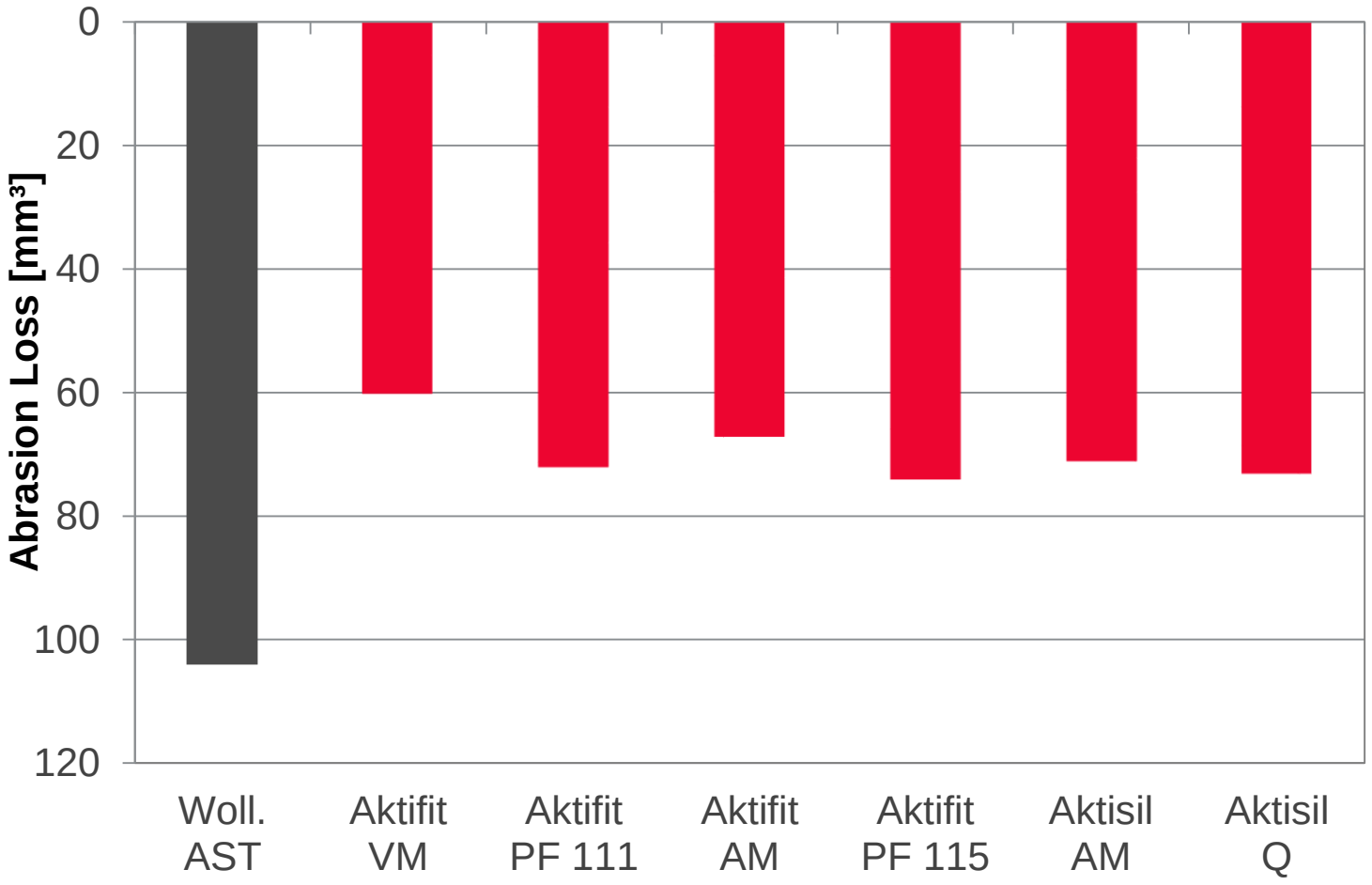
Wollastonite AST
Compression Set VW

VW PV 3307, 50 % defl., 5 s, 94 h / 23 °C

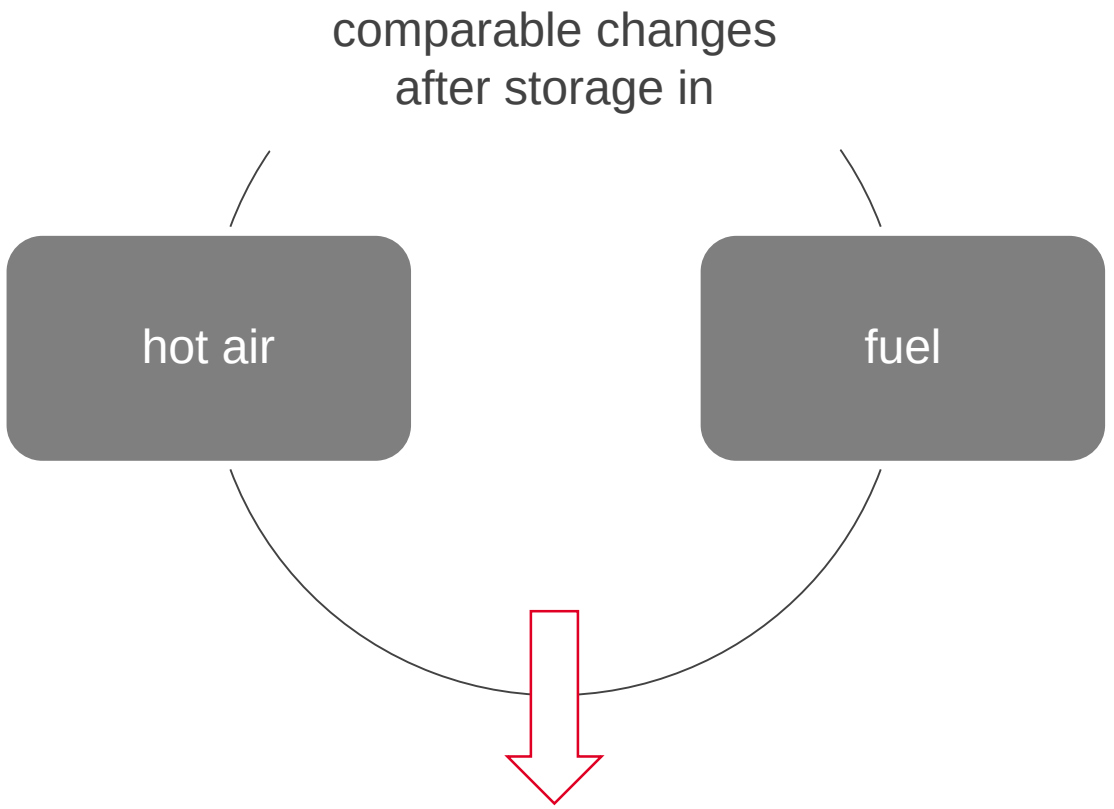


Wollastonite AST
Abrasion Resistance

DIN ISO 4649



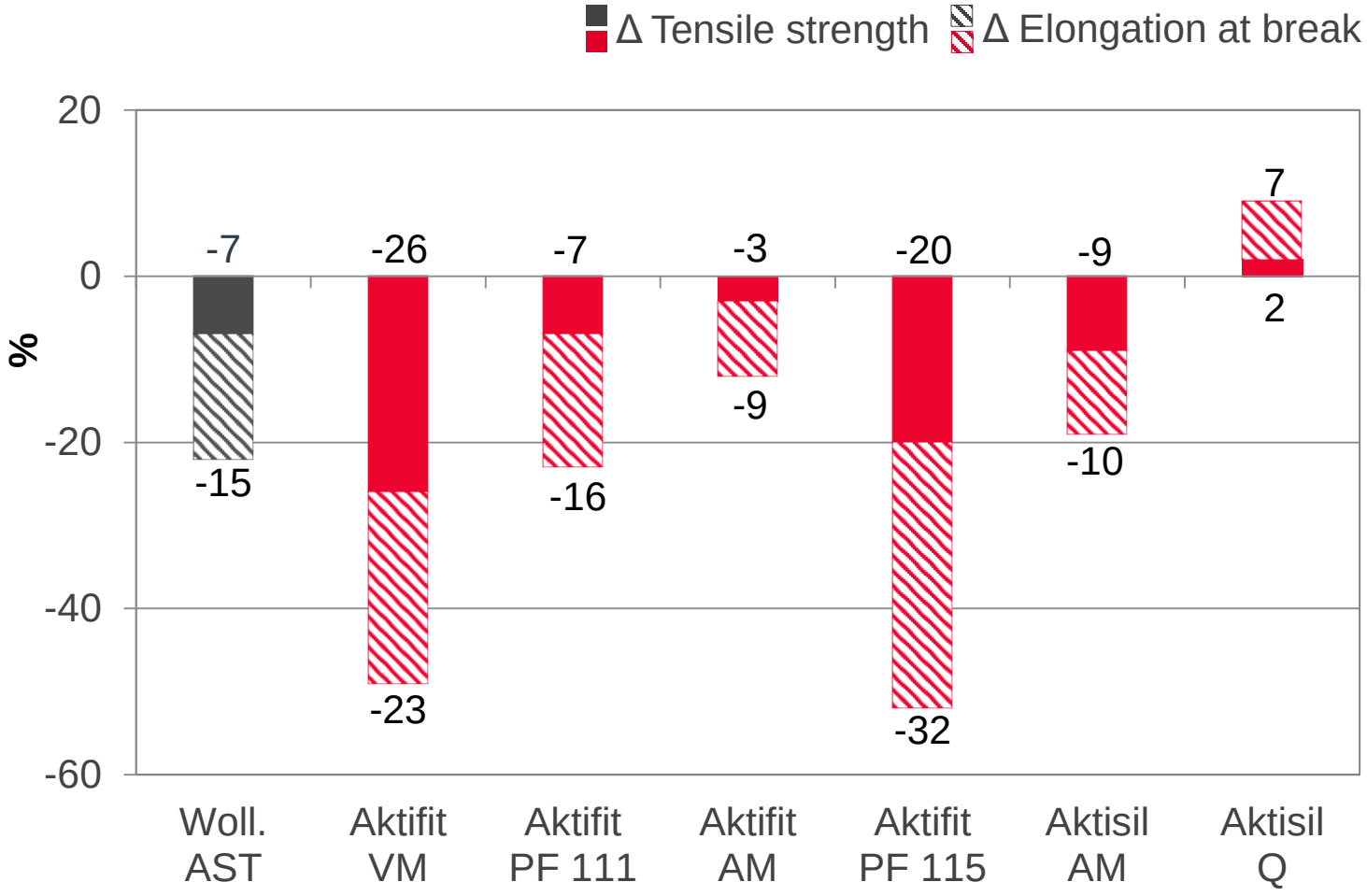
Wollastonite AST
Media Resistance



higher tensile strength and comparable elongation at break are retained with Neuburg Siliceous Earth

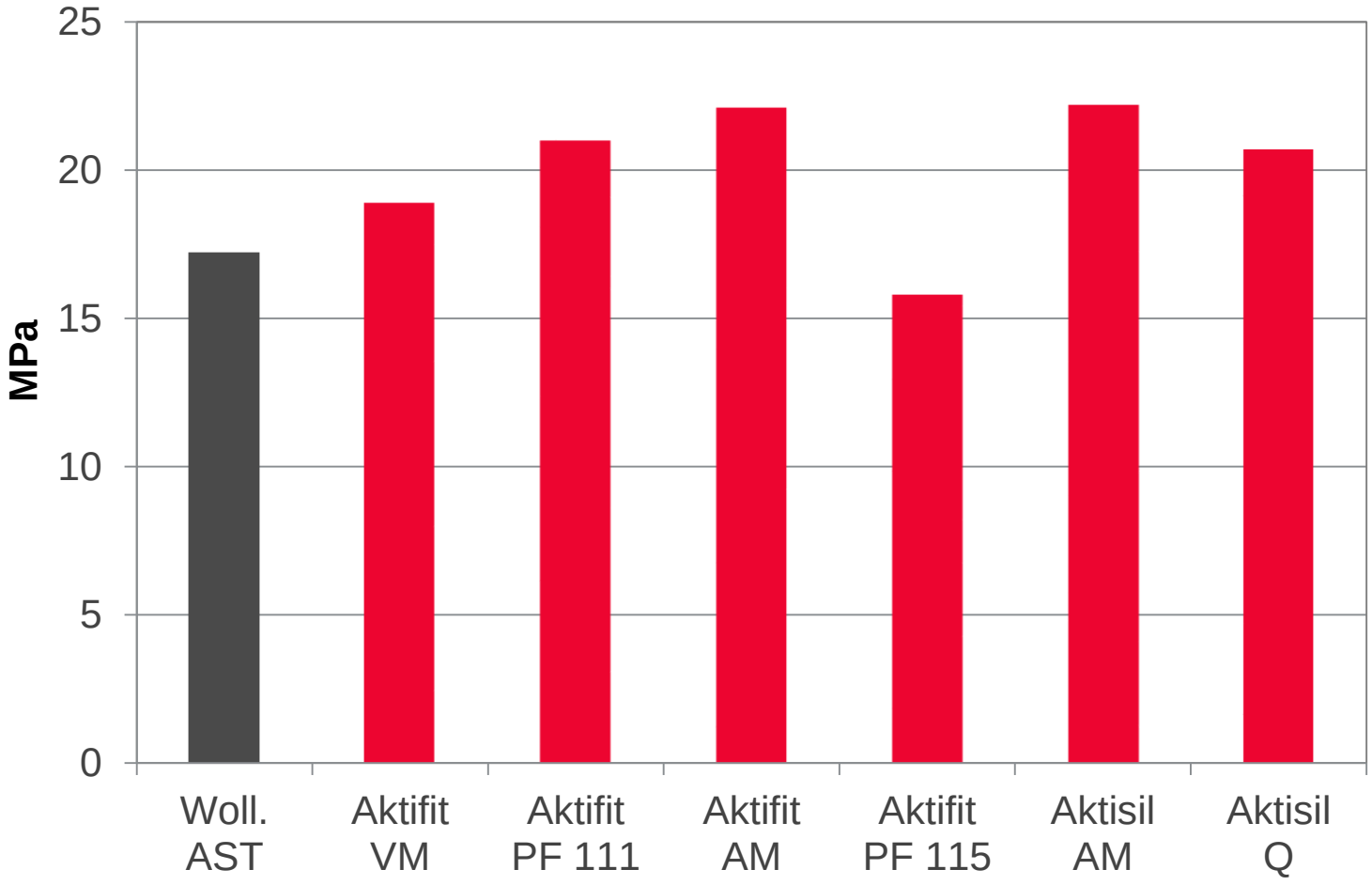
Wollastonite AST
Oil Resistance

OS206304, 168 h / 150 °C



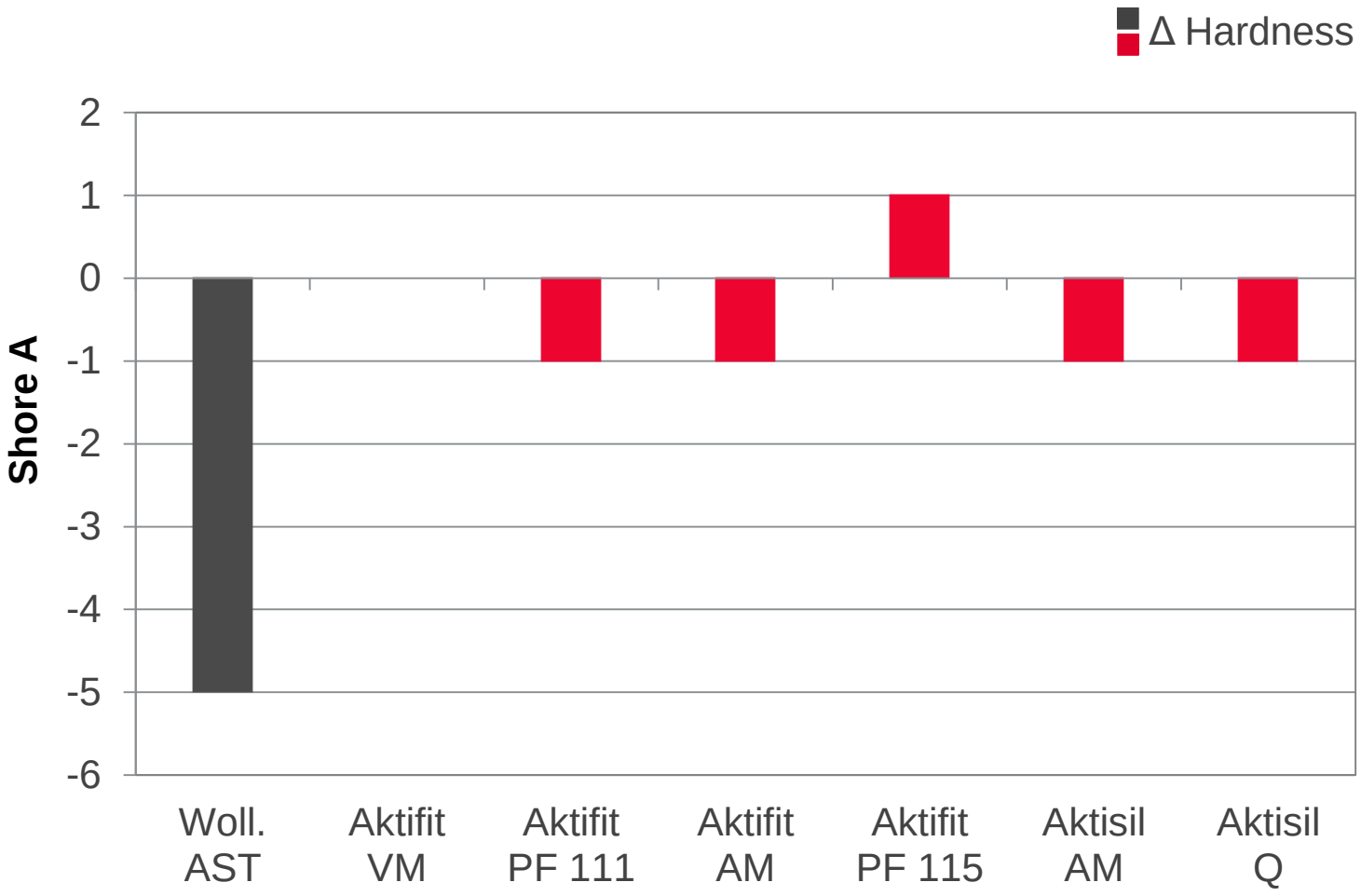
Wollastonite AST
Oil Resistance – Tensile Strength

DIN 53 504, S2



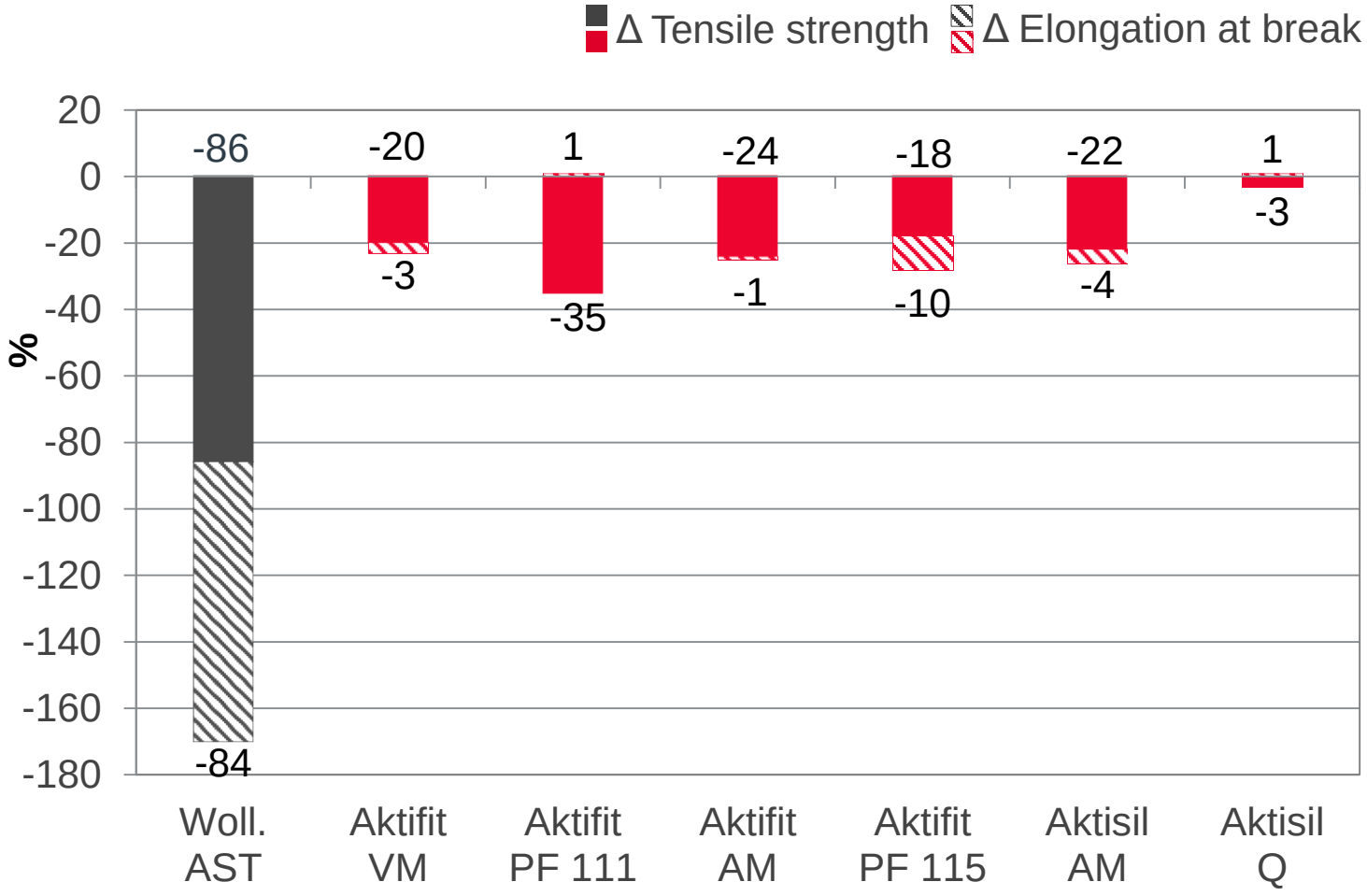
Wollastonite AST
Oil Resistance

OS206304, 168 h / 150 °C



Wollastonite AST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C



Wollastonite AST
Acid Resistance

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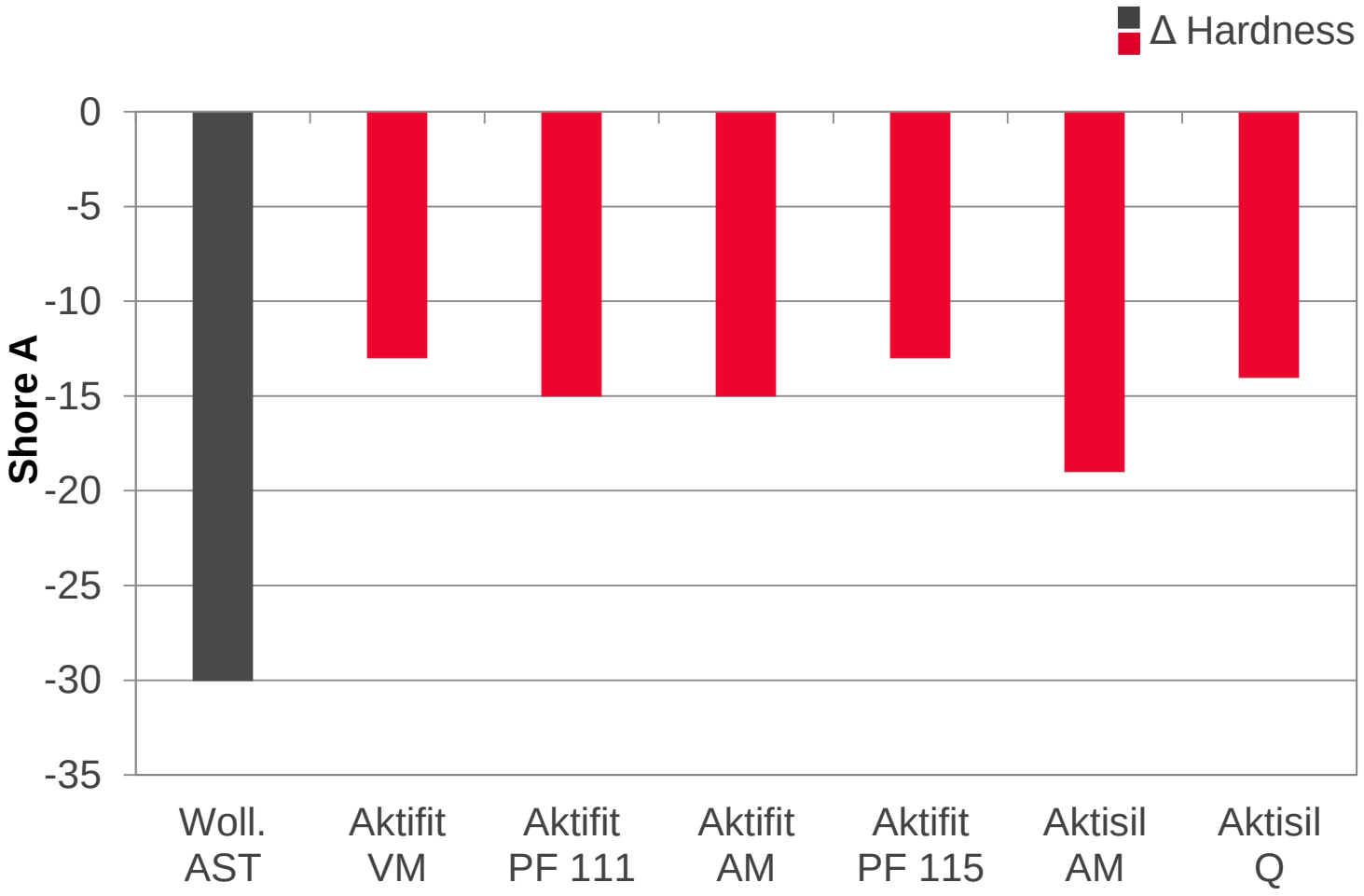
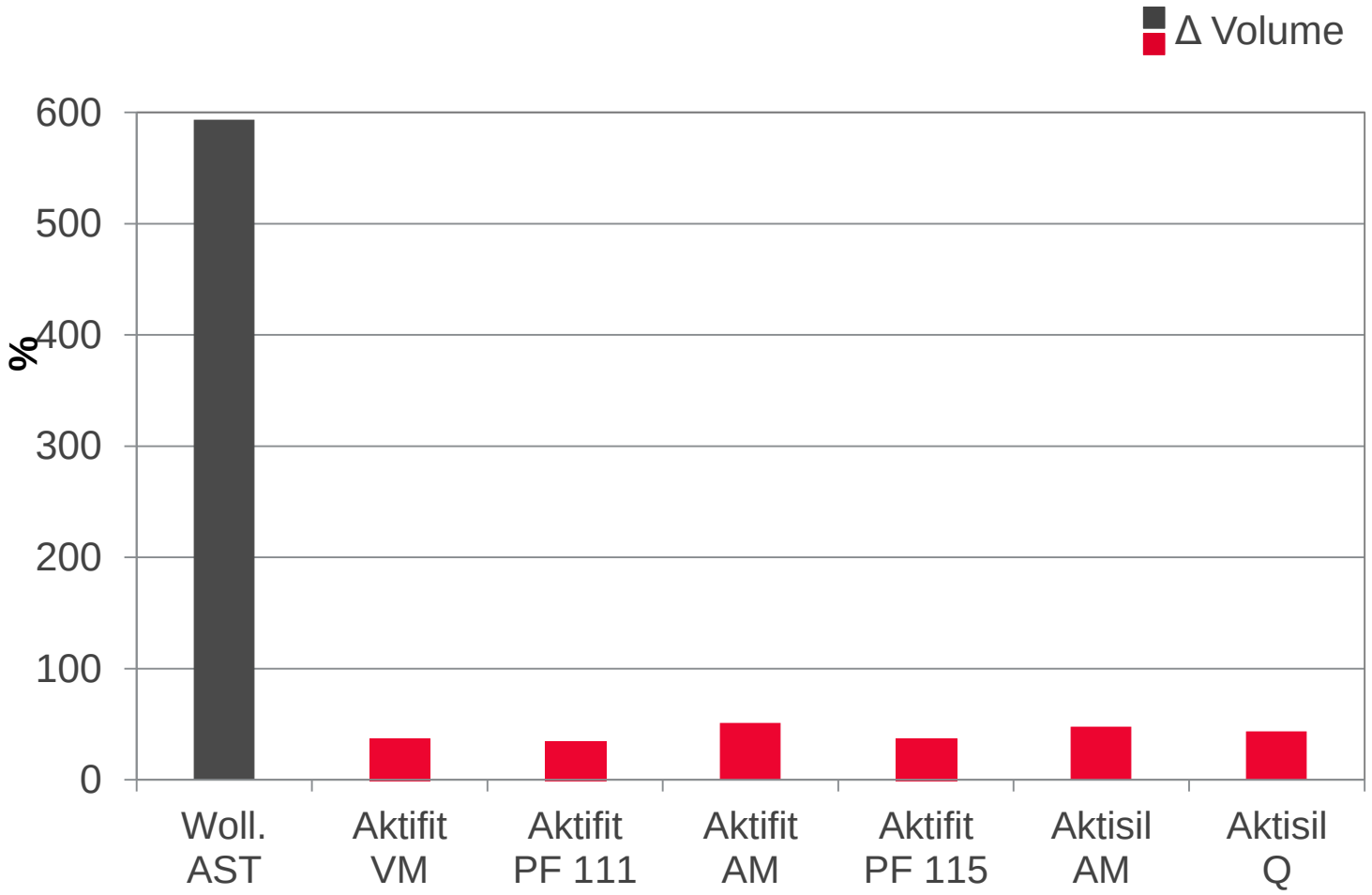
Acetic acid pH 3, 168 h / 100 °C



Wollastonite AST
Acid Resistance

HOFFMANN MINERAL

Acetic acid pH 3, 168 h / 100 °C



Wollastonite AST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C

before	after
	
	Δ weight: +288 % Δ volume: +593 %

Evaluation
NSE vs. Wollastonite AST

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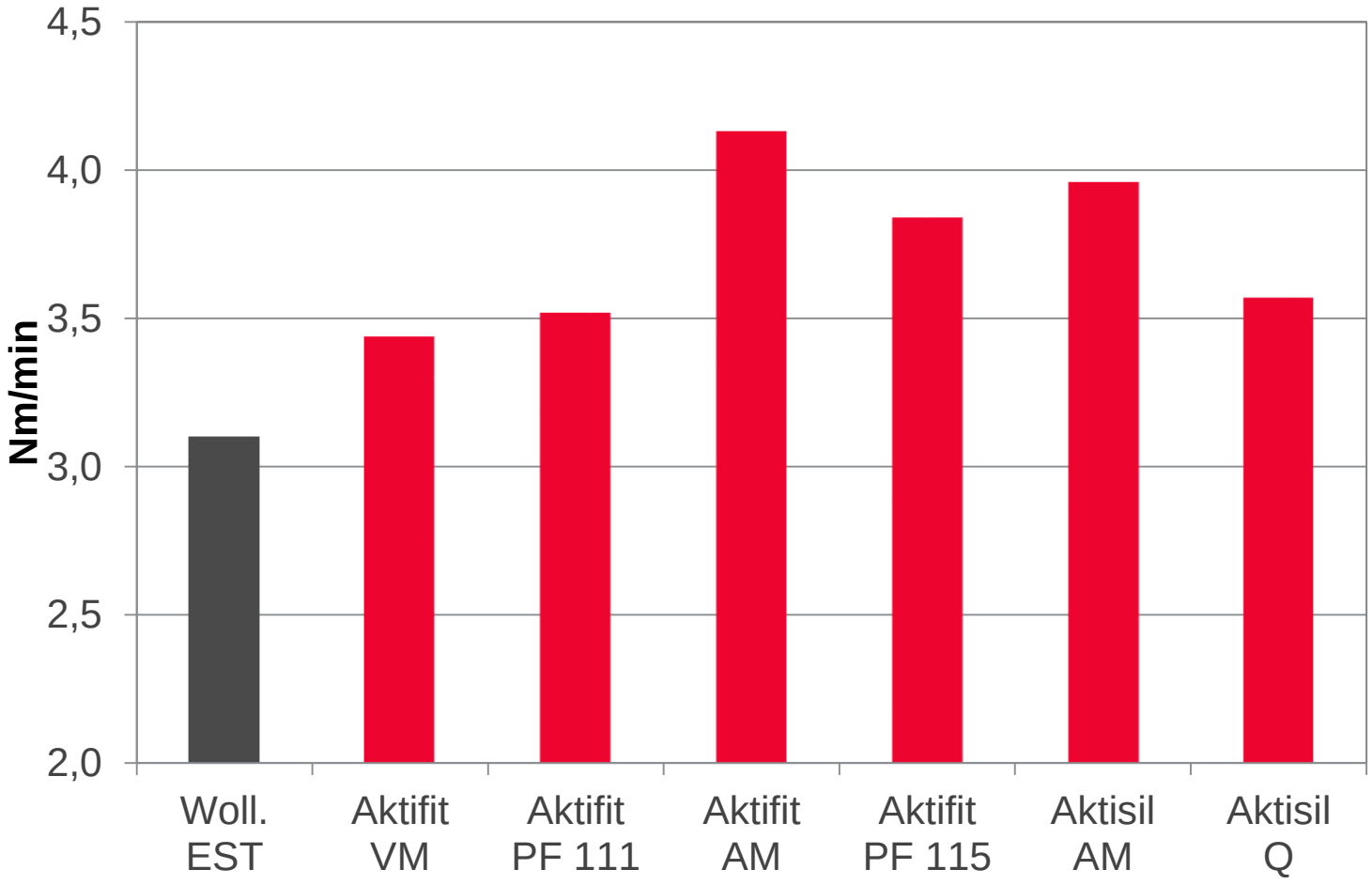
Wollastonite AST 65 Shore A	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Cure speed	=	=	+	+	+	=
Viscosity	=	=	=	=	=	=
Tensile strength (TS)	+	+	+	=	+	=
Elongation at break		=	=	=	=	
Modulus 100 %	+	=	+	+	+	+
CS ISO 200 °C	=	=	=	=	=	=
CS ISO 200 °C, no post-cure	+	=	+	=	=	+
CS ISO 232 °C	=	+	=	=	=	+
CS ISO 232 °C, no post-cure	+	+	+	=	+	+
CS VW 23 °C	=	=	=	=	+	=
CS VW 150 °C	=	=	=	=	=	=
Abrasion resistance	+	+	+	+	+	+
Hot air resistance 210 °C	=	=	=	=	=	=
TS after storage in hot air 210 °C	+	+	+	=	+	+
Hot air resistance 230 °C	=	=	=	=	=	=
TS after storage in hot air 230 °C	+	+	+	=	+	=
Fuel resistance	=	=	=	=	=	=
TS after storage in fuel	+	+	+	=	+	+
Oil resistance		=	+		=	+
TS after storage in oil	=	+	+	=	+	+
Resistance to acetic acid	+	+	+	+	+	+

Neuburg Siliceous Earth vs. Wollastonite EST

Hardness
65 Shore A

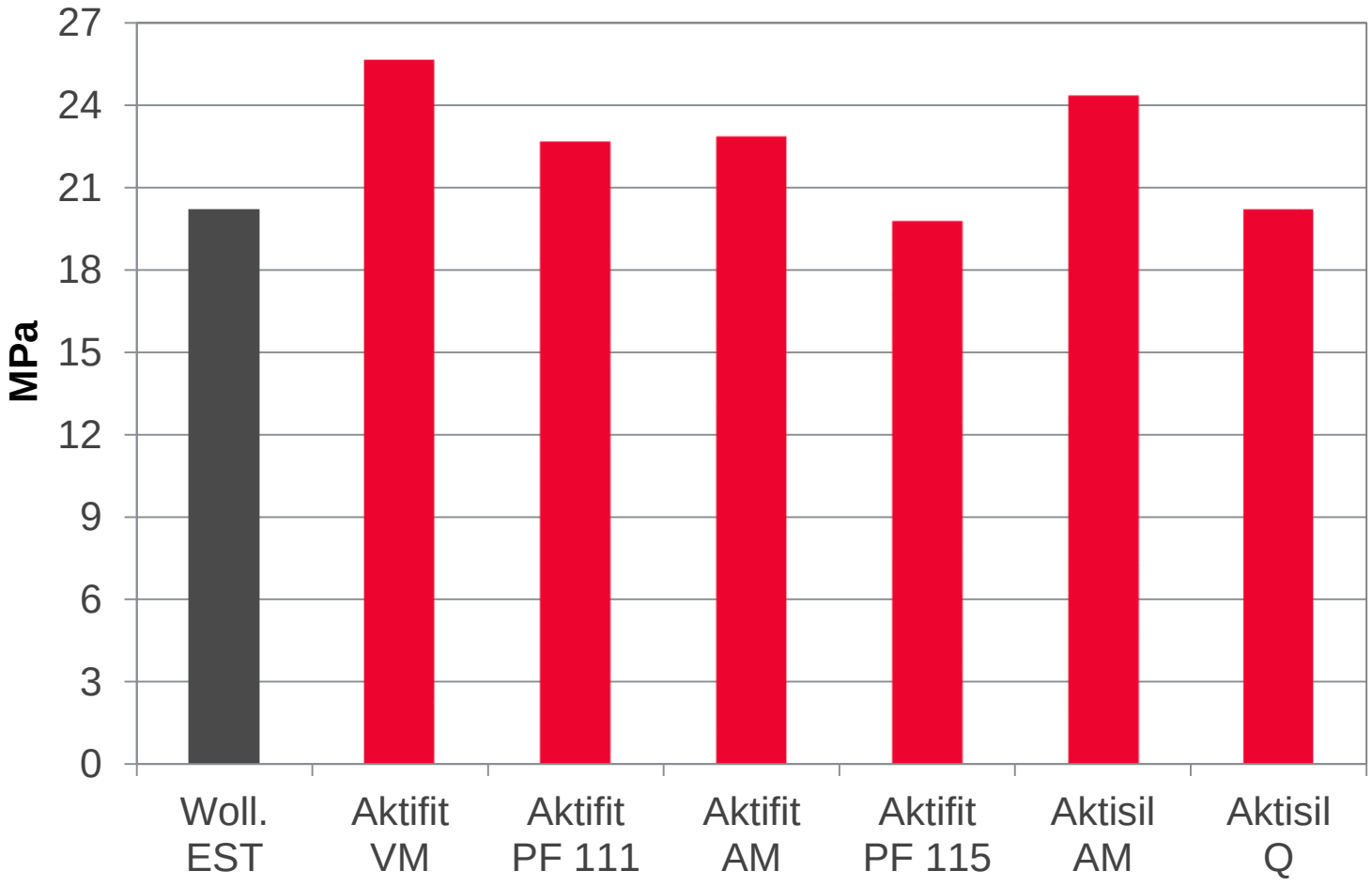
Wollastonite EST
Max. Cure Speed

DIN 53 529, T3 – Göttfert Elastograph, 177 °C, Amplitude 0.2°



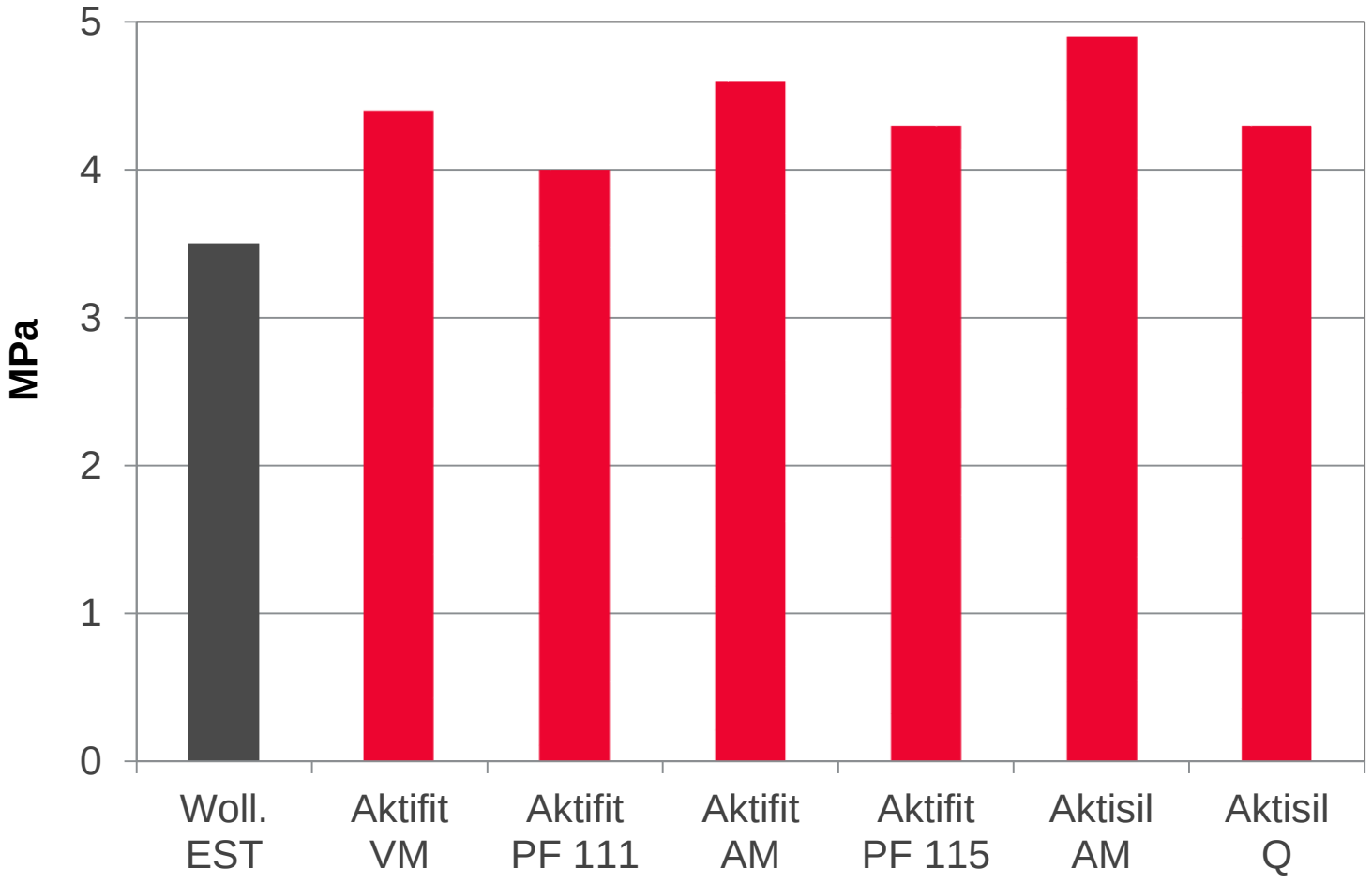
Wollastonite EST
Tensile Strength

DIN 53 504, S2



Wollastonite EST
Modulus 100 %

DIN 53 504, S2



Wollastonite EST
Compression Set ISO

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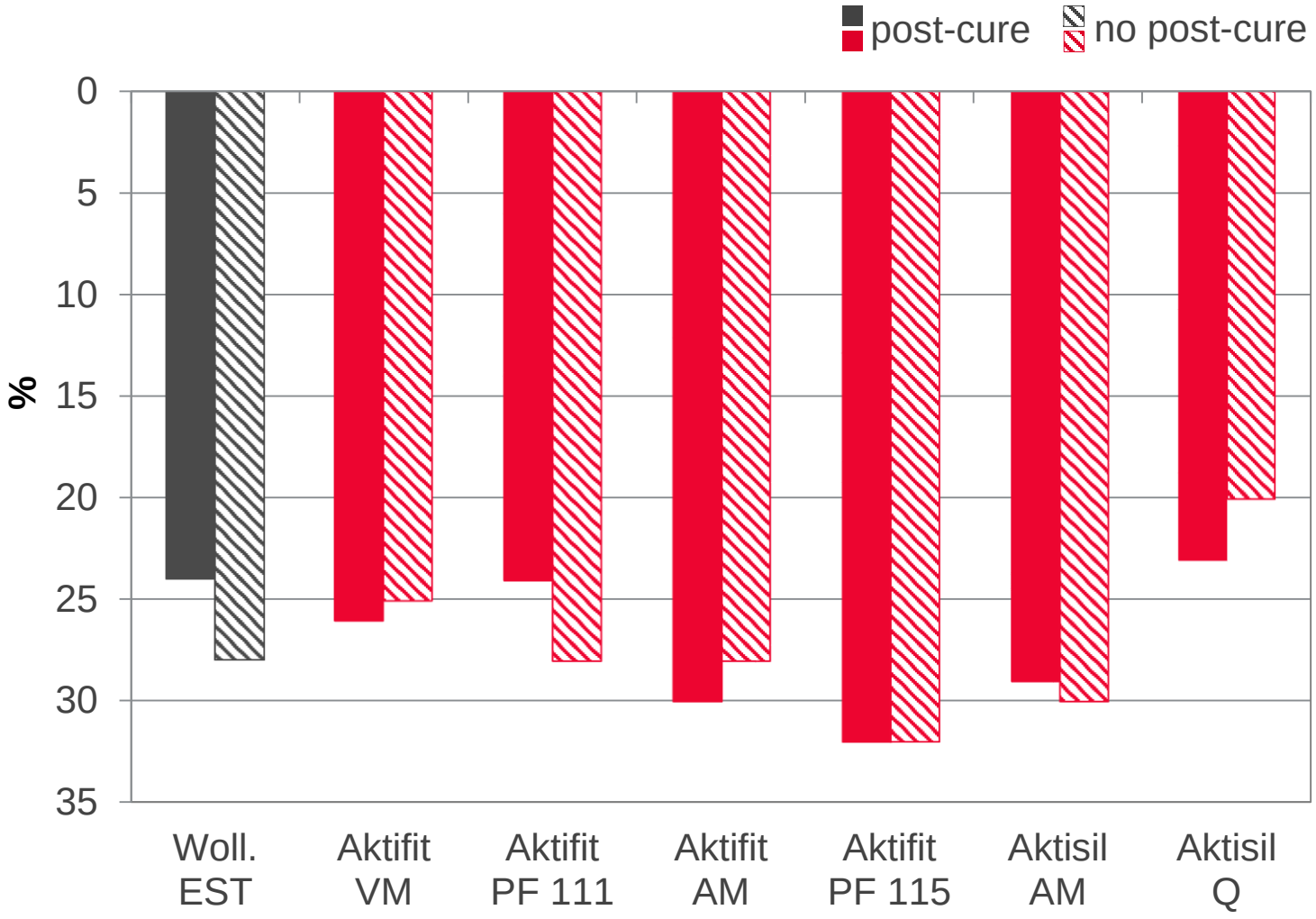
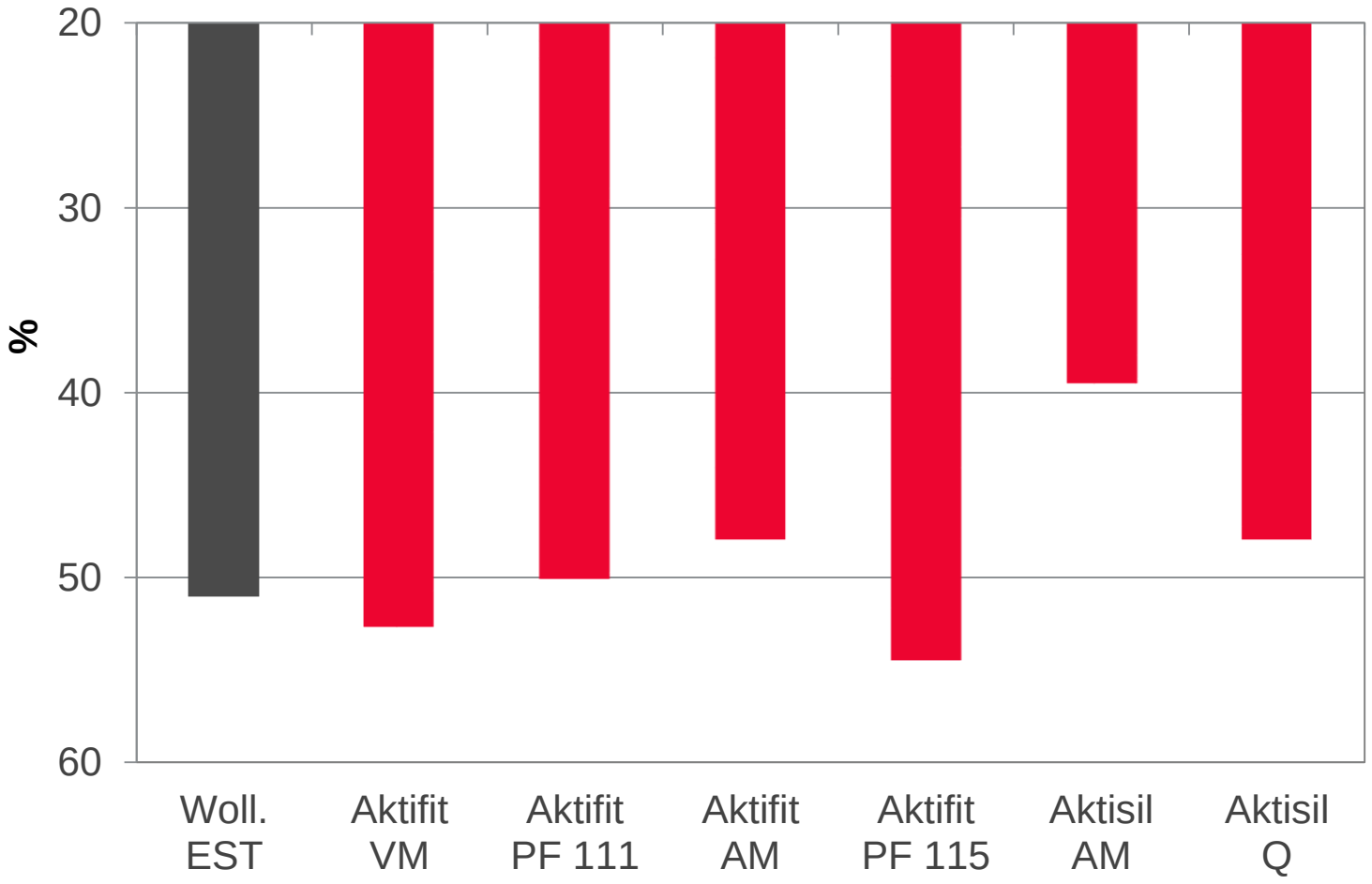
DIN ISO 815-1 B, 25 % defl., 70 h / 232 °C



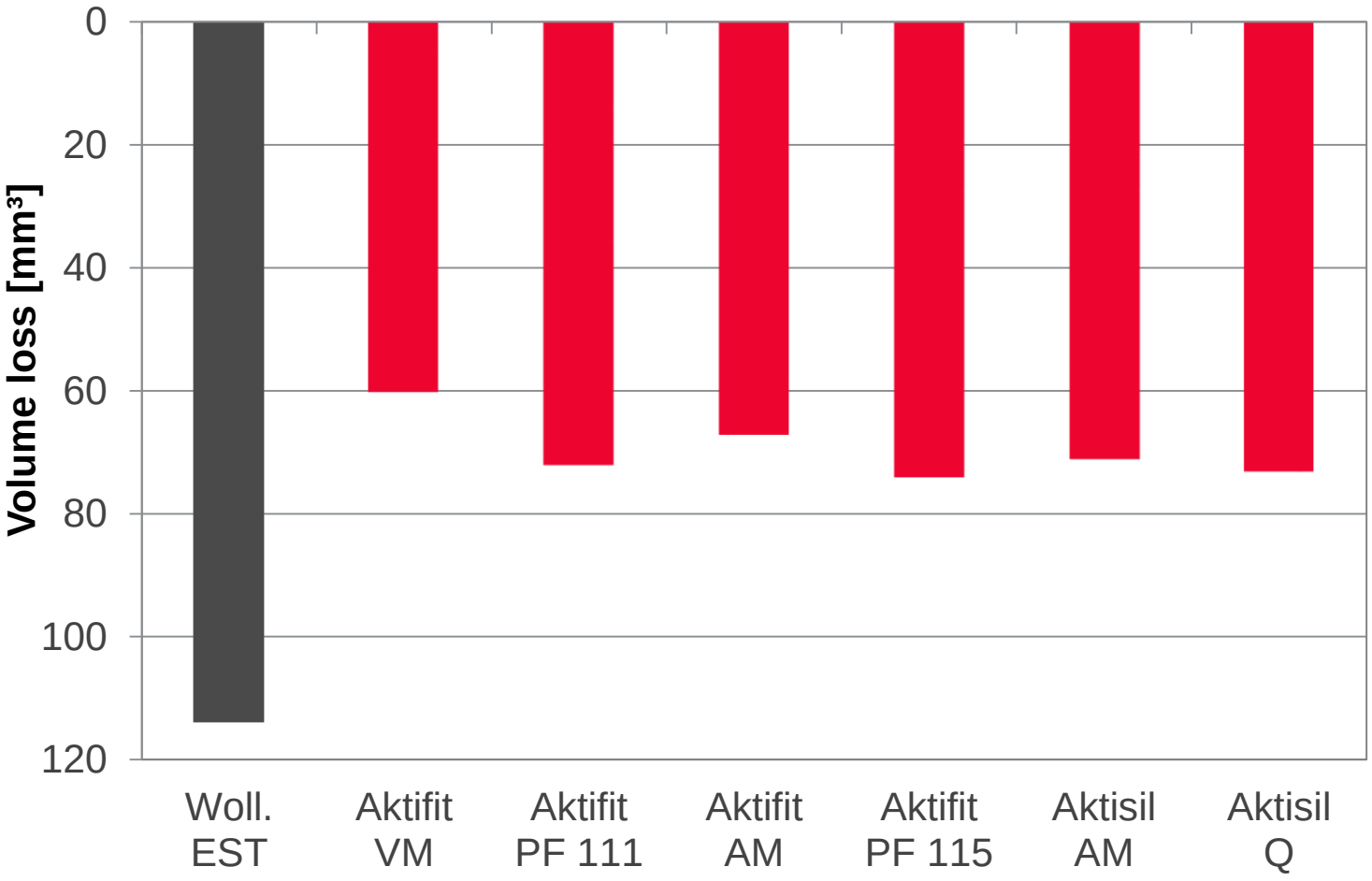
Wollastonite EST
Compression Set VW

VW PV 3307, 50 % defl., 5 s, 94 h / 23 °C

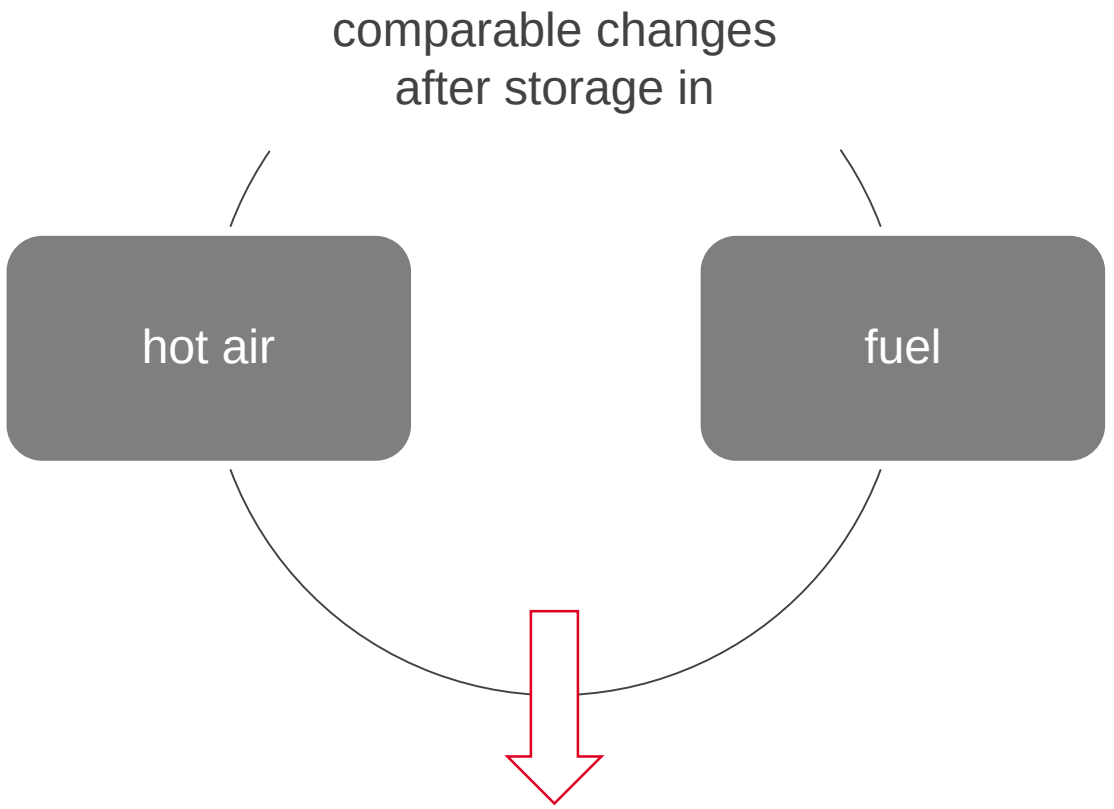


Wollastonite EST
Abrasion Resistance

DIN ISO 4649



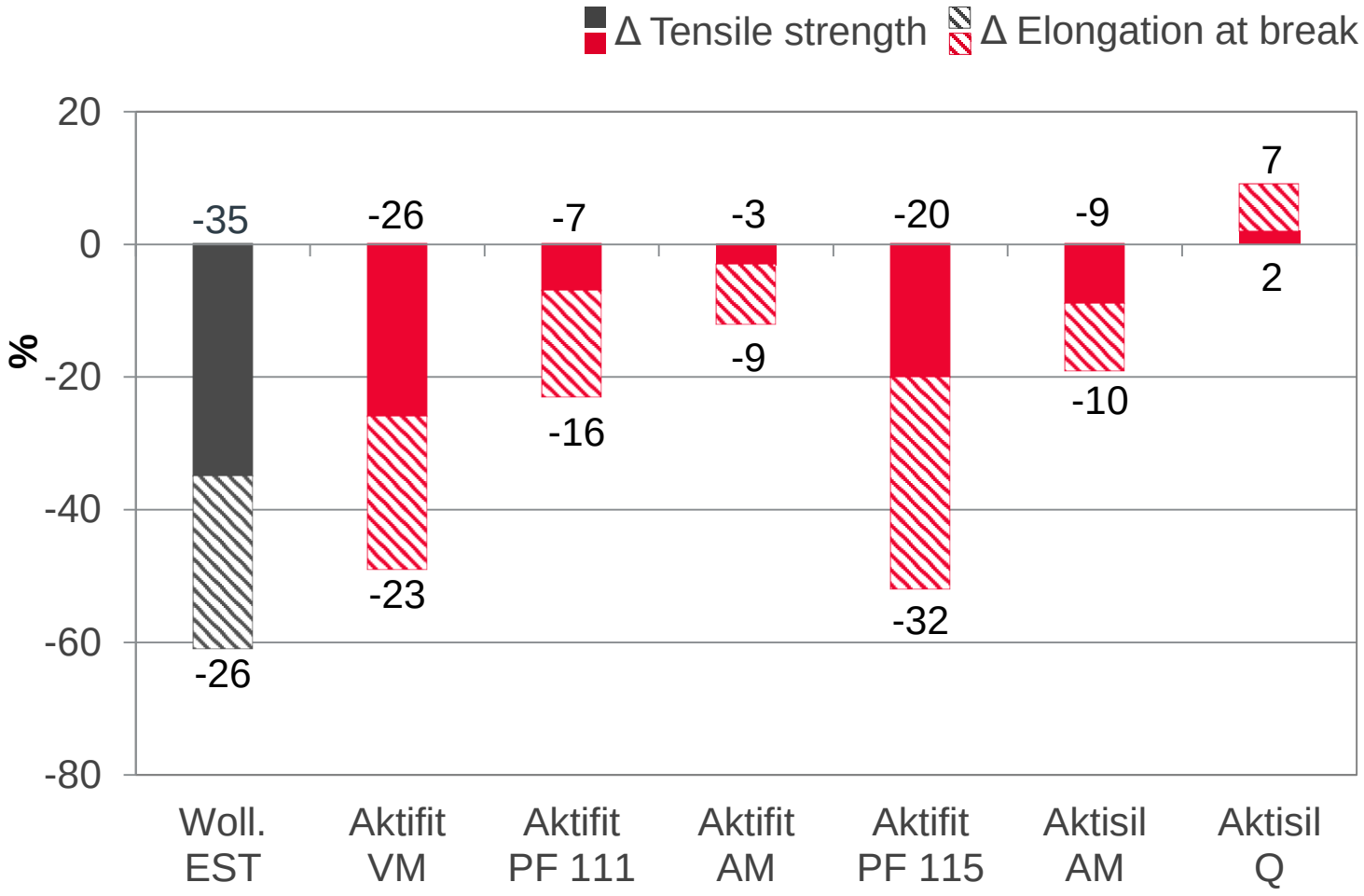
Wollastonite EST
Media Resistance



higher tensile strength and comparable elongation at break are retained with Neuburg Siliceous Earth

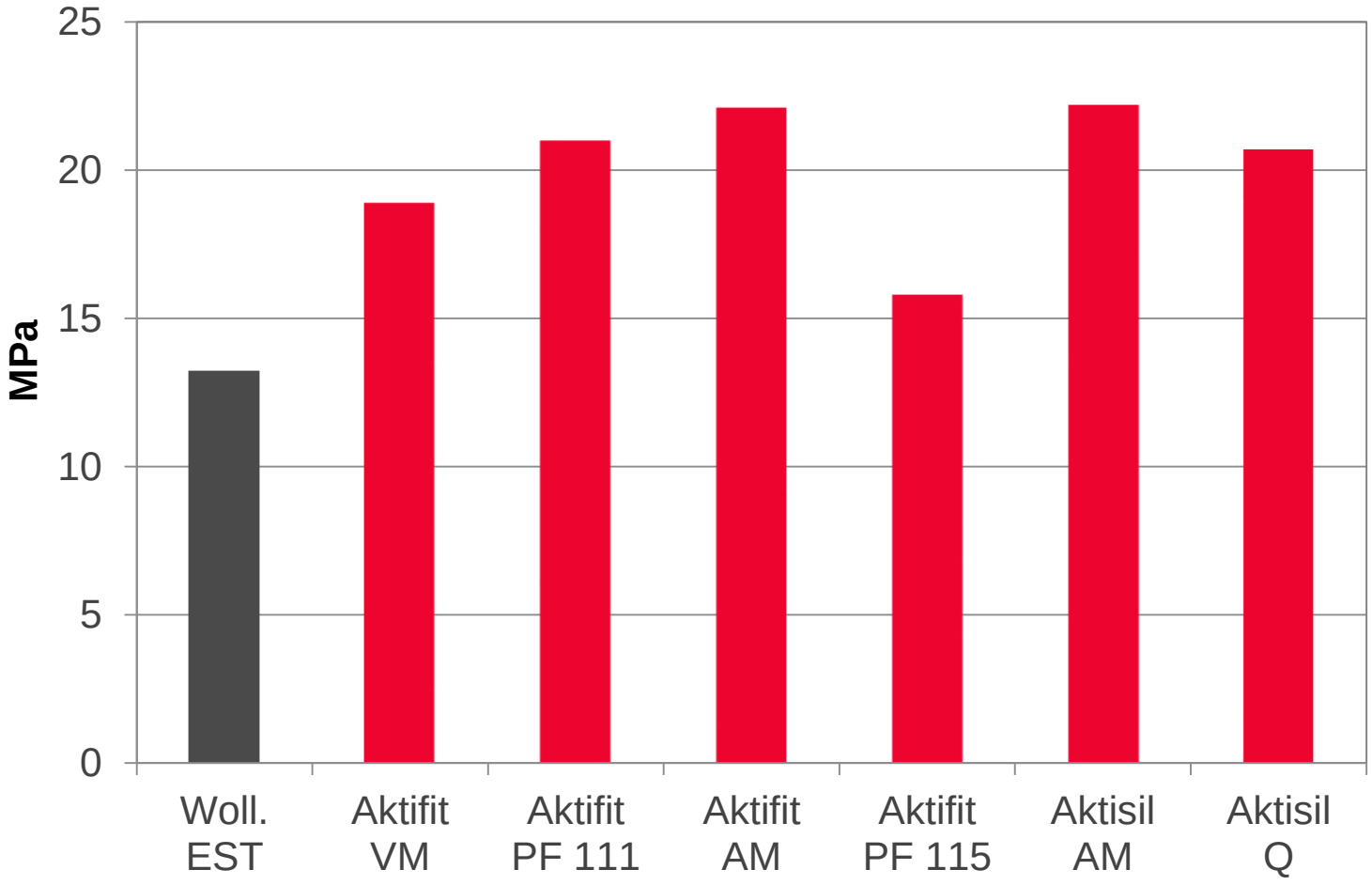
Wollastonite EST
Oil Resistance

OS206304, 168 h / 150 °C



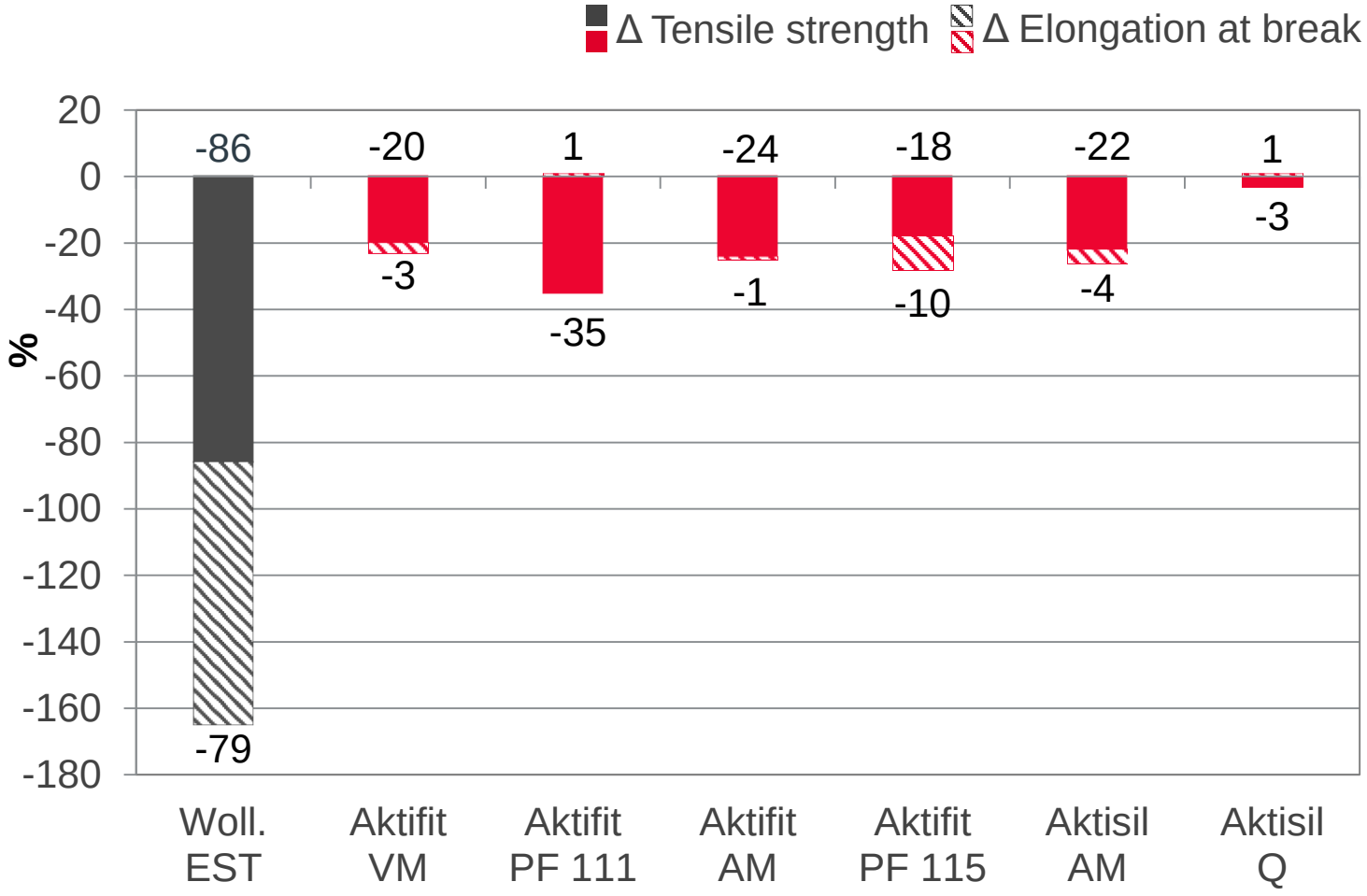
Wollastonite EST
Oil Resistance – Tensile Strength

DIN 53 504, S2



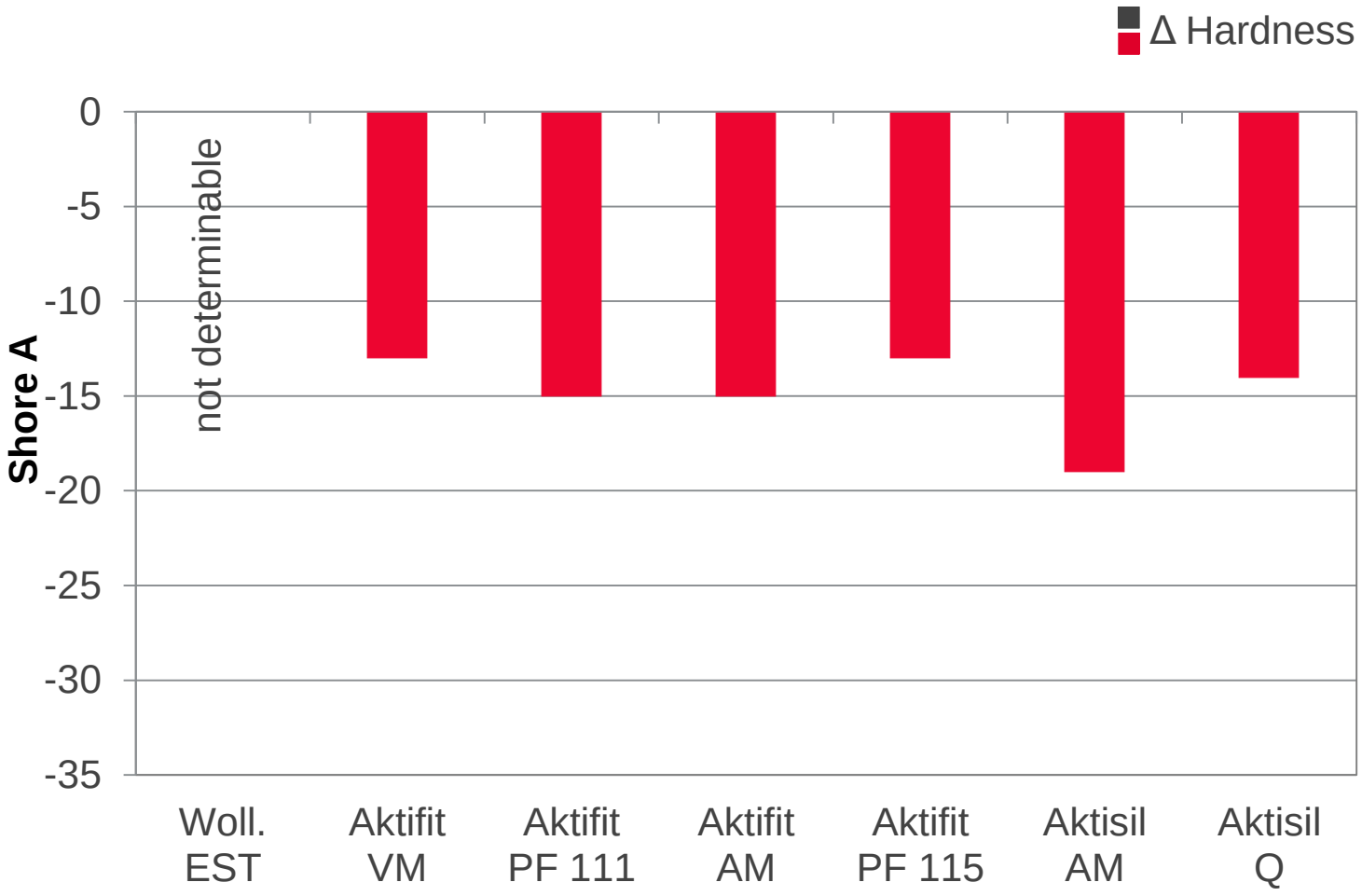
Wollastonite EST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C



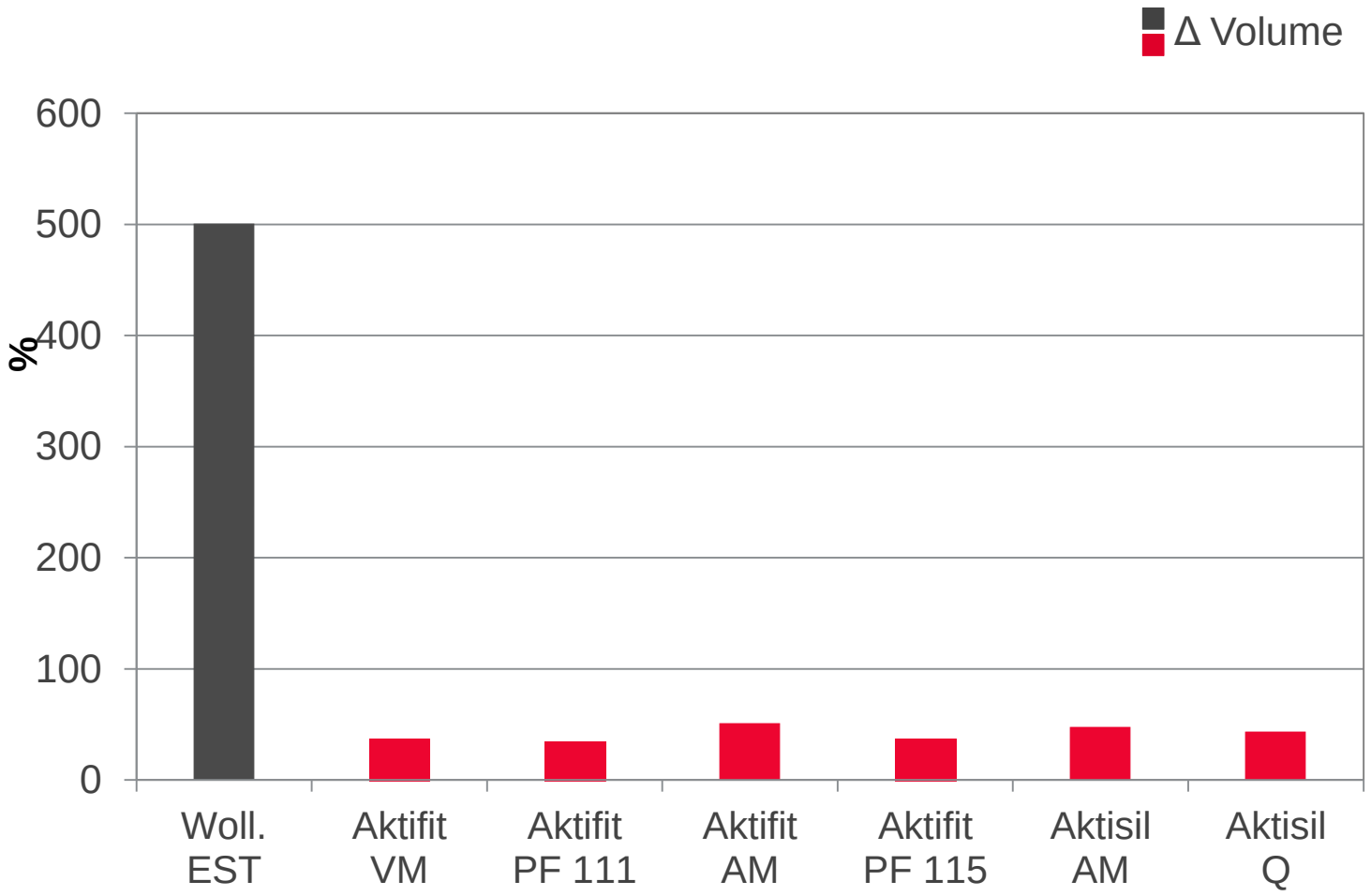
Wollastonite EST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C



Wollastonite EST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C



Wollastonite EST
Acid Resistance

Acetic acid pH 3, 168 h / 100 °C

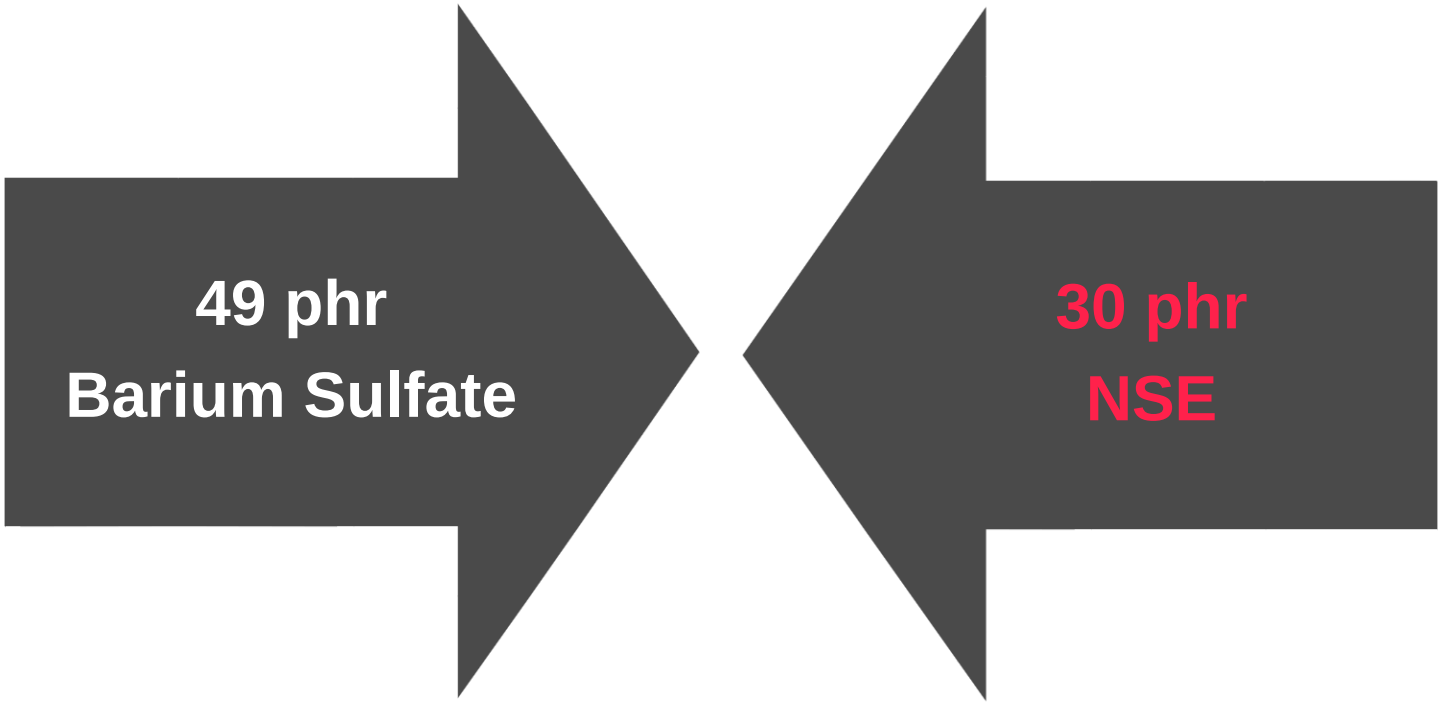
before	after
	
	Δ weight: +227 % Δ volume: +500 %

Evaluation
NSE vs. Wollastonite EST

HOFFMANN MINERAL

Wollastonite EST 65 Shore A	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Cure speed	+	+	+	+	+	+
Viscosity	=	=	=	=	=	=
Tensile strength (TS)	+	+	+	=	+	=
Modulus100 %	+	+	+	+	+	+
CS ISO 200 °C	=	=	=	=	=	=
CS ISO 200 °C, no post-cure	=	=	=	=	=	=
CS ISO 232 °C	=	=				=
CS ISO 232 °C, no post-cure	=	=	=		=	+
CS VW 23 °C	=	=	=	=	+	=
CS VW 150 °C	=	=	=	=	=	=
Abrasion resistance	+	+	+	+	+	+
Hot air resistance 210 °C	=	=	=		=	
TS after hot air 210 °C	+	+	+	=	+	=
Hot air resistance 230 °C	=	=	=		=	
TS after hot air 230 °C	+	+	+	=	+	=
Fuel resistance	=	=	=	=	=	=
TS after storage in fuel	+	+	+	+	+	+
Oil resistance	=	+	+	=	+	+
TS after storage in oil	+	+	+	+	+	+
Resistance to acetic acid	+	+	+	+	+	+

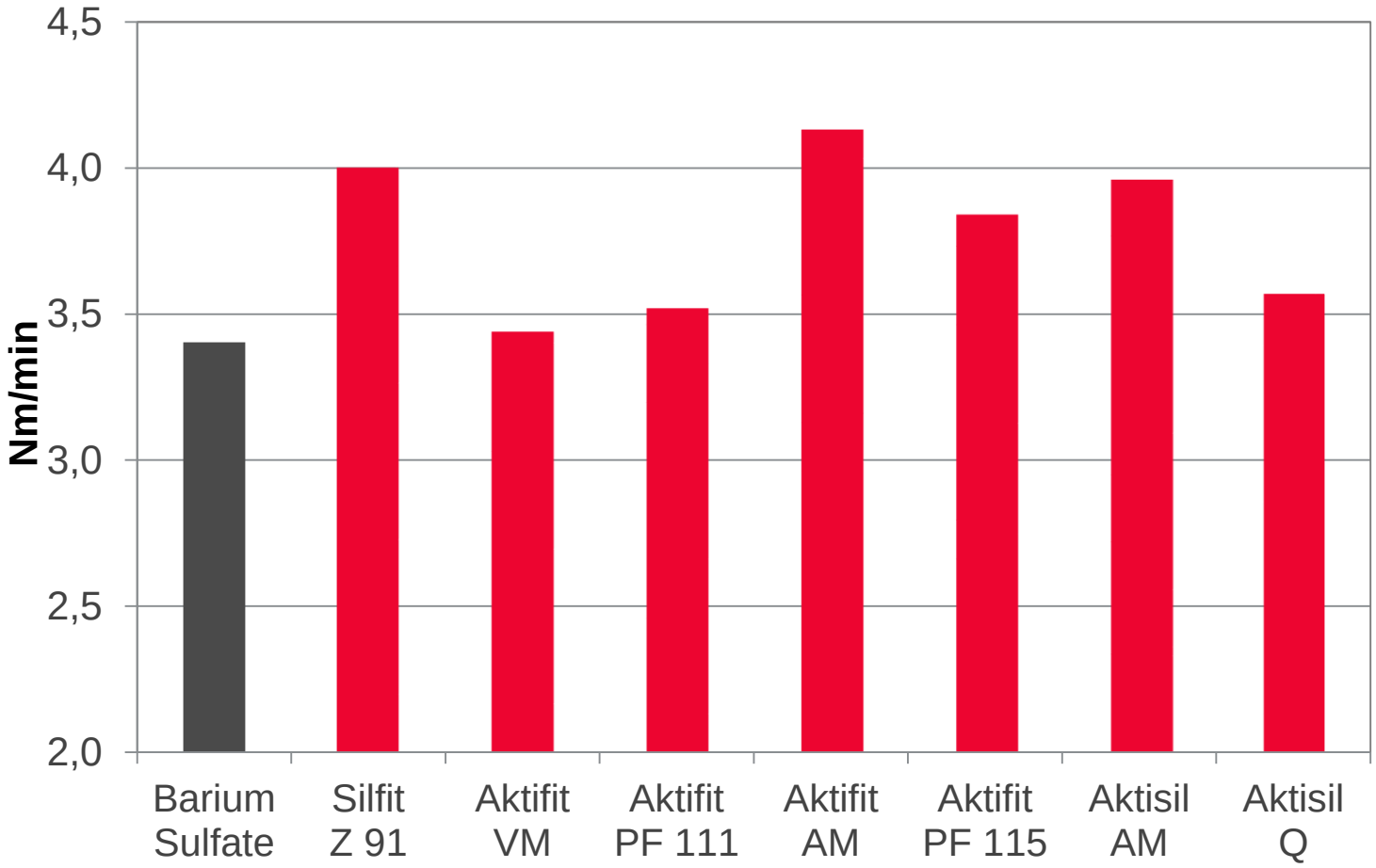
Neuburg Siliceous Earth vs. Barium Sulfate



Hardness
65 Shore A

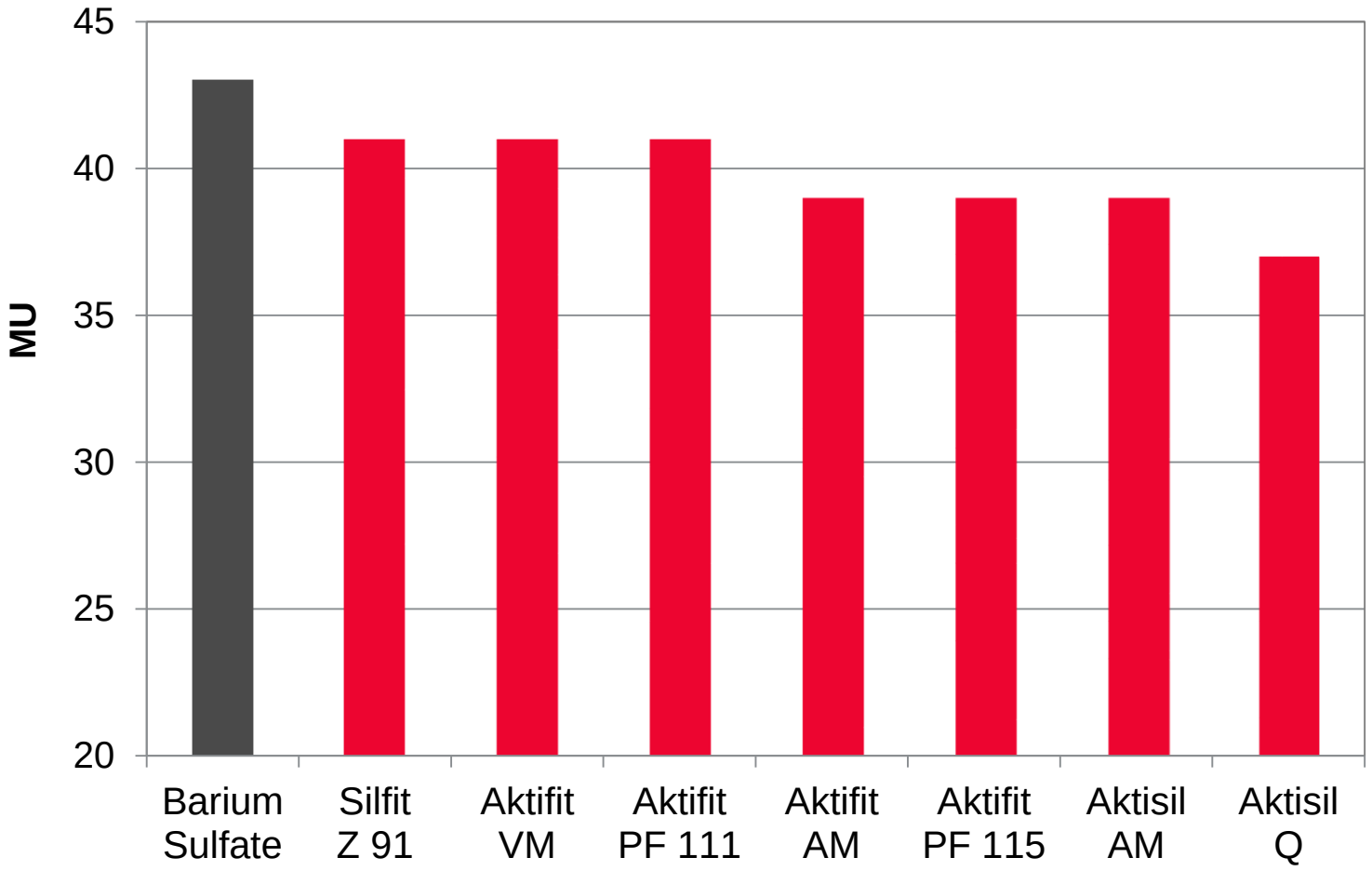
Barium Sulfate
Max. Cure Speed

DIN 53 529, T3 – Göttfert Elastograph, 177 °C, Amplitude 0.2°



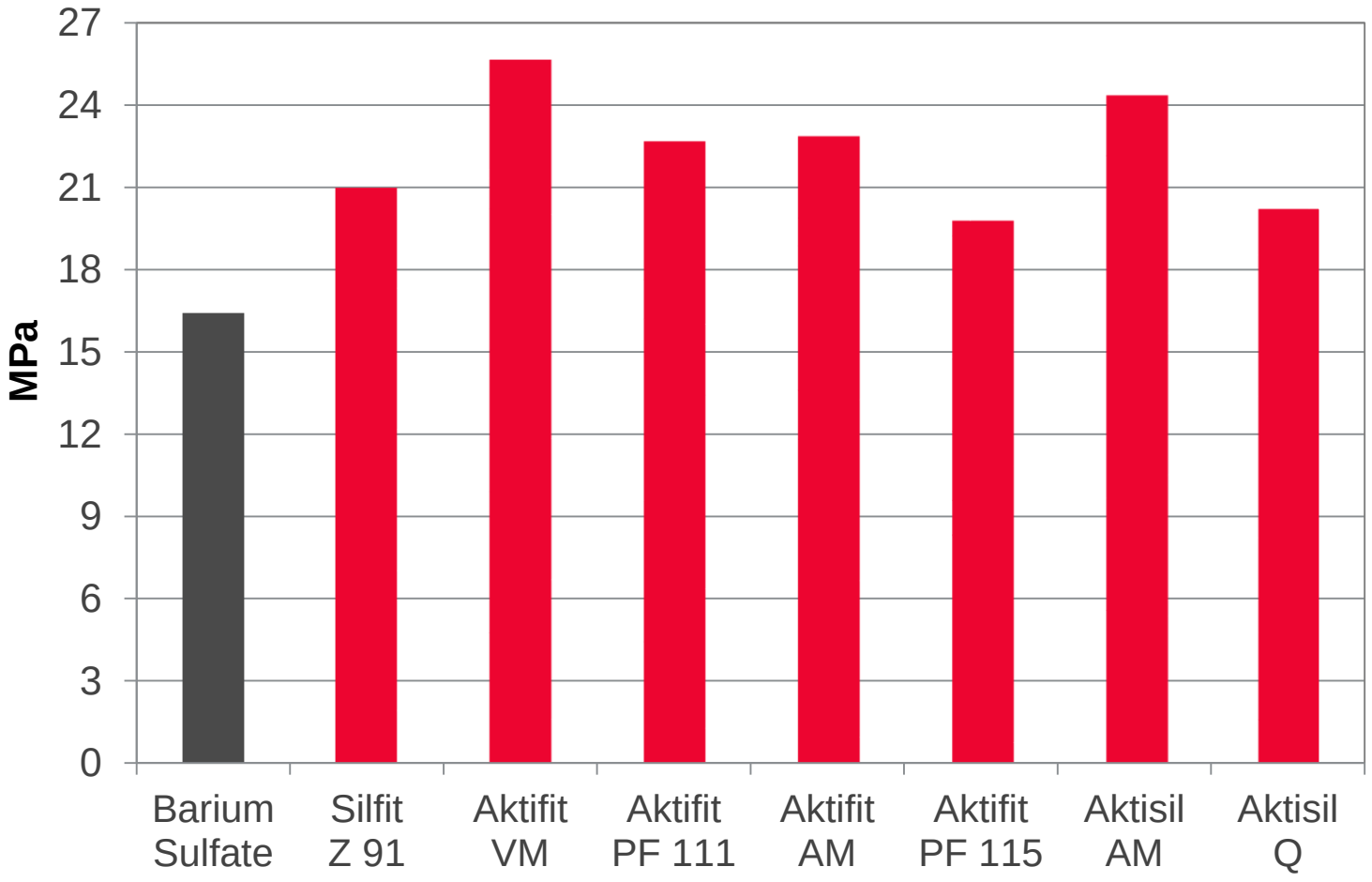
Barium Sulfate
Mooney Viscosity

DIN 53 523 T3, ML 1+4, 120 °C



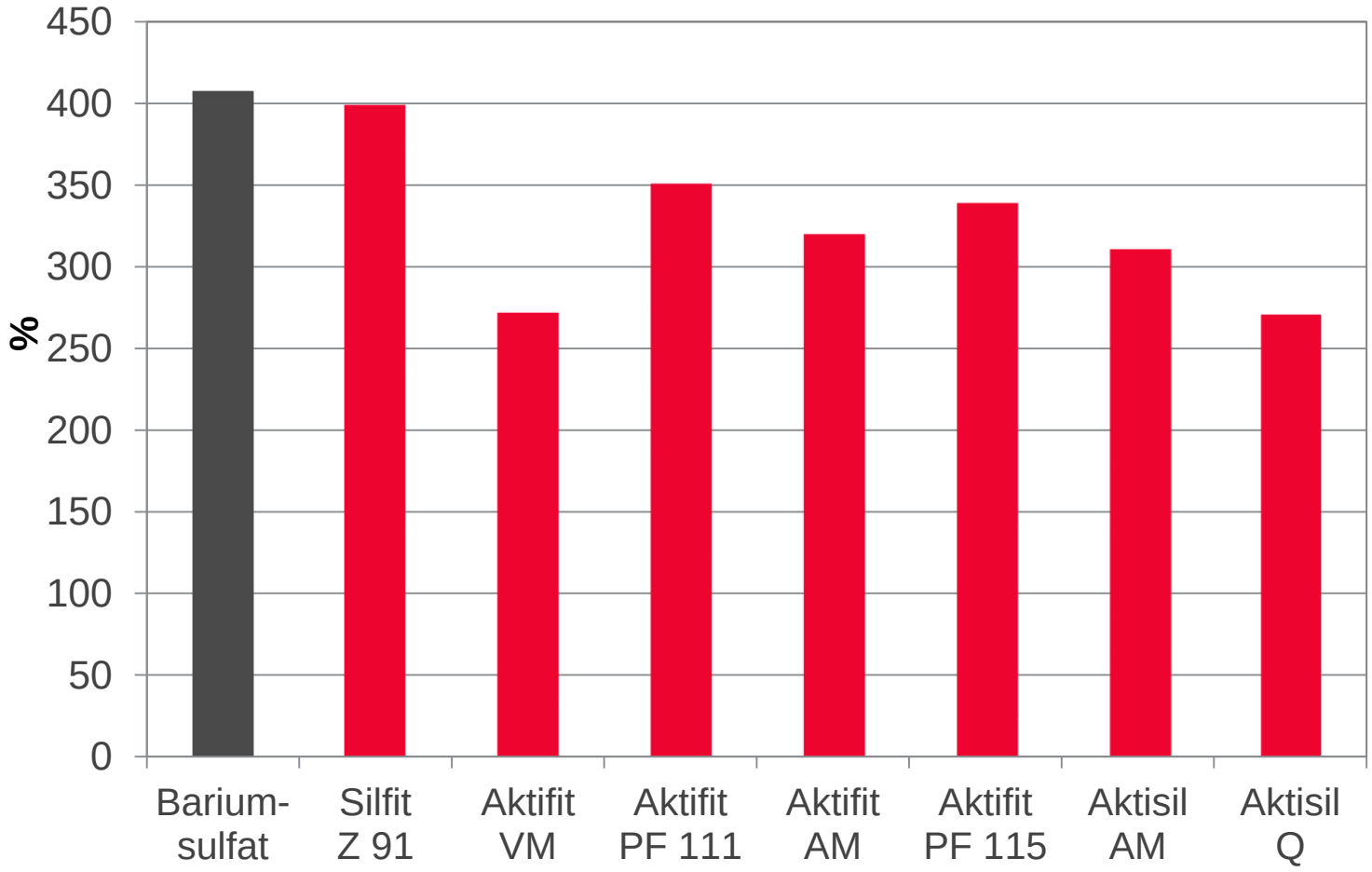
Barium Sulfate
Tensile Strength

DIN 53 504, S2



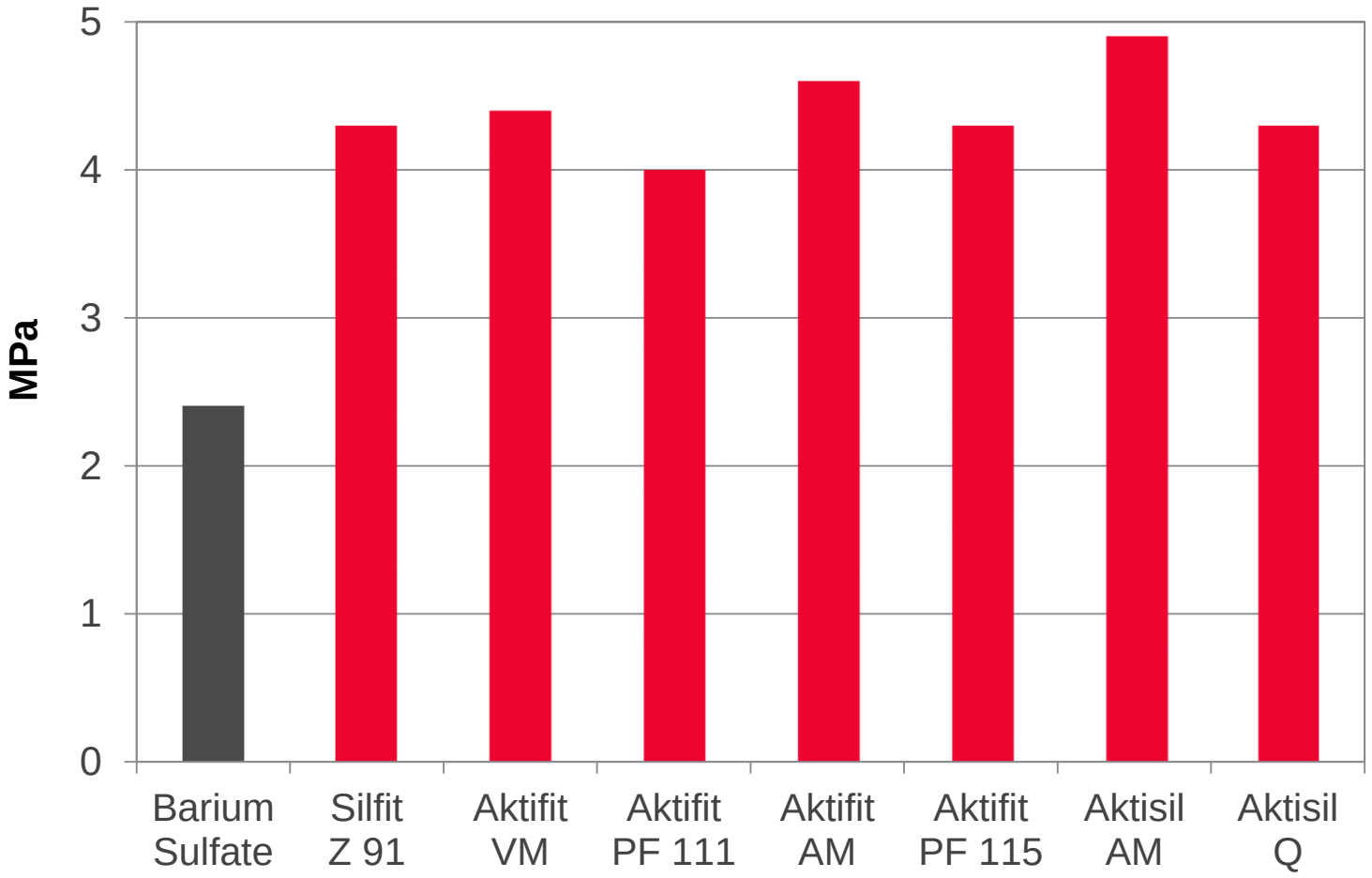
Barium Sulfate
Elongation at Break

DIN 53 504, S2



Barium Sulfate
Modulus 100 %

DIN 53 504, S2



Barium Sulfate
Tear Resistance

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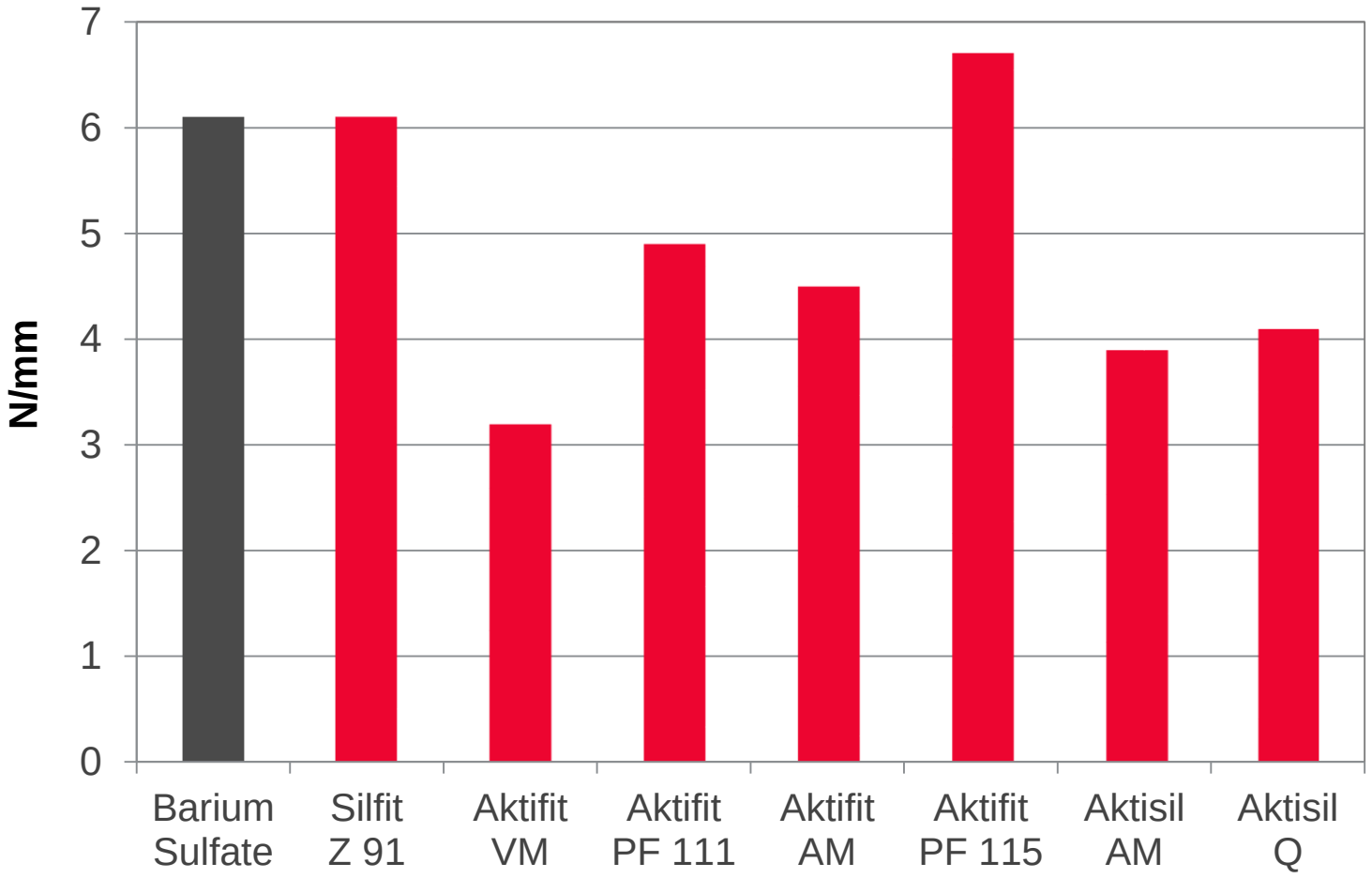
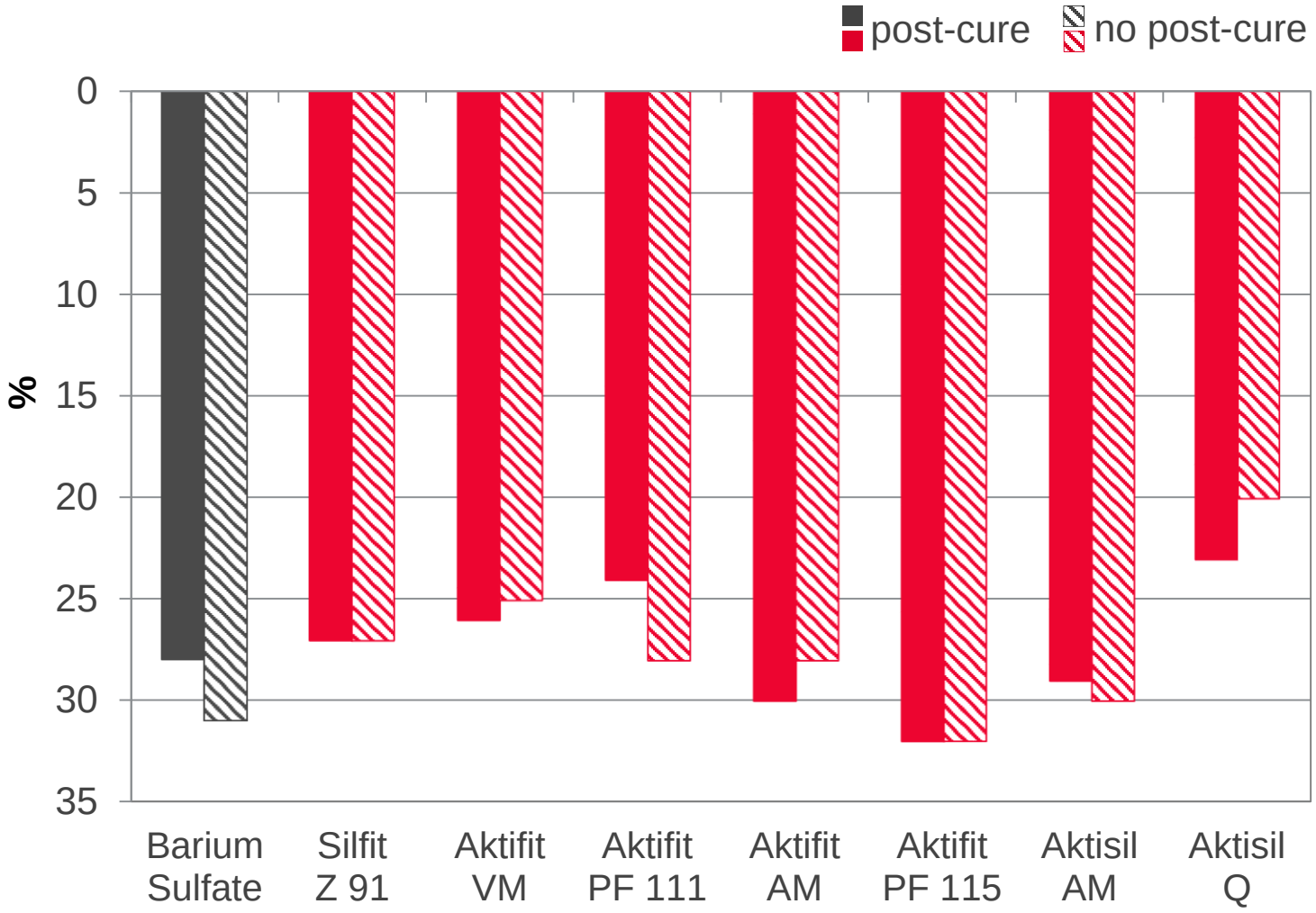
DIN ISO 34-1 A, trouser tear



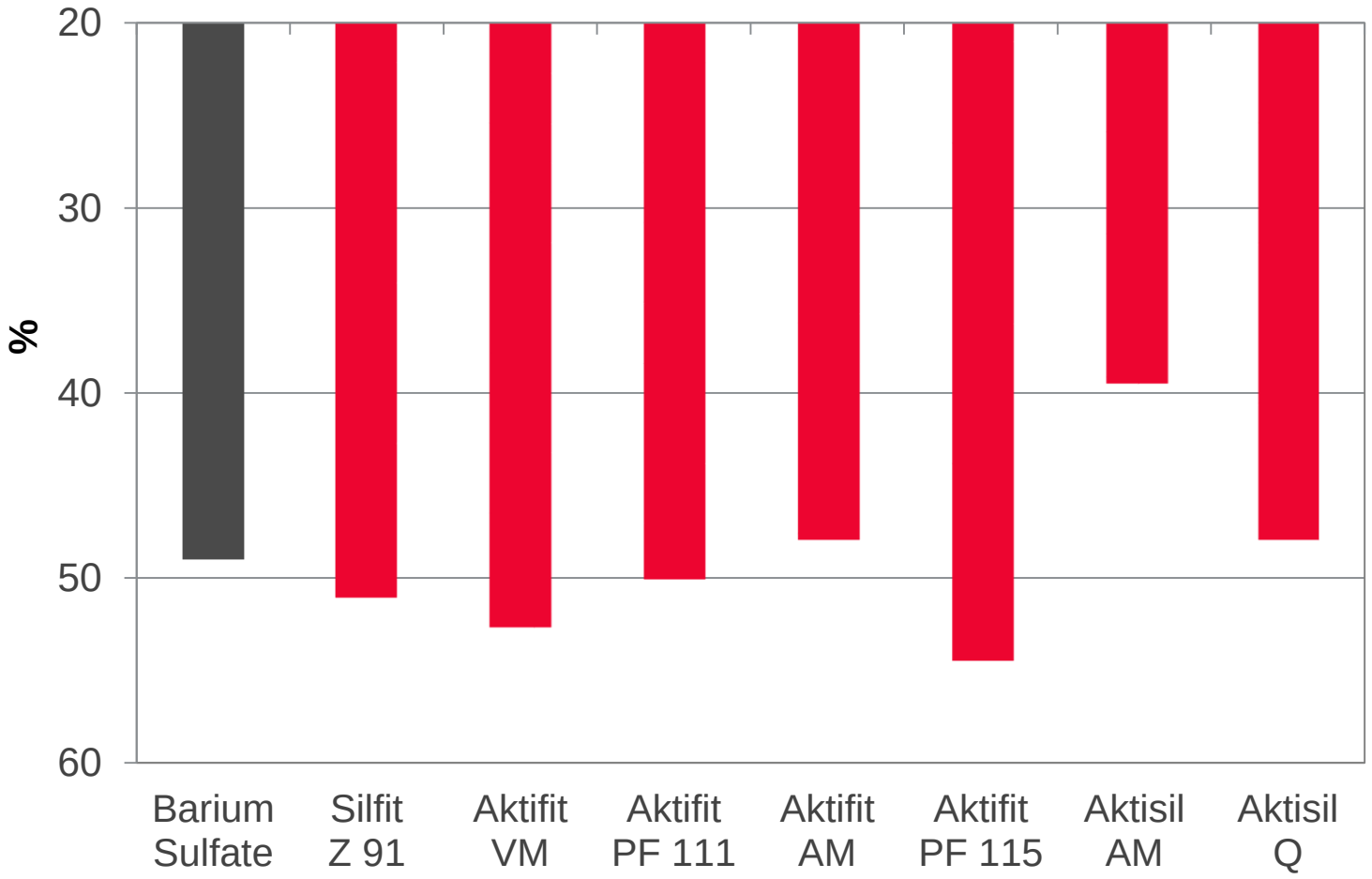
Barium Sulfate
Compression Set ISO

DIN ISO 815-1 B, 25 % defl., 70 h / 232 °C



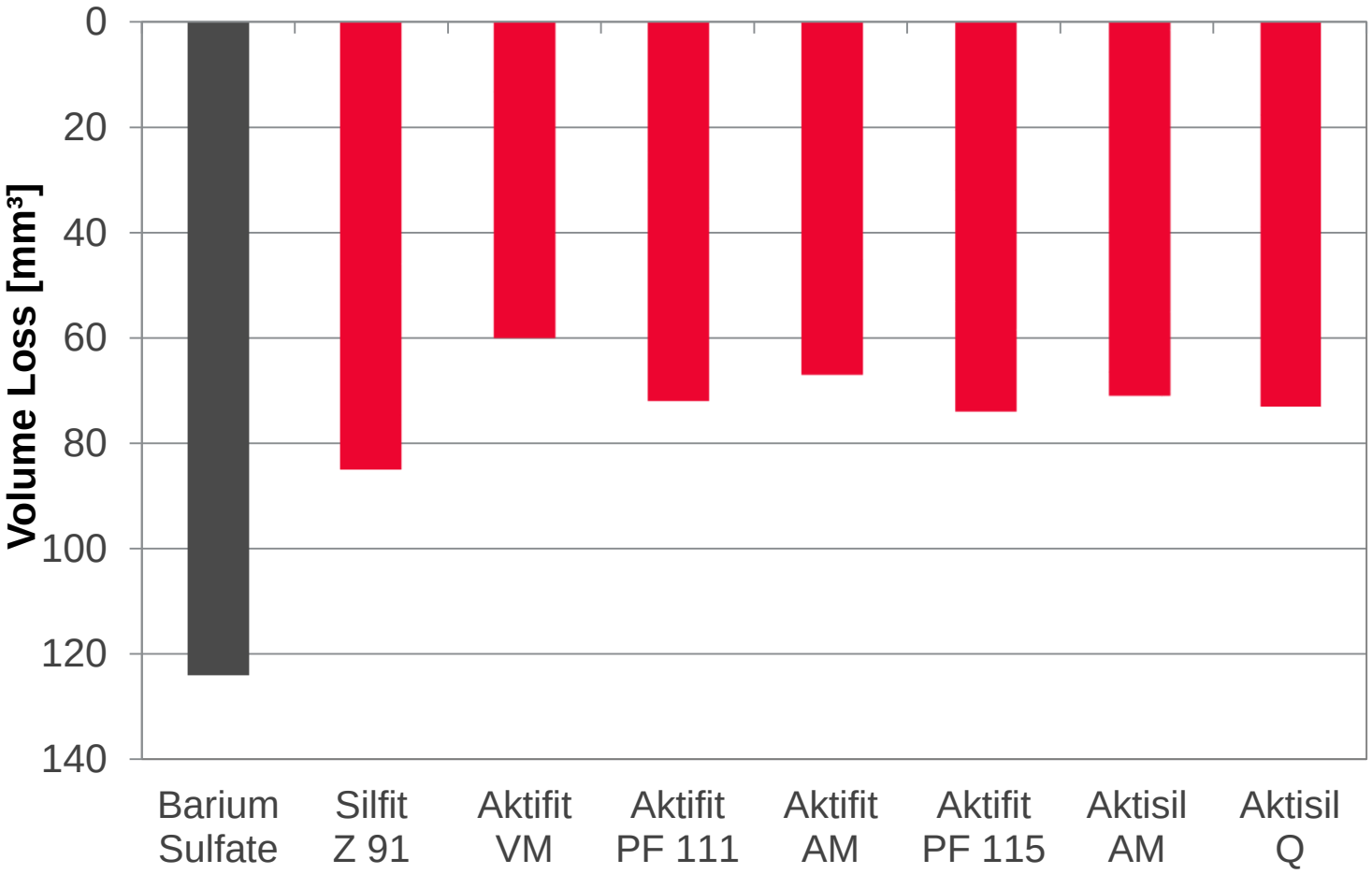
Barium Sulfate
Compression Set VW

VW PV 3307, 50 % defl., 5 s, 94 h / 23 °C



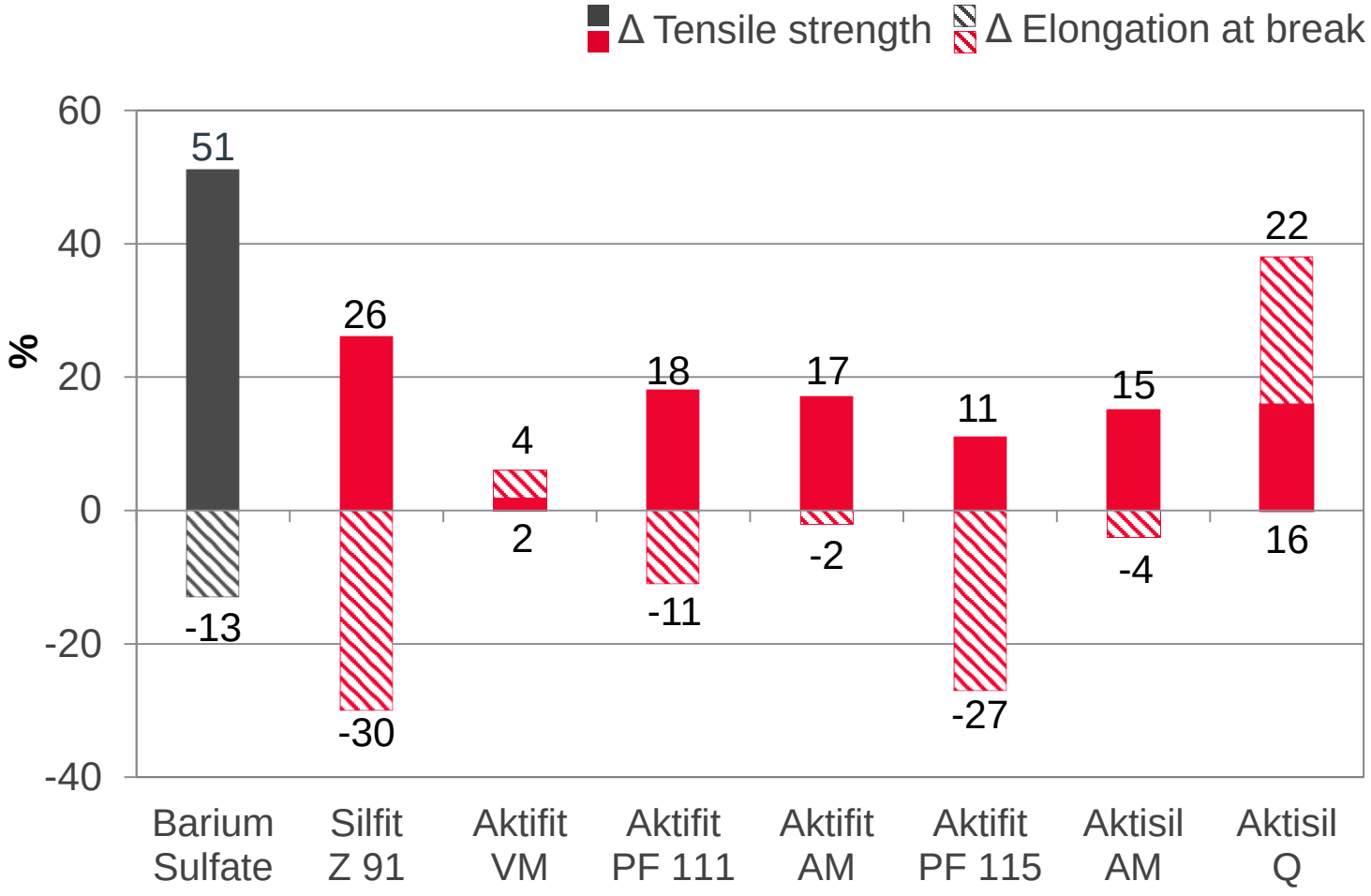
Barium Sulfate
Abrasion Resistance

DIN ISO 4649



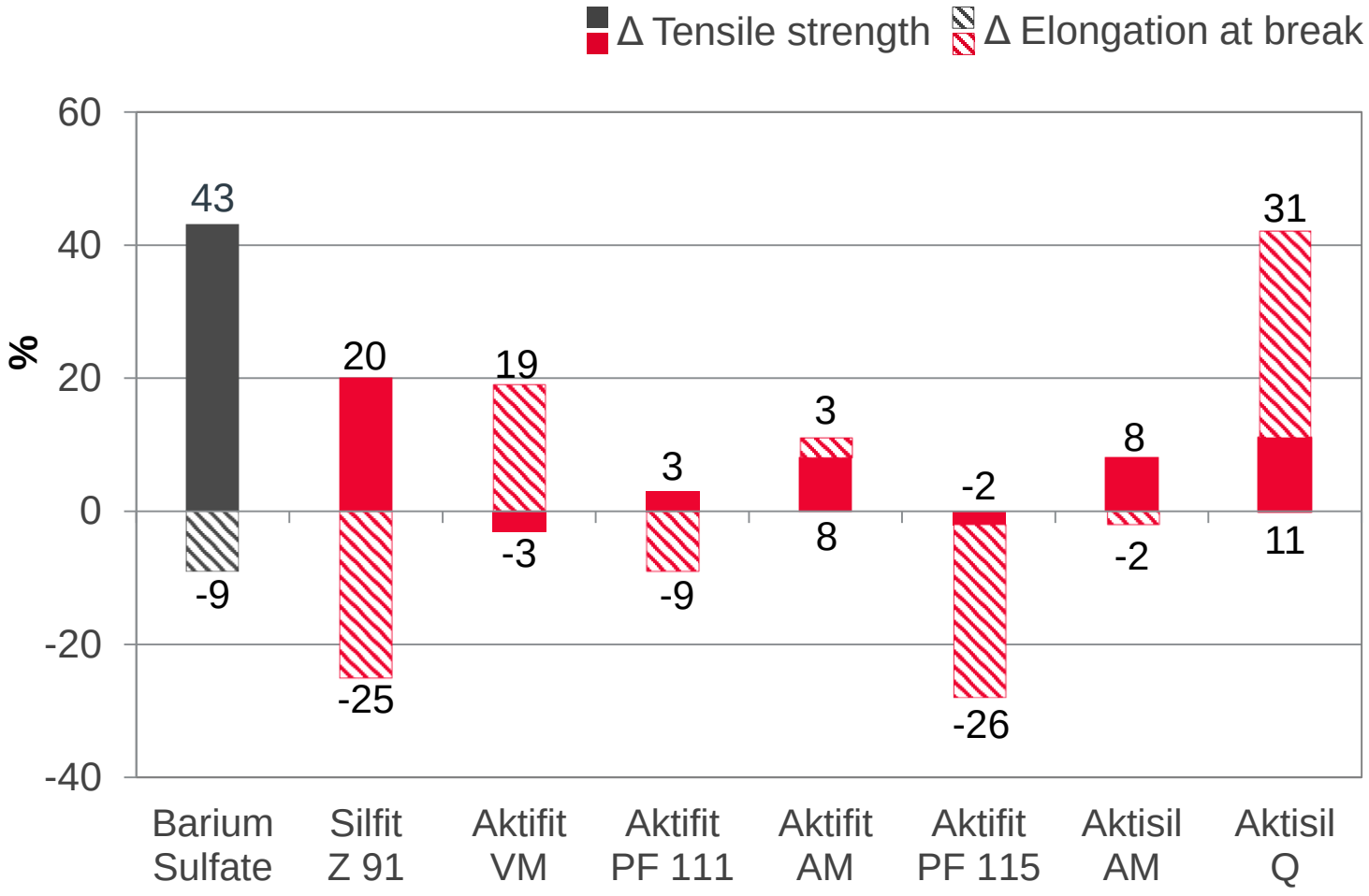
Barium Sulfate
Hot Air Resistance – 230 °C

94 h / 230 °C, determined 30 min. after removal



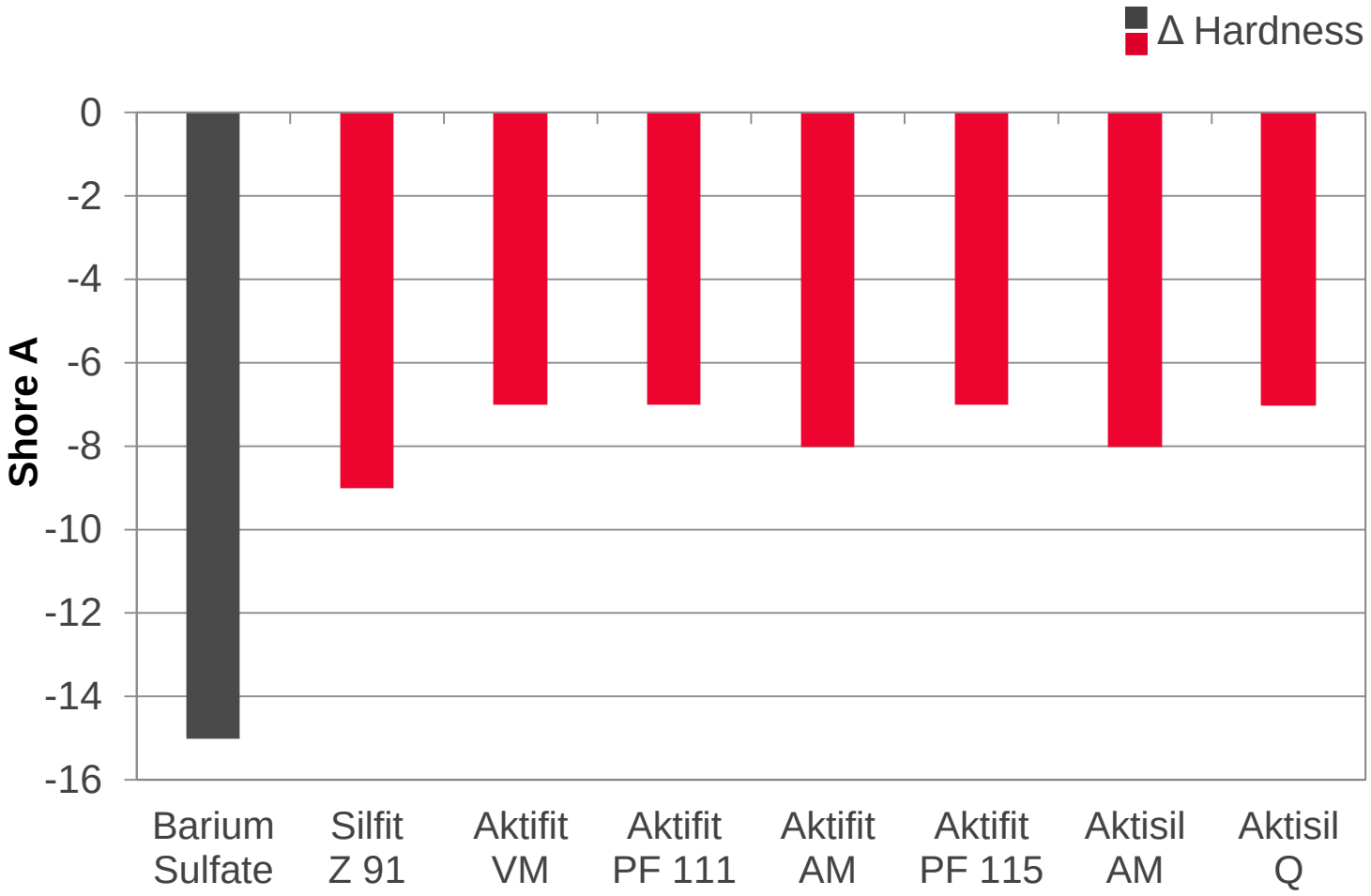
Barium Sulfate
Hot Air Resistance – 210 °C

504 h / 210 °C, determined 30 min. after removal



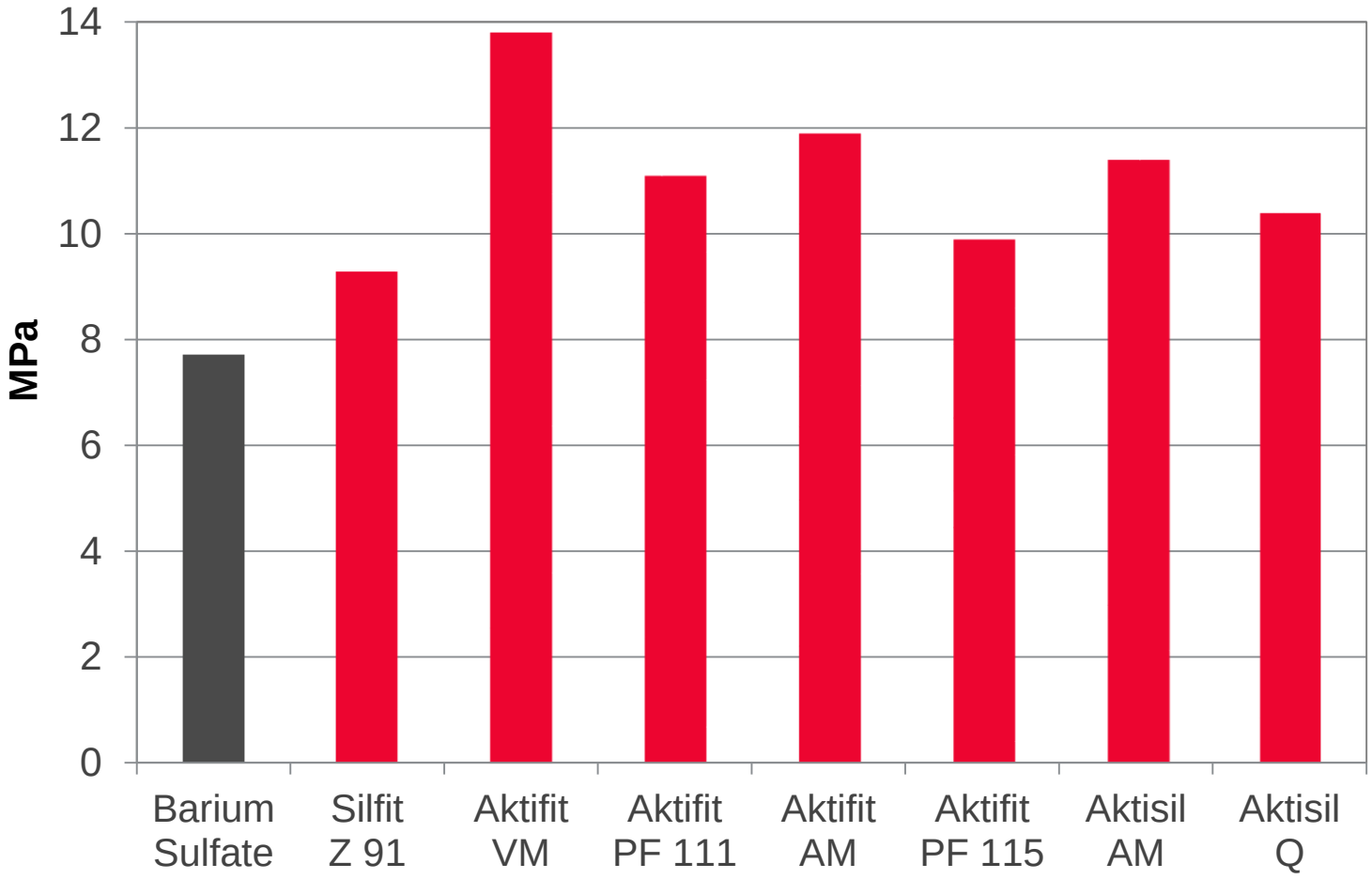
Barium Sulfate
Fuel Resistance

FAM B, 70 h / 23 °C



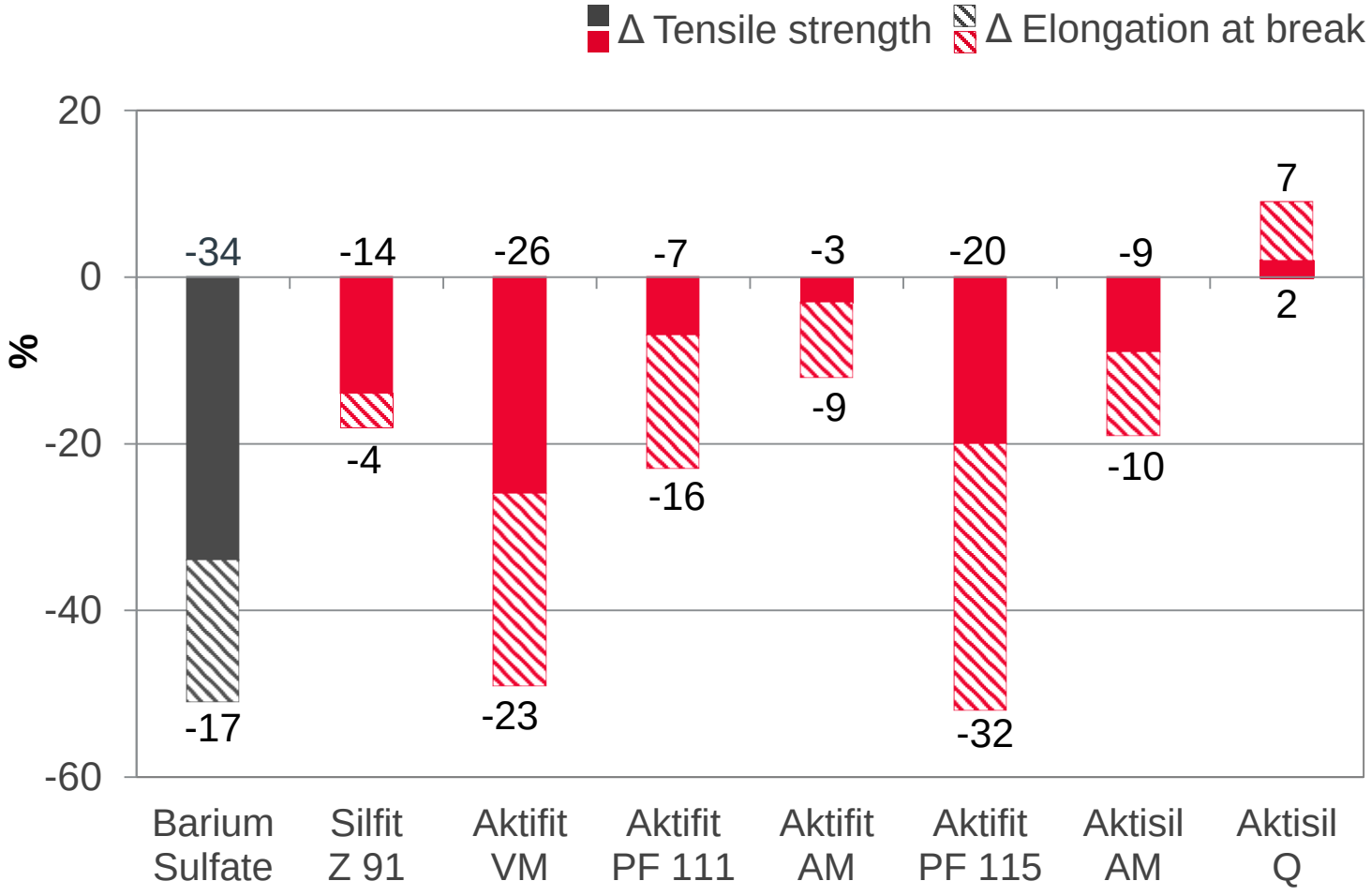
Barium Sulfate
Fuel Resistance – Tensile Strength

FAM B, 70 h / 23 °C



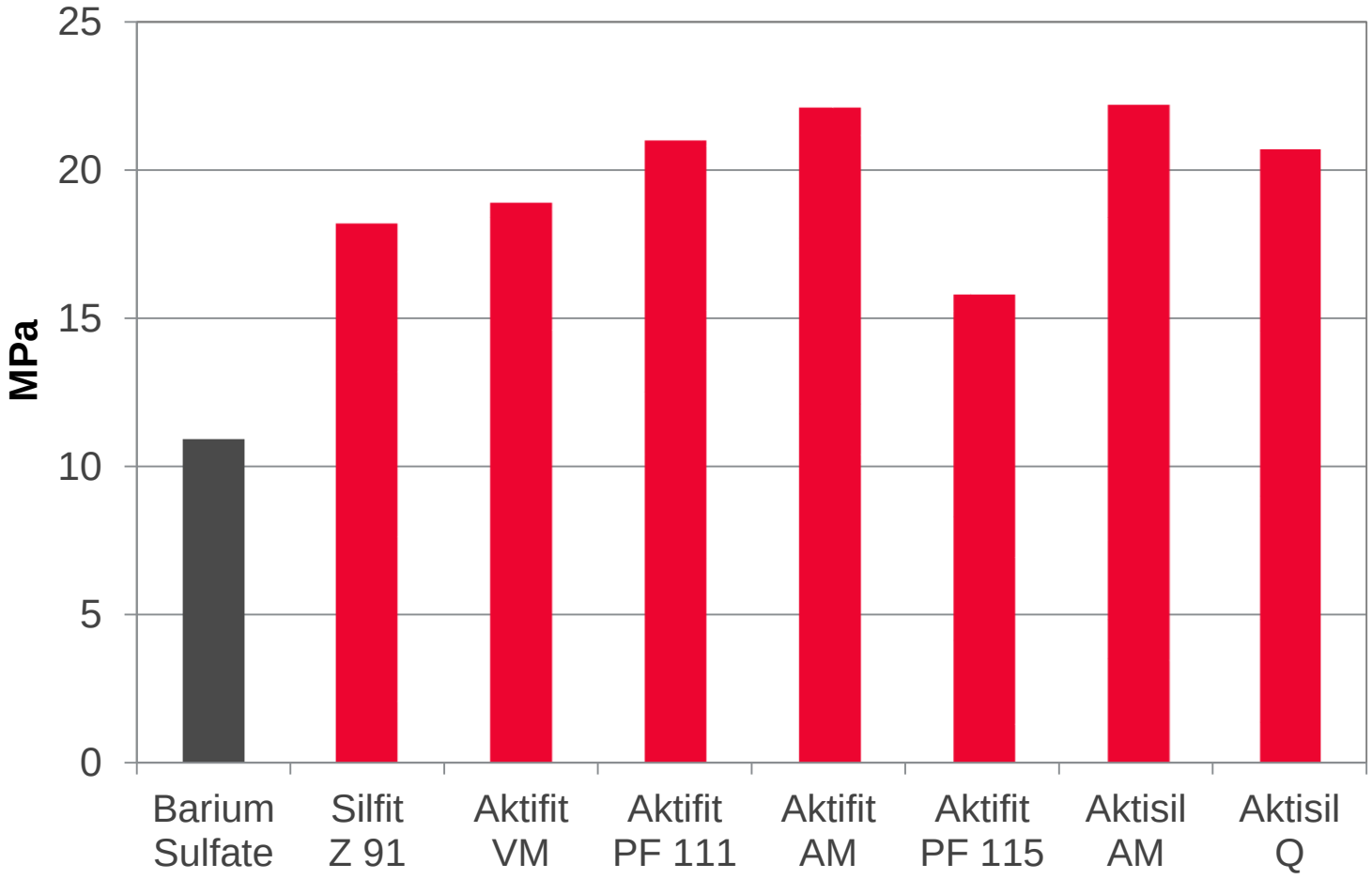
Barium Sulfate
Oil Resistance

OS206304, 168 h / 150 °C



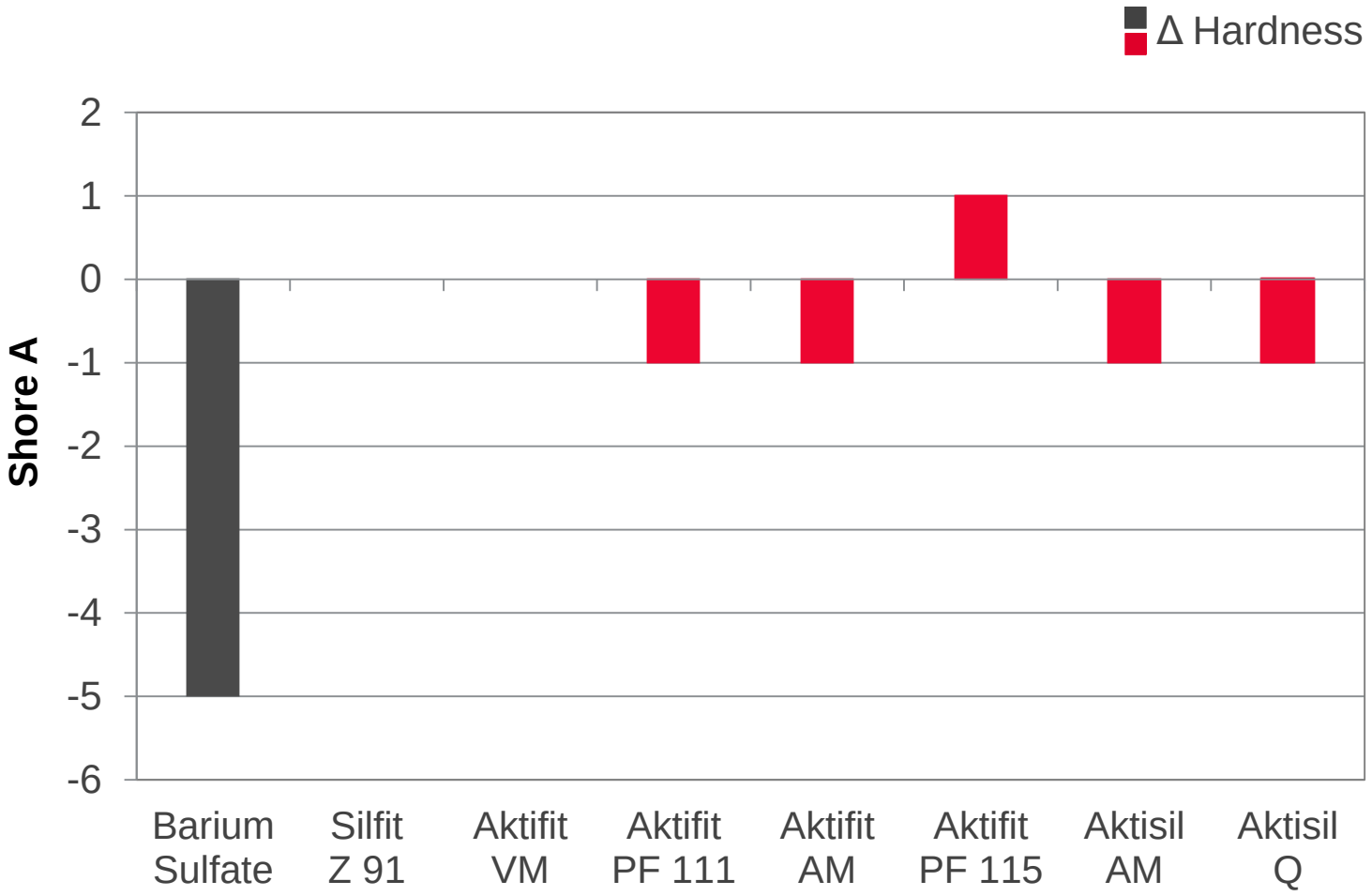
Barium Sulfate
Oil Resistance – Tensile Strength

OS206304, 168 h / 150 °C



Barium Sulfate
Oil Resistance

OS206304, 168 h / 150 °C



Barium Sulfate
Acid Resistance

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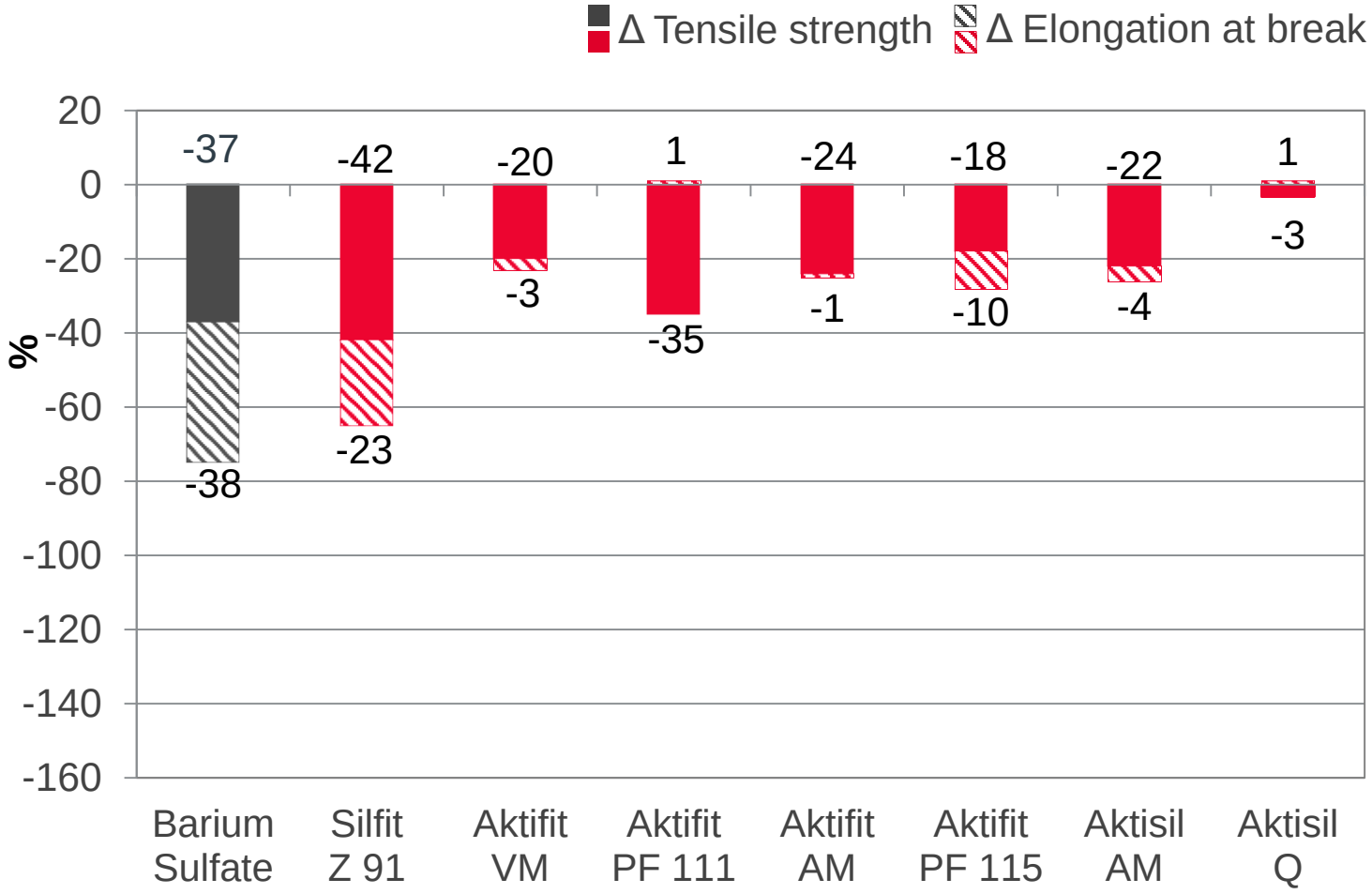
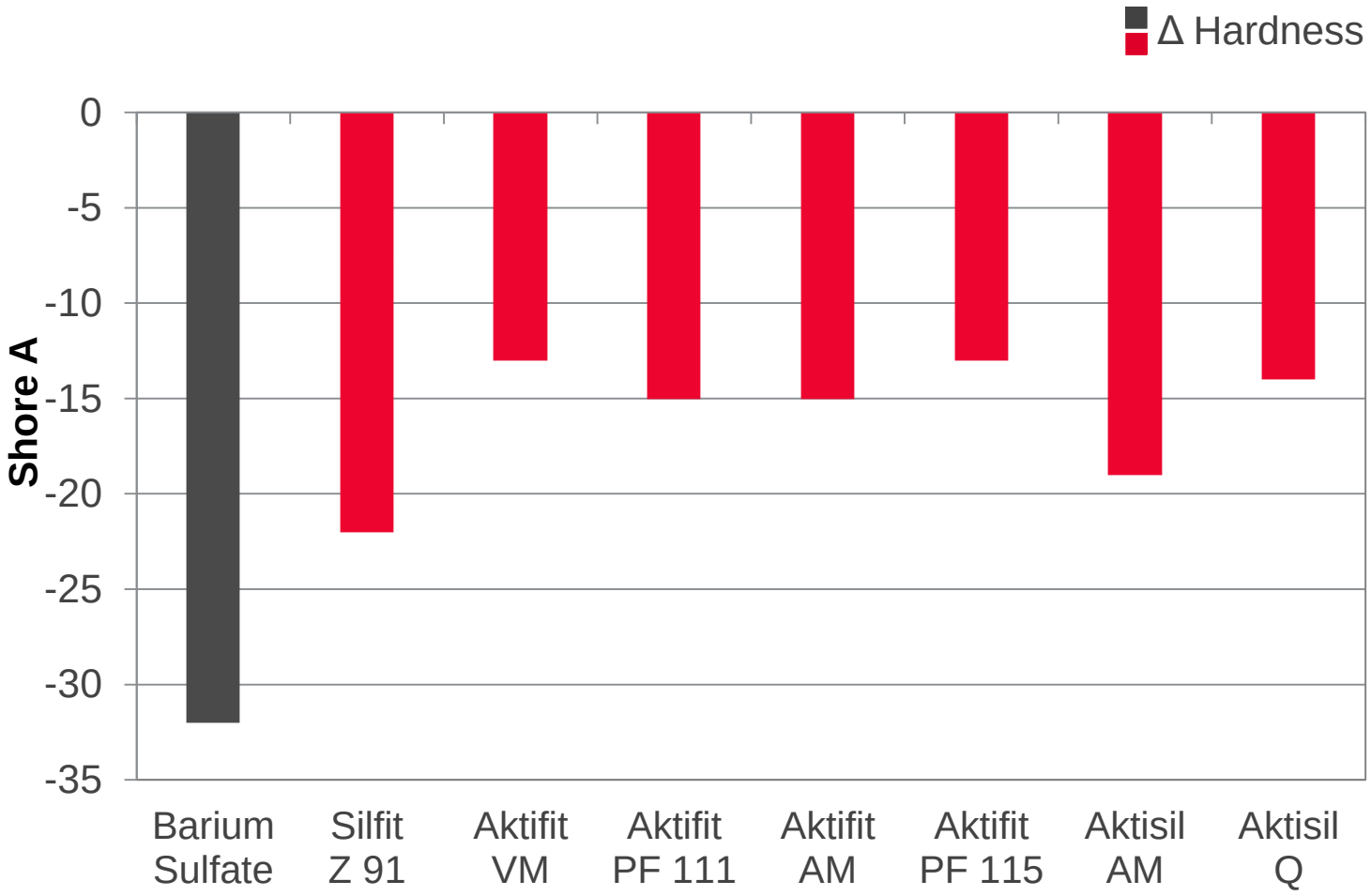
SUMMARY

Acetic acid pH 3, 168 h / 100 °C



Barium Sulfate
Acid Resistance

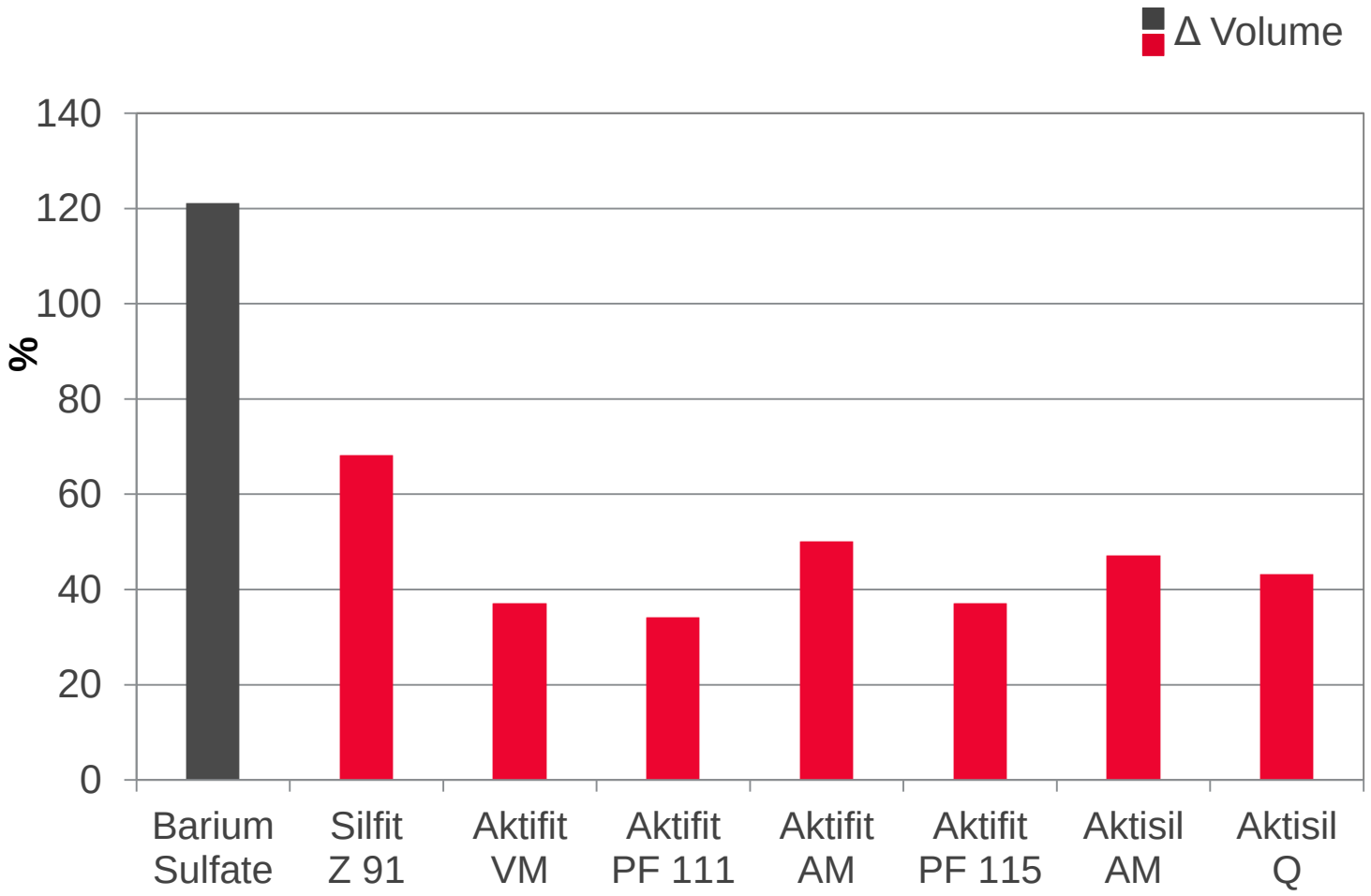
Acetic acid pH 3, 168 h / 100 °C



Barium Sulfate
Acid Resistance

HOFFMANN MINERAL

Acetic acid pH 3, 168 h / 100 °C



Acid Resistance

Acetic acid pH 3, 168 h / 100 °C

before	after
	
	Δ weight: +55 % Δ volume: +121 %

Evaluation
NSE vs. Barium Sulfate

Barium Sulfate 65 Shore A	Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Cure speed	+	=	=	+	+	+	=
Viscosity	=	=	=	+	+	+	+
Tensile strength (TS)	+	+	+	+	+	+	+
Modulus100 %	+	+	+	+	+	+	+
Tear resistance	=				=		
CS ISO 200 °C	=	=	=	=	=	=	=
CS ISO 200 °C, no post-cure	=	=	=	=	=	=	=
CS ISO 232 °C	=	=	+	=		=	+
CS ISO 232 °C, no post-cure	+	+	=	=	=	=	+
CS VW 23 °C	=	=	=	=		+	=
CS VW 150 °C	=	=	=	=	=	=	=
Abrasion resistance	+	+	+	+	+	+	+
Hot air resistance 210 °C	=	+	+	+	+	+	=
Hot air resistance 230 °C	=	+	+	+	+	+	=
Fuel resistance	+	+	+	+	+	+	+
Oil resistance	+	=	+	+	=	+	+
Resistance to acetic acid	+	+	+	+	+	+	+

We supply material for good ideas!

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Table of Results

Loading 30 phr		Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Rheology								
Mooney Viscosity, ML Min., 120 °C	MU	41	41	41	39	39	39	37
Rotorless Curemeter M_{min} 177 °C	Nm	0.05	0.04	0.04	0.04	0.05	0.04	0.04
Rotorless Curemeter V_{max} 177 °C	Nm/min.	4.0	3.4	3.5	4.1	3.8	4.0	3.6
Rotorless Curemeter t_{90} 177 °C	min.	0.8	0.8	0.9	0.8	0.8	0.8	0.8
Mechanical Properties – Cure Conditions 7 min. / 177 °C, no post-cure								
Hardness	Sh. A	65	64	65	65	65	64	63
Tensile Strength	MPa	15	22	16	18	17	19	16
Modulus 50 %	MPa	1.74	1.70	1.68	1.68	1.72	1.83	1.60
Modulus 100 %	MPa	3.2	3.9	3.5	3.7	3.6	4.2	3.6
Elongation at Break	%	405	278	336	364	395	312	257
Tear Resistance	N/mm	6.2	3.1	5.4	4.7	6.0	4.5	4.0
CS ISO, 70 h / 200 °C, 25 % defl.	%	19	20	21	20	21	21	18
CS ISO 70 h / 232 °C, 25 % defl.	%	27	25	28	28	32	30	20

Table of Results

Loading 30 phr		Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Mechanical Properties – Cure Conditions 7 min. / 177 °C, Post-cure 2 h / 232 °C								
Hardness	Sh. A	66	65	66	66	65	66	65
Tensile Strength	MPa	21	26	23	23	20	24	20
Modulus 50 %	MPa	1.91	1.75	1.76	1.83	1.84	1.92	1.72
Modulus 100 %	MPa	4.3	4.4	4.0	4.6	4.3	4.9	4.3
Elongation at Break	%	399	272	351	320	339	311	271
Tear Resistance	N/mm	6.1	3.2	4.9	4.5	6.7	3.9	4.1
CS ISO, 70 h / 200 °C, 25 % def.	%	21	21	19	20	20	21	20
CS ISO 70 h / 232 °C, 25 % def.	%	27	26	24	30	32	29	23
CS VW PV3307 94 h / 23 °C, 50 % def.	%	51	53	50	48	54	39	48
CS VW PV3307 94 h / 150 °C, 50 % def.	%	37	37	36	38	39	34	38
Abrasion Loss	mm^3	85	60	72	67	74	71	73

Table of Results

Loading 30 phr		Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Hot Air Aging, 504 h / 210 °C, determined after 30 min. after removal								
Hardness	Sh. A	69	68	68	68	69	69	67
Tensile Strength	MPa	25	25	23	25	19	26	22
Elongation at Break	%	301	323	320	330	252	304	356
Δ Hardness	Sh. A	+3	+3	+2	+2	+4	+3	+2
Δ Tensile Strength	%	+20	-3	+3	+8	-2	+8	+11
Δ Elongation at Break	rel.%	-25	+19	-9	+3	-26	-2	+31
Hot Air Aging, 94 h / 230 °C, determined after 30 min. after removal								
Hardness	Sh. A	67	67	68	67	68	68	65
Tensile Strength	MPa	26	26	27	27	22	28	23
Elongation at Break	%	280	283	313	314	247	299	331
Δ Hardness	Sh. A	+1	+2	+2	+1	+3	+2	0
Δ Tensile Strength	%	+26	+2	+18	+17	+11	+15	+16
Δ Elongation at Break	rel.%	-30	+4	-11	-2	-27	-4	+22

Table of Results

Loading 30 phr		Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Storage in Fuel FAM B, 70 h / 23 °C								
Hardness	Sh. A	57	58	59	58	58	58	58
Tensile Strength	MPa	9.3	14	11	12	9.9	11	10
Elongation at Break	%	335	220	255	246	268	238	206
Δ Hardness	Sh. A	-9	-7	-7	-8	-7	-8	-7
Δ Tensile Strength	%	-56	-46	-51	-48	-50	-53	-49
Δ Elongation at Break	rel.%	-16	-19	-27	-23	-21	-24	-24
Δ Weight	%	+7.9	+7.3	+7.8	+8.0	+8.0	+6.8	+8.0
Δ Volume	%	+19	+18	+19	+19	+19	+17	+19
Storage in Engine Oil OS206304, 168 h / 150 °C								
Hardness	Sh. A	66	65	65	65	66	65	64
Tensile Strength	MPa	18	19	21	22	16	22	21
Elongation at Break	%	383	210	295	291	231	281	291
Δ Hardness	Sh. A	0	0	-1	-1	+1	-1	-1
Δ Tensile Strength	%	-14	-26	-7	-3	-20	-9	+2
Δ Elongation at Break	rel.%	-4	-23	-16	-9	-32	-10	+7
Δ Weight	%	+0.6	+0.8	+0.7	+0.6	+0.6	+0.7	+0.6
Δ Volume	%	+1.0	+1.4	+1.2	+0.9	+1.4	+1.2	+0.7

Table of Results

Loading 30 phr		Silfit Z 91	Aktifit VM	Aktifit PF 111	Aktifit AM	Aktifit PF 115	Aktisil AM	Aktisil Q
Storage in Acetic Acid pH3, 168 h / 100 °C								
Hardness	Sh. A	44	52	51	51	52	47	51
Tensile Strength	MPa	12	21	15	18	16	19	20
Elongation at Break	%	306	265	355	316	304	300	274
Δ Hardness	Sh. A	-22	-13	-15	-15	-13	-19	-14
Δ Tensile Strength	%	-42	-20	-35	-24	-18	-22	-3
Δ Elongation at Break	rel.%	-23	-3	+1	-1	-10	-4	+1
Δ Weight	%	+36	+20	+17	+26	+19	+24	+23
Δ Volume	%	+68	+37	+34	+50	+37	+47	+43

Table of Results only Competitors

		30 phr Wollastonite AST	30 phr Wollastonite EST	49 phr Barium Sulfate
Rheology				
Mooney Viscosity, ML Min., 120 °C	MU	39	37	43
Rotorless Curemeter M_{min} 177 °C	Nm	0.03	0.03	0.04
Rotorless Curemeter V_{max} 177 °C	Nm/min.	3.4	3.1	3.4
Rotorless Curemeter t_{90} 177 °C	min.	0.9	0.9	0.9
Mechanical Properties – Cure Conditions 7 min. / 177 °C, no post-cure				
Hardness	Sh. A	61	63	61
Tensile Strength	MPa	18	16	15
Modulus 50 %	MPa	1.88	1.64	1.44
Modulus 100 %	MPa	4.2	3.2	2.1
Elongation at Break	%	397	393	421
Tear Resistance	N/mm	6.0	5.9	4.7
CS ISO, 70 h / 200 °C, 25 % def.	%	24	21	22
CS ISO 70 h / 232 °C, 25 % def.	%	35	28	31

Table of Results only Competitors

		30 phr Wollastonite AST	30 phr Wollastonite EST	49 phr Barium Sulfate
Mechanical Properties – Cure Conditions 7 min. / 177 °C, Post-cure 2 h / 232 °C				
Hardness	Sh. A	67	64	67
Tensile Strength	MPa	19	20	16
Modulus 50 %	MPa	1.71	1.67	1.44
Modulus 100 %	MPa	3.9	3.5	2.4
Elongation at Break	%	337	399	407
Tear Resistance	N/mm	6.2	6.9	6.1
CS ISO, 70 h / 200 °C, 25 % def.	%	22	18	22
CS ISO 70 h / 232 °C, 25 % def.	%	29	24	28
CS VW PV3307 94 h / 23 °C, 50 % Ddf.	%	51	51	49
CS VW PV3307 94 h / 150 °C, 50 % def.	%	35	36	36
Abrasion Loss	mm^3	104	114	124

Table of Results only Competitors

		30 phr Wollastonite AST	30 phr Wollastonite EST	49 phr Barium Sulfate
Hot Air Aging, 504 h / 210 °C, determined after 30 min. after removal				
Hardness	Sh. A	64	64	65
Tensile Strength	MPa	20	21	24
Elongation at Break	%	331	390	372
Δ Hardness	Sh. A	-3	0	-2
Δ Tensile Strength	%	+6	+3	+43
Δ Elongation at Break	rel.%	-2	-2	-9
Hot Air Aging, 94 h / 230 °C, determined after 30 min. after removal				
Hardness	Sh. A	65	65	65
Tensile Strength	MPa	22	22	25
Elongation at Break	%	325	335	353
Δ Hardness	Sh. A	-2	+1	-2
Δ Tensile Strength	%	+18	+8	+51
Δ Elongation at Break	rel.%	-4	-16	-13

Table of Results only Competitors

		30 phr Wollastonite AST	30 phr Wollastonite EST	49 phr Barium Sulfate
Storage in FAM B, 70 h / 23 °C				
Hardness	Sh. A	56	55	52
Tensile Strength	MPa	8.6	7.0	7.7
Elongation at Break	%	241	261	329
Δ Hardness	Sh. A	-11	-9	-15
Δ Tensile Strength	%	-53	-66	-53
Δ Elongation at Break	rel.%	-28	-35	-19
Δ Weight	%	+7.6	+7.2	+7.4
Δ Volume	%	+19	+18	+20
Storage in Engine Oil OS206304, 168 h / 150 °C				
Hardness	Sh. A	62	62	62
Tensile Strength	MPa	17	13	11
Elongation at Break	%	286	297	340
Δ Hardness	Sh. A	-5	-2	-5
Δ Tensile Strength	%	-7	-35	-34
Δ Elongation at Break	rel.%	-15	-26	-17
Δ Weight	%	+0.6	+0.6	+0.5
Δ Volume	%	+1.2	+1.1	+1.3

Table of Results only Competitors

		30 phr Wollastonite AST	30 phr Wollastonite EST	49 phr Barium Sulfate
Storage in Acetic Acid pH3, 168 h / 100 °C				
Hardness	Sh. A	37	not determinable	35
Tensile Strength	MPa	2.6	2.8	10
Elongation at Break	%	54	84	252
Δ Hardness	Sh. A	-30	not determinable	-32
Δ Tensile Strength	%	-86	-86	-37
Δ Elongation at Break	rel.%	-84	-79	-38
Δ Weight	%	+288	+227	+55
Δ Volume	%	+593	+499	+121