

Silfit Z 91 and alternative fillers in grey sulfur-cured EPDM washing machine gasket

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Objective

To broaden the range of filler options for grey sulfur-cured EPDM washing machine seal formulations, alternative fillers are evaluated alongside Silfit Z 91.

Comparative assessment of alternative fillers versus Silfit Z 91 in a grey sulfur-cured EPDM washing machine seal formulation.



Experimental details

- Base formulation
- Fillers
- Mixing and curing
- Test standards overview

Base formulation

Material	Description	phr
Vistalon 3666 B	Ethylene-propylene-diene rubber, semi-crystalline, oil extended, ML 1+4 (125 °C): 52 MU	175
Zinkoxyd aktiv	Zinc oxide	5
Edenor C18 98-100 GW	Stearic acid	1
Filler	*see "Fillers and characteristics"*	150
Kronos 2222	Titanium dioxide, white pigment	9
Corax N 550/30	Carbon black, black pigment	0.35
Silanogran PST 15-E	Triethoxysilyl-modified polybutadiene, 50 %, coupling agent	4.8
Aflux 37	Processing aid	3
DEG	Diethylene glycol, filler activator	3
Process oil P 460	Paraffinic mineral oil, plasticizer	25
Rhenogran MBT-80	Mercaptobenzothiazole, 80 %, accelerator	2.4
Rhenogran TP-50	Zinc dithiophosphate, 50 %, accelerator	4.68
Rhenogran CLD-80	Caprolactam disulfide, 80 %, sulfur donor	1.2
Sulfur	Sulfur, curing agent	0.7
Total		**385.13**

Fillers and characteristics

	Silfit Z 91	Sillitin Z 89	Sillitin V 88	Sillitin V 85	Gloxil bright	Polestar 200R
Particle size D_{50}, [µm]	2.1	2.1	5.0	5.0	1.9	3.6
Particle size D_{97}, [µm]	9.5	9.5	18.0	18.0	12.0	19
Specific surface area (BET) [m^2/g]	10	11	9	10	9	6.5
Oil absorption [g/100 g]	65	55	45	45	65	60
Color value L*	96.5	96.1	95.0	93.5	98.6	97.8
Color value b*	1.0	4.2	5.0	9.0	2.1	3.2
Calcination	✓	-	-	-	✓	✓

Mixing and curing

Compound preparation	
Two-roll mill	Ø 150 x 300 mm
Batch size	approx. 800 g
Roll temperature	50 °C
Mixing time	approx. 25 min

Press curing	
Temperature	180 °C
Time	5 min

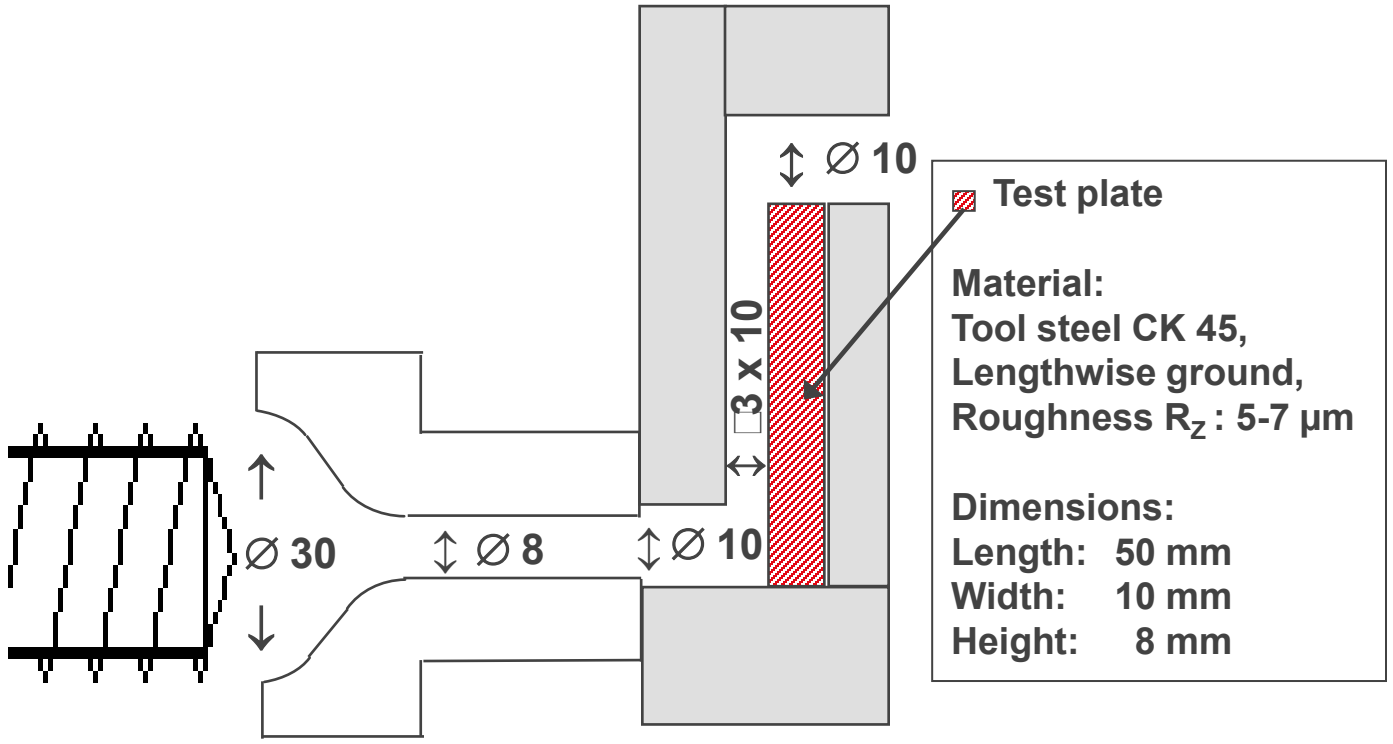
Test standards overview

Test	Standard
Mooney viscosity ML 1+4 (100 °C)	DIN ISO 289-1
Mooney scorch ML +5 (120 °C)	DIN ISO 289-2
Cure characteristics	DIN 53 529, parts 1 – 4
Tensile test	DIN 53 504, S2
Compression set	DIN ISO 815-1, type B
Hardness	DIN ISO 7619-1
Tear resistance – Trousers specimen	DIN ISO 34-1, A
Tear resistance – Graves specimen	DIN ISO 34-1, Bb
Aging behavior in liquid media	DIN ISO 1817
Aging behavior in air	ISO 188, D
Plate-out – Mold fouling	Internal

Parameters for plate-out evaluation

Extruder		Schwabenthan Polytest 30 R
Screw diameter	mm	30
Process length	mm	450
Temperature set point Head / Zone 1 / Zone 2	°C	60 / 60 / 60
Screw speed	rpm	100
Plate-out test device		see image
Measurement channel l x b x h	mm	50 x 10 x 3
Test plate material		Tool steel CK 45, Lengthwise ground
Test plate surface roughness R_z (transverse to the flow direction)	µm	5-7
Feed strips	mm	30 x 6

Parameters for plate-out evaluation



all dimensions in mm

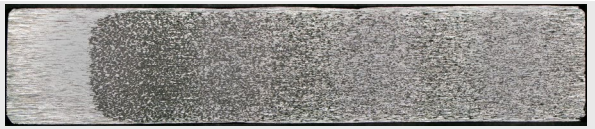
Results

- Plate-out – Mold fouling
- Rheological properties
- Properties of the vulcanizates
- Aging in hot air 168 h / 120 °C
- Aging in 2 % Persil detergent solution 100 h / 100 °C

Plate-out – Mold fouling

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Deposit on the test plates

	Extruded amount [kg]	Throughput [g/min]	Deposit coverage [0 → 3]	20x microscope image
Silfit Z 91	5	455	0.5	
Sillitin Z 89	5	473	2.0	
Sillitin V 88	5	463	1.5	
Sillitin V 85	5	431	1.5	
Gloxil bright	5	445	0.0	
Polestar 200R	5	423	0.5	

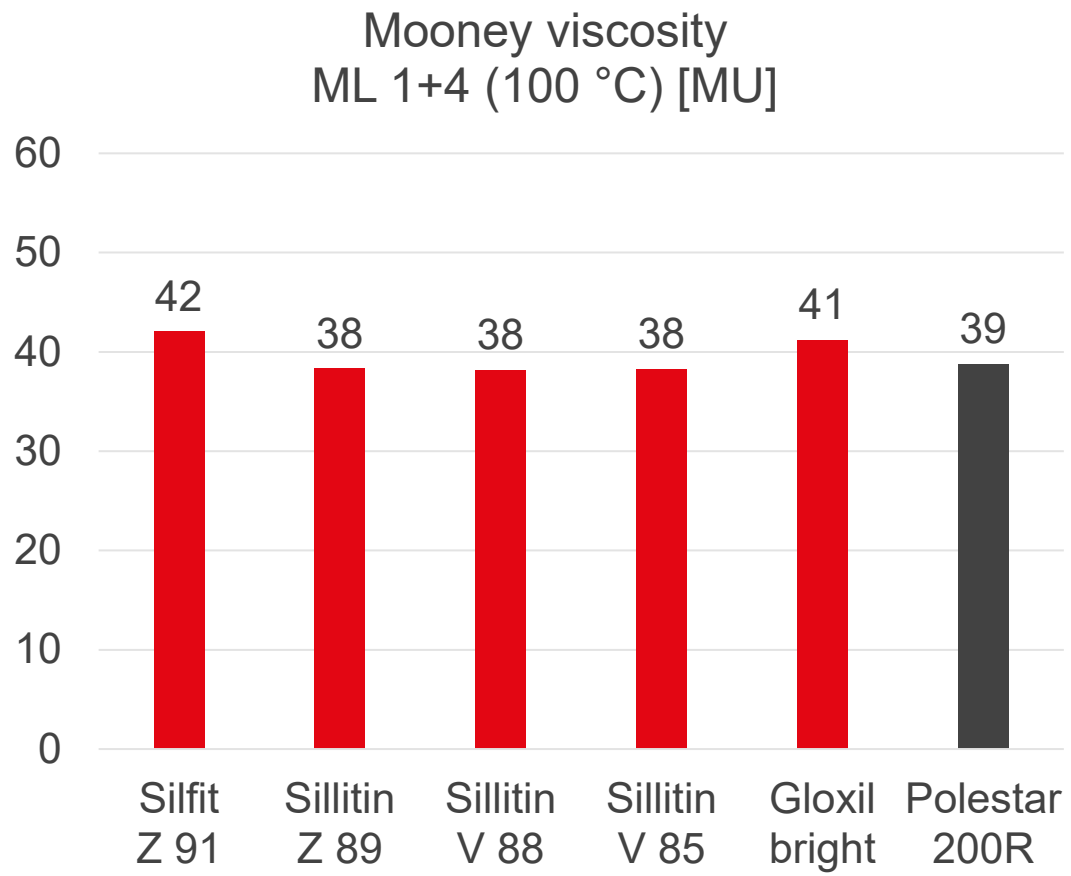
- No mold fouling with Gloxil bright.

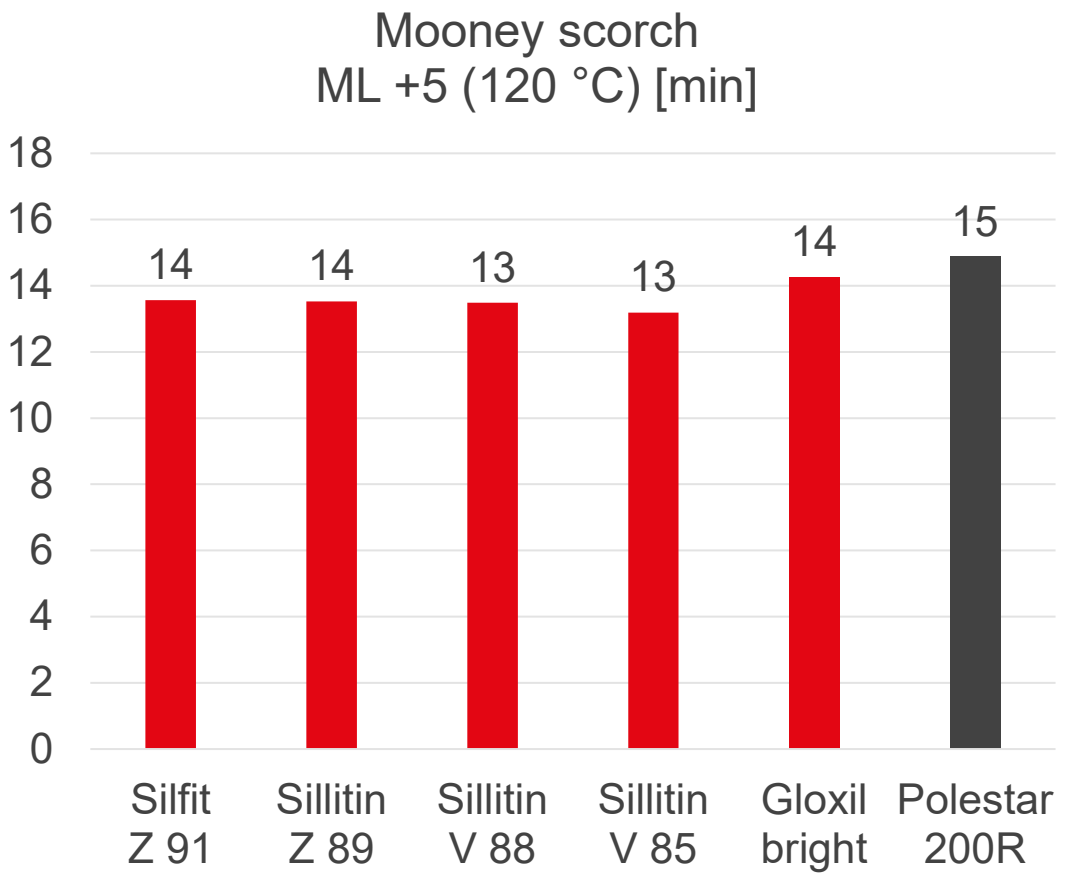
Rheological properties

DIN ISO 289-1
DIN ISO 289-2
DIN 53 529, parts 1 – 4

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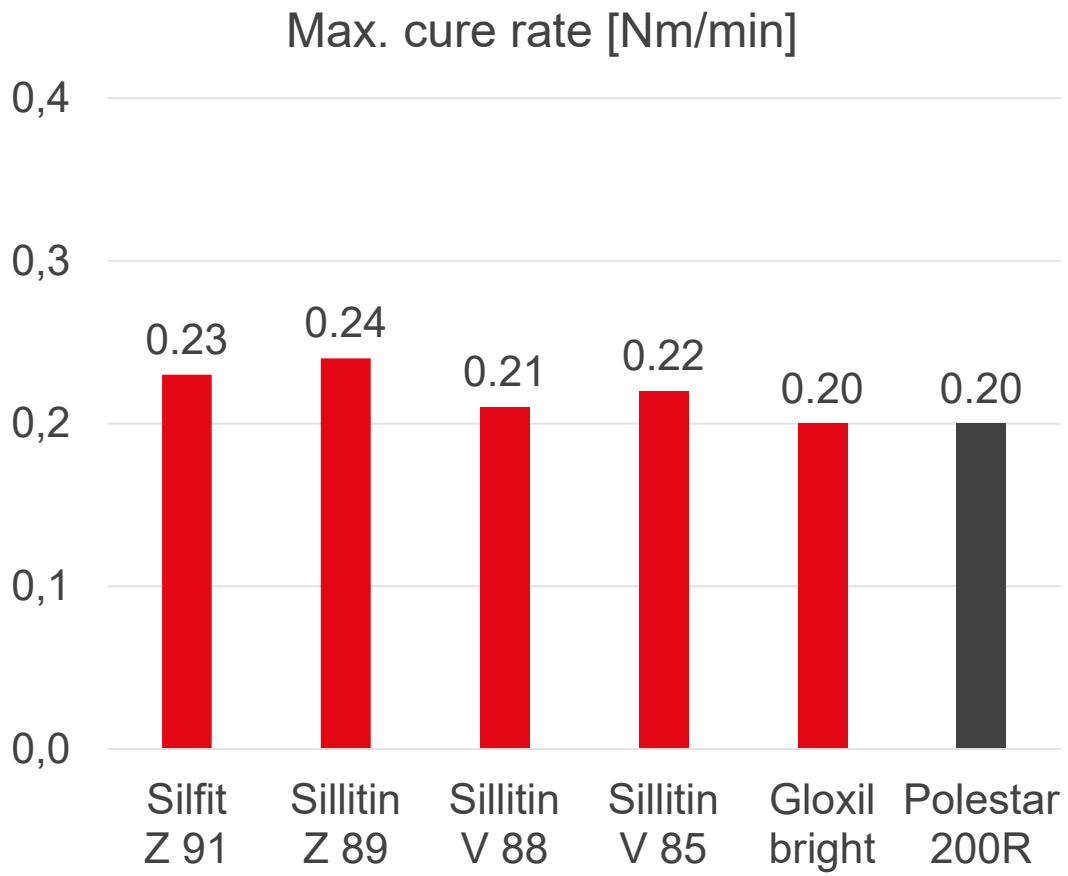
Mooney test

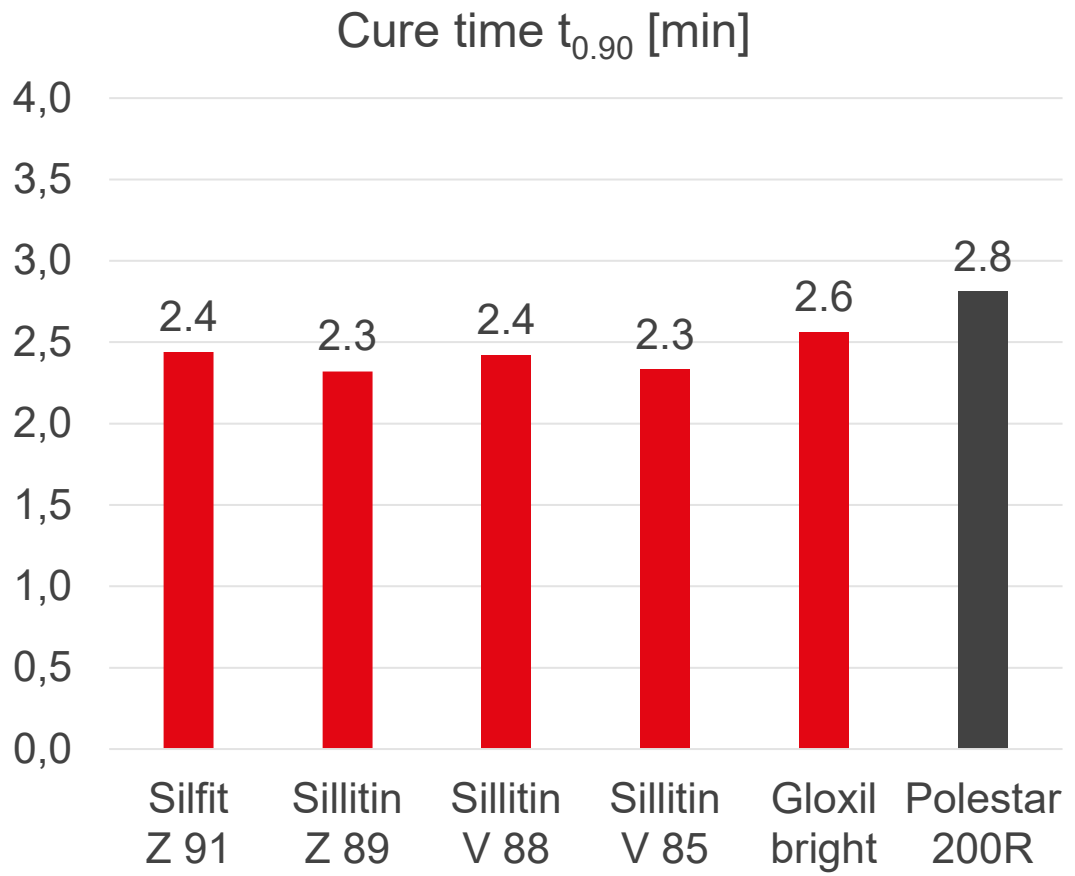




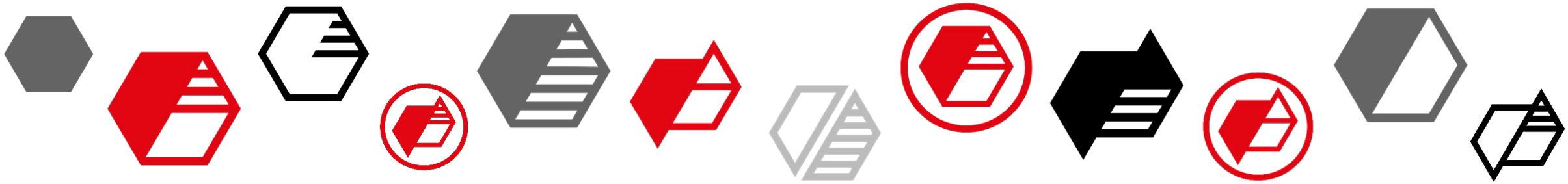
- Slightly lower viscosity for the non-calcined products Sillitin Z 89, Sillitin V 88 and Sillitin V 85.
- Similar scorch time for all Hoffmann Mineral products.

Rheology – Moving die rheometer, 180 °C , 0.2° arc





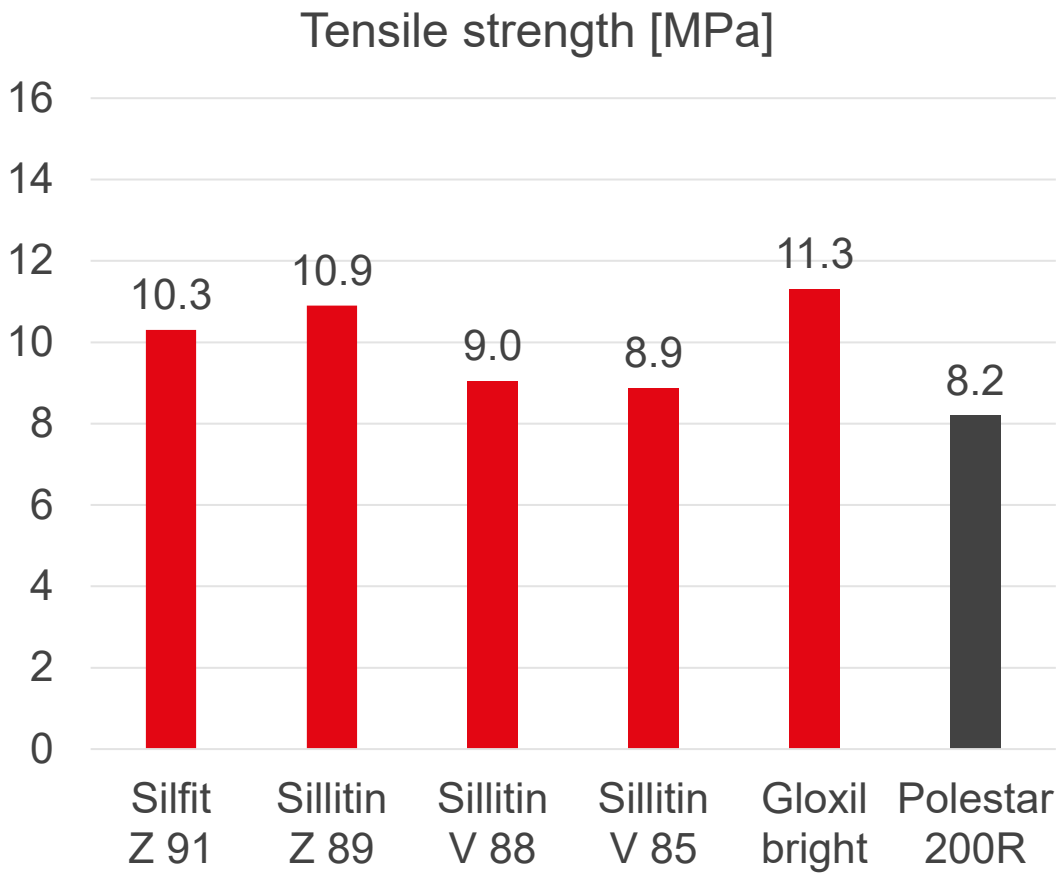
- Similar maximum cure rate and optimum cure time $t_{0.90}$ for all Hoffmann Mineral products.

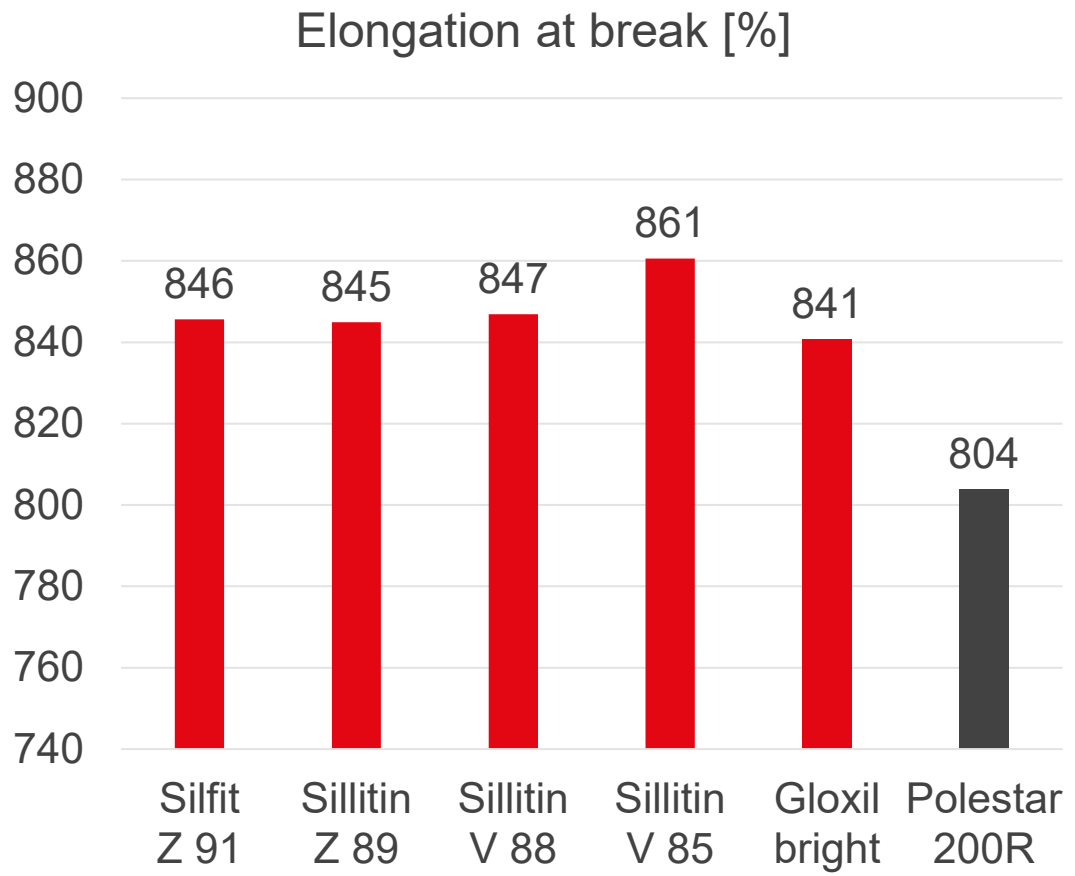


Properties of the vulcanizates

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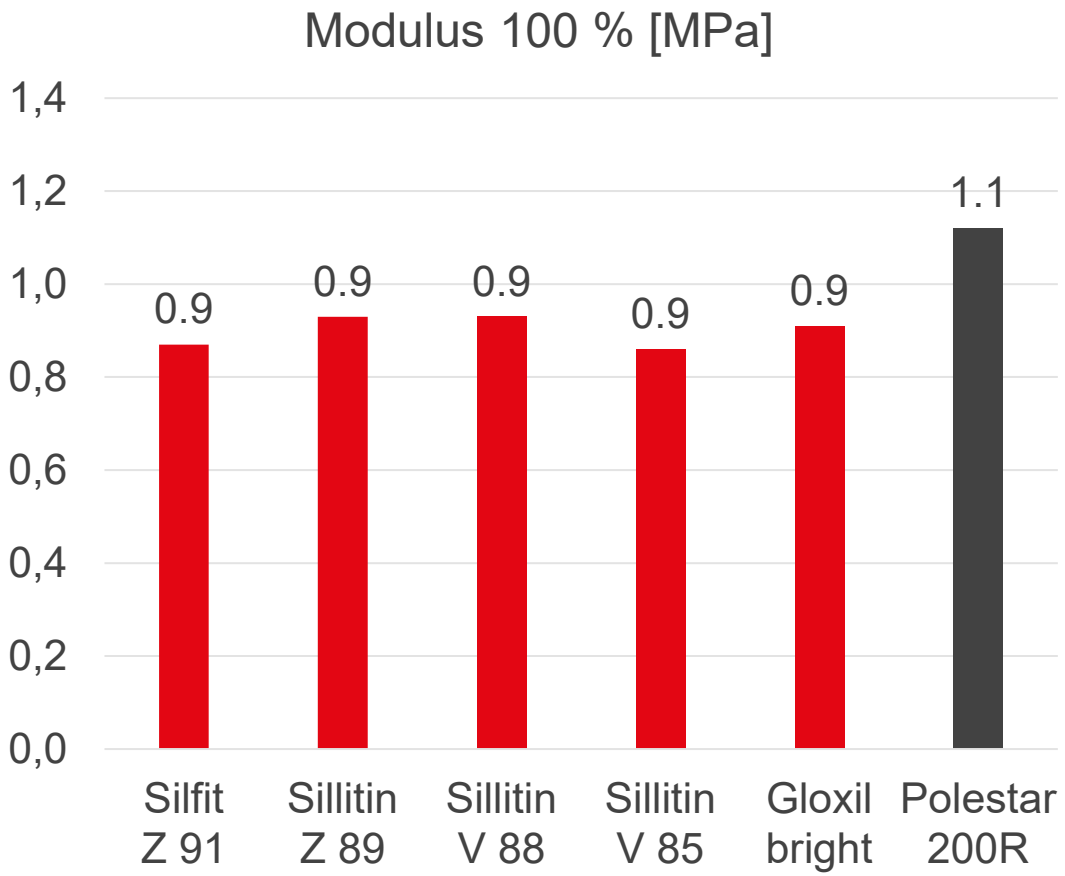
Mechanical properties

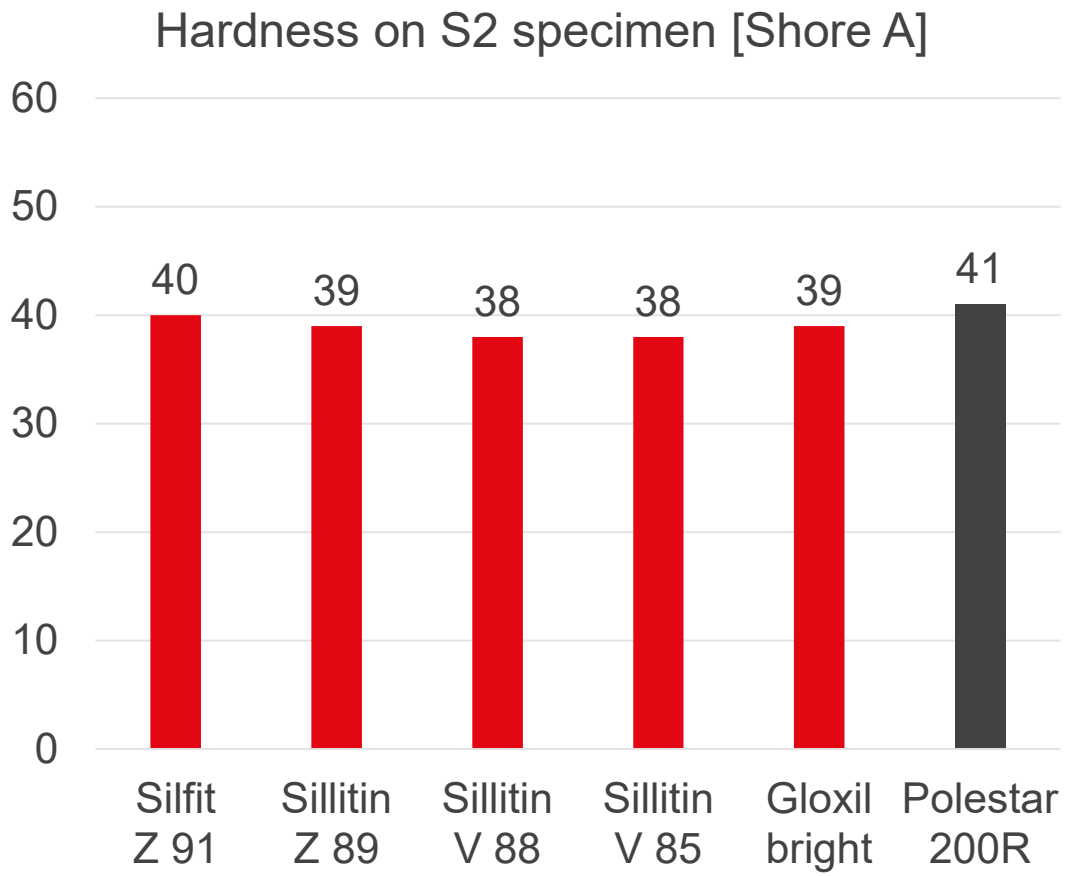




- Higher tensile strength for Gloxil bright.
- Similar elongation at break for all Hoffmann Mineral products.

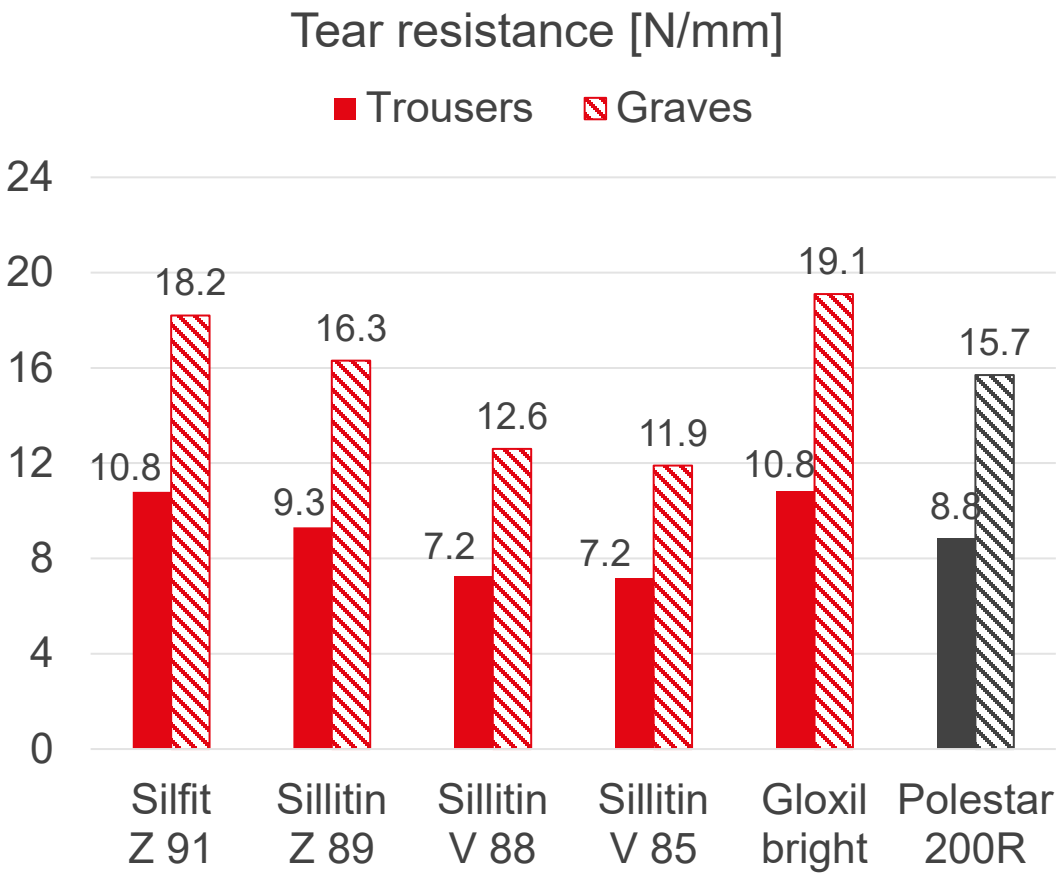
Mechanical properties

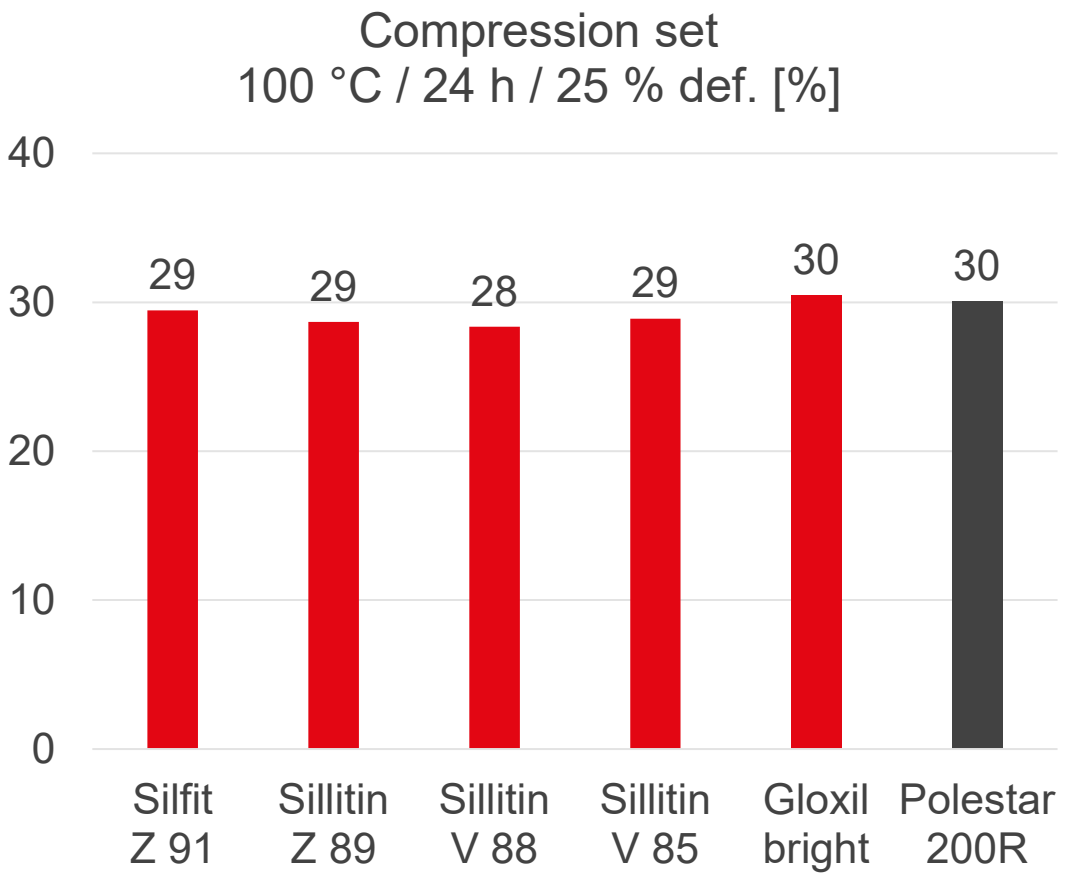




- Similar modulus 100 % and hardness for all Hoffmann Mineral products.

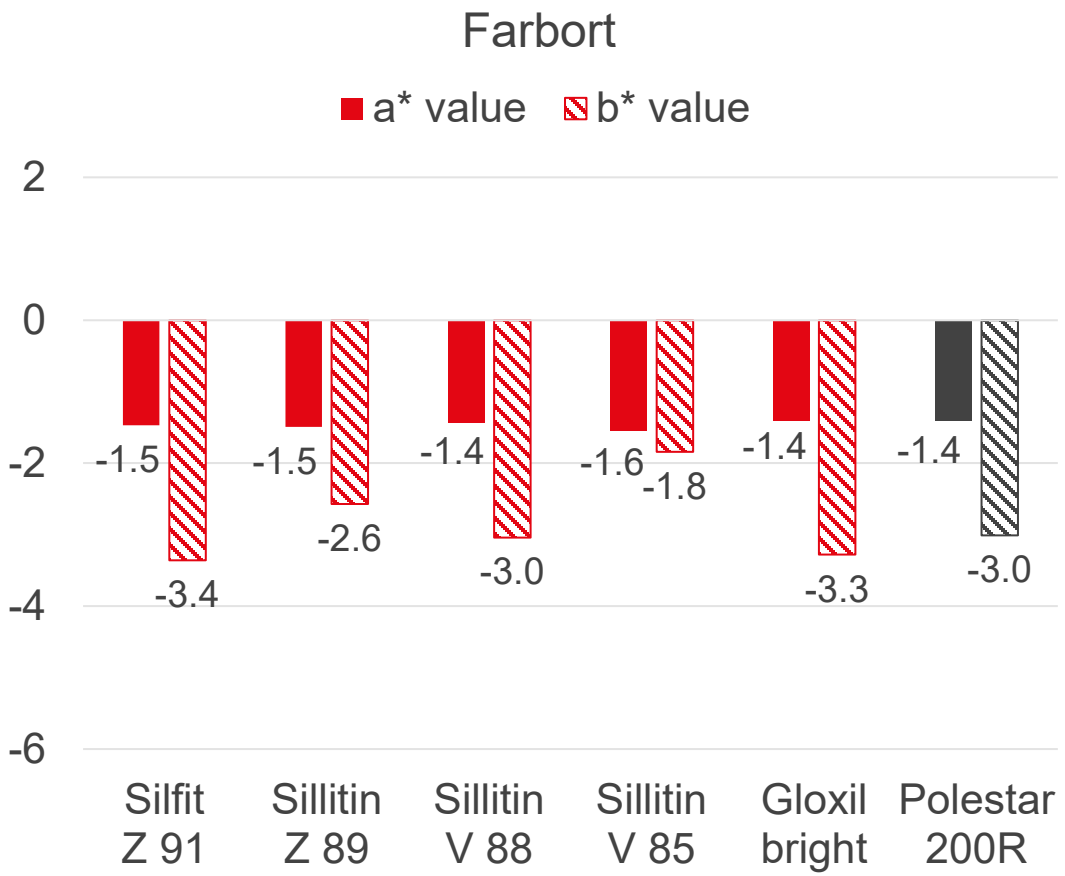
Mechanical properties

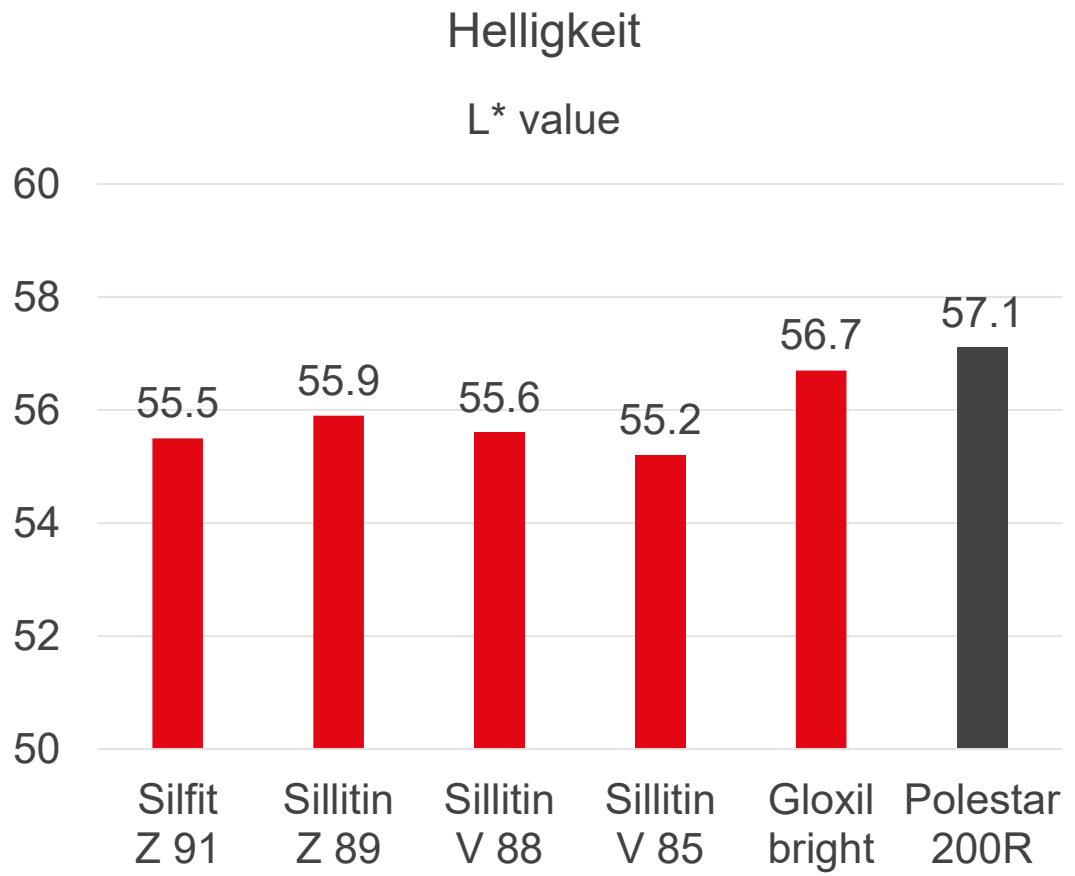




- Similar tear resistance for Gloxil bright.
- Similar compression set for all Hoffmann Mineral products.

Color – Color coordinates and brightness





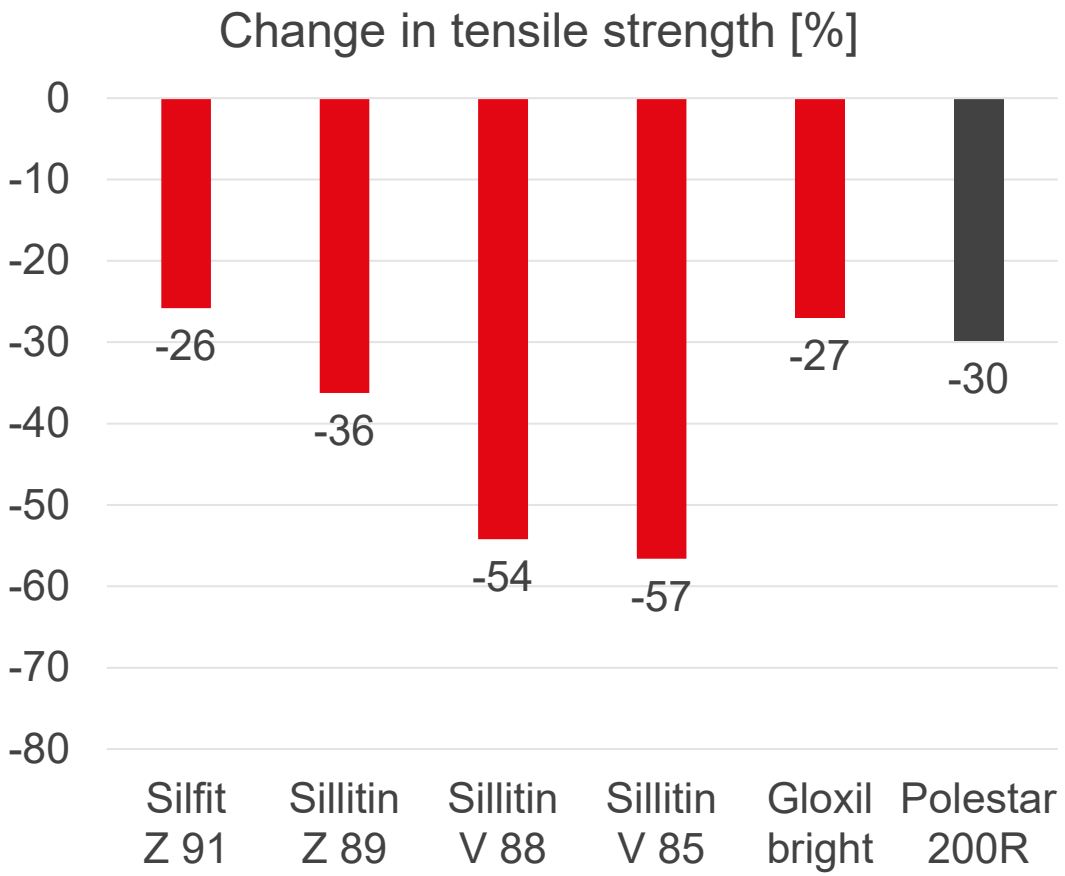
- Similar color coordinates for Sillitin V 88 and Gloxil bright.
- Similar brightness for the non-calcined products, and slightly higher for Gloxil bright.

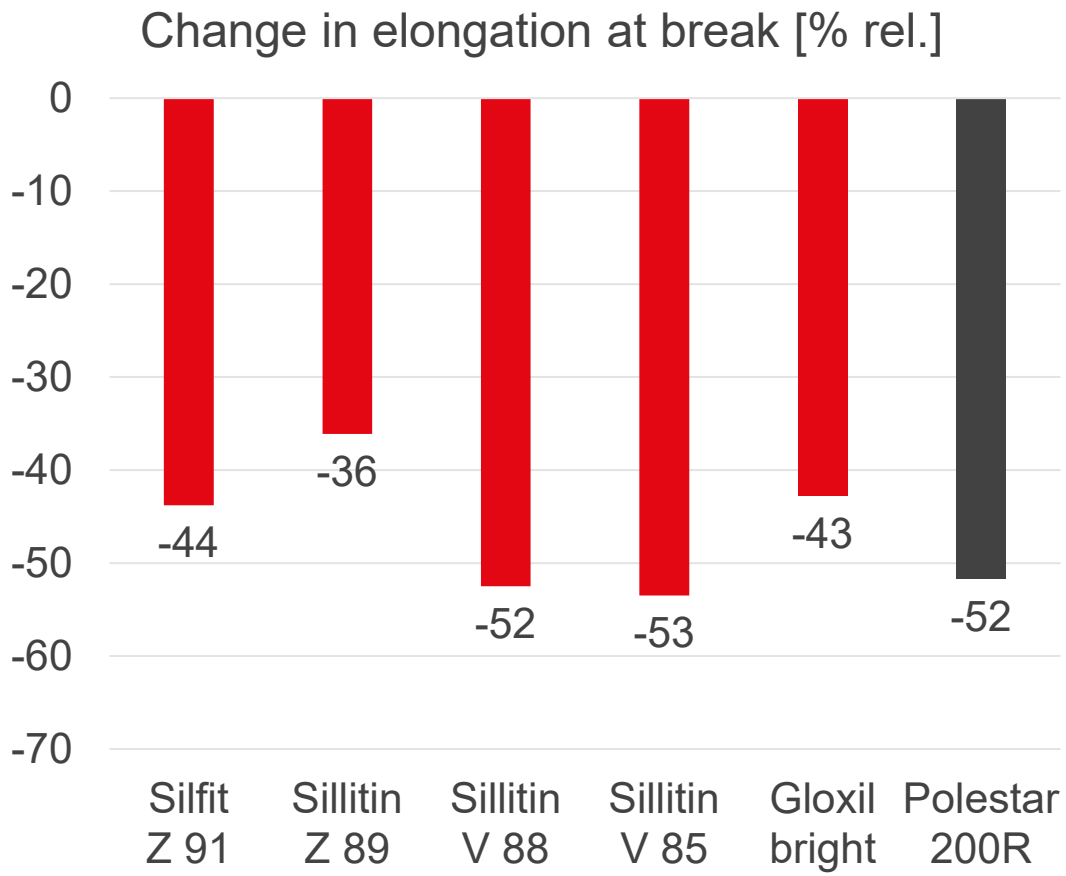
Aging in hot air 168 h / 120 °C

ISO 188, D

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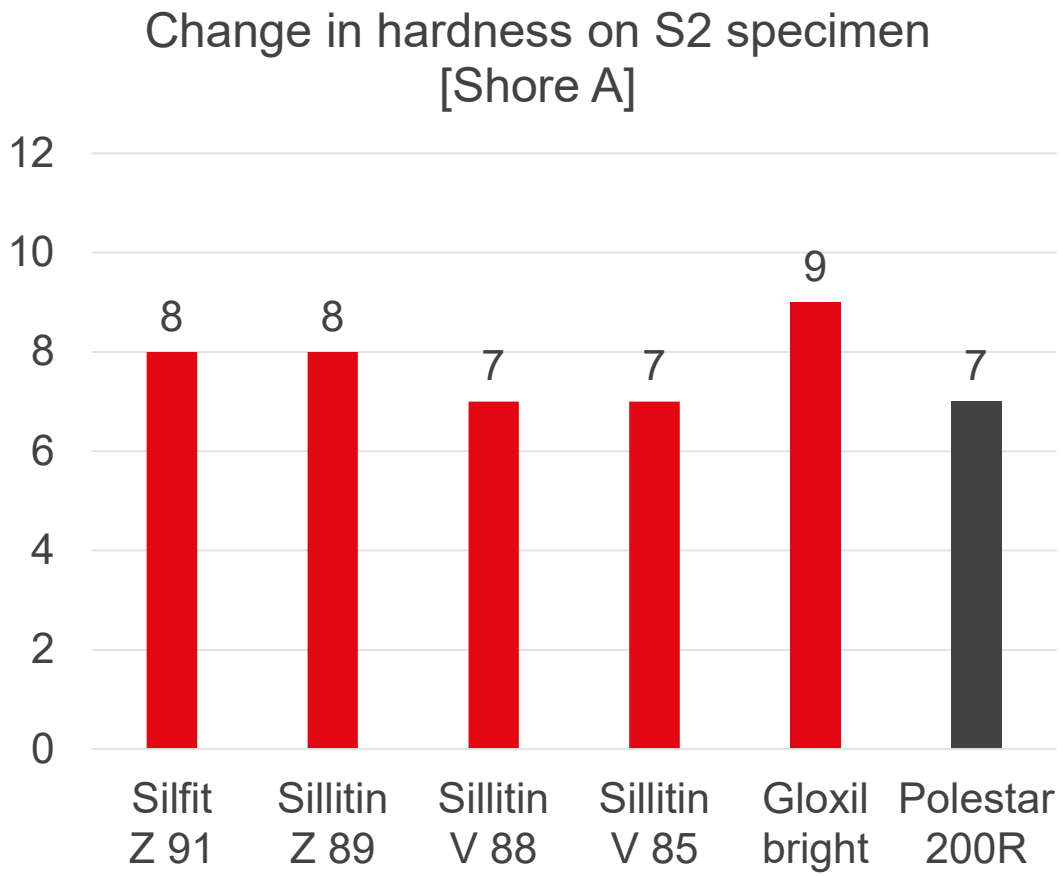
Aging in hot air 168 h / 120 °C





- Similar changes in tensile strength and elongation at break for Sillitin Z 89 and Gloxil bright.

Aging in hot air 168 h / 120 °C



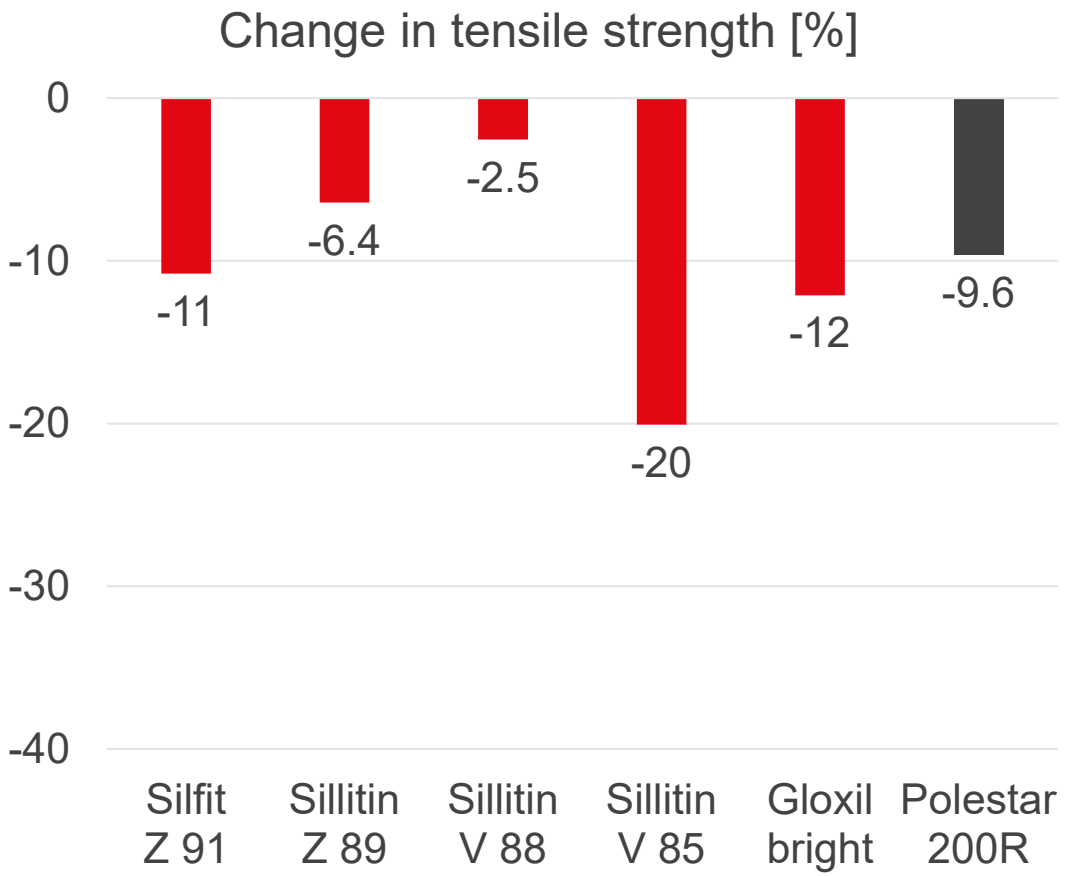
- Similar change in hardness for all Hoffmann Mineral products.

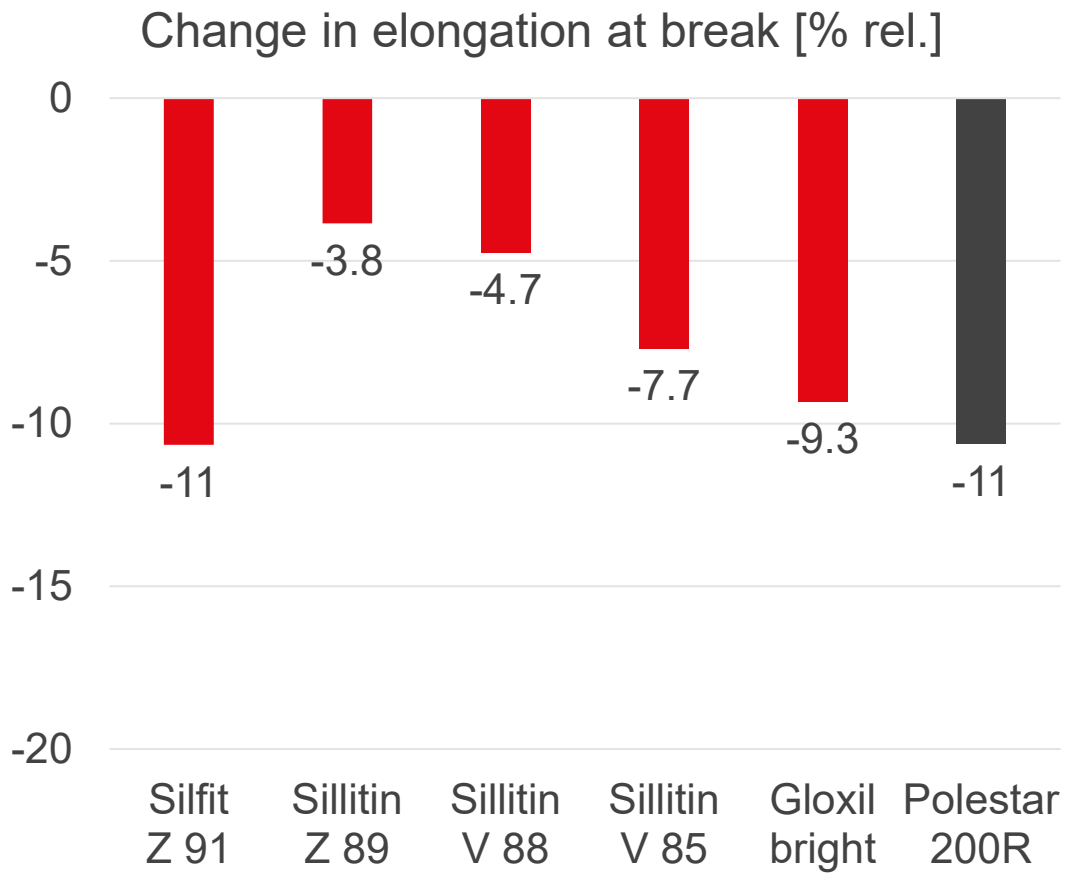
Aging in 2 % Persil detergent solution 100 h / 100 °C

DIN ISO 1817

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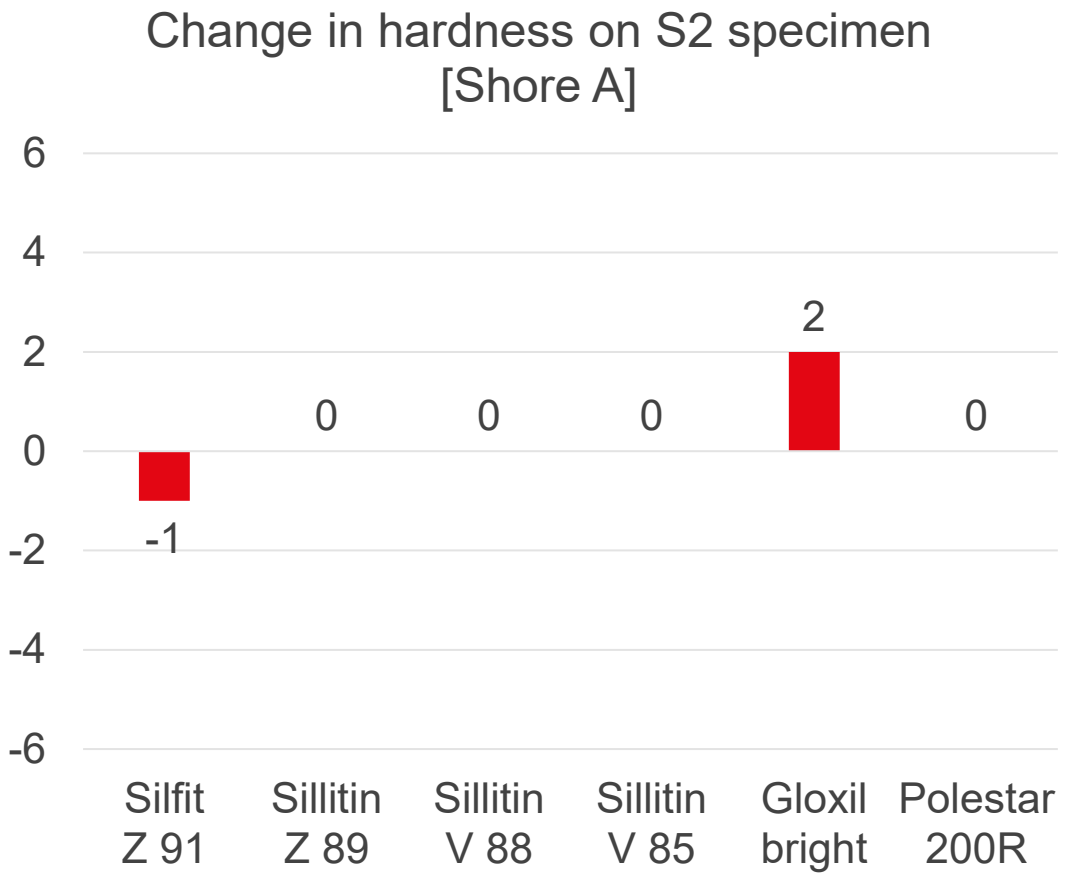
Aging in 2 % Persil detergent solution 100 h / 100 °C

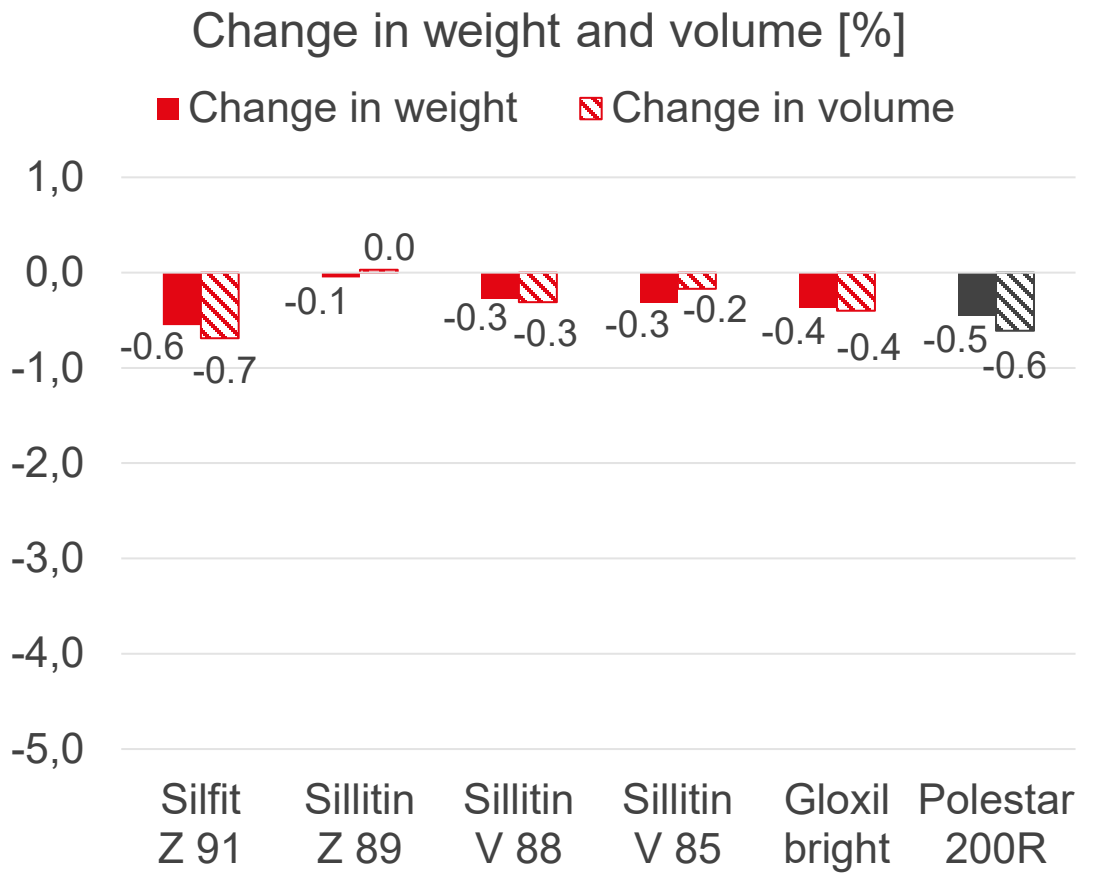




- Similar changes in tensile strength and elongation at break for Gloxil bright, and slightly better performance for Sillitin Z 89 and Sillitin V 88.

Aging in 2 % Persil detergent solution 100 h / 100 °C





- Similar changes in hardness, weight and volume for all Hoffmann Mineral products.

Alternative fillers vs. Silfit Z 91

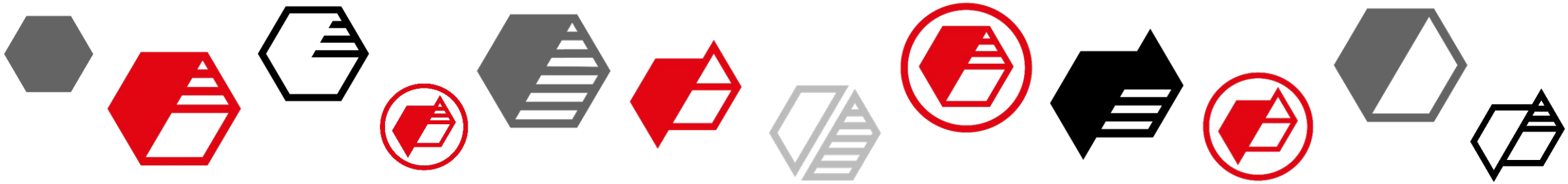
40 Shore A	Sillitin Z 89	Sillitin V 88	Sillitin V 85	Gloxil bright	Polestar 200R
Mooney viscosity	+	+	+	=	+
Scorch time	=	=	=	=	=
Max. cure rate	=	=	=	=	=
Cure time $t_{0.90}$	=	=	=	=	=
Mold fouling				+	=
Tensile strength	=			+	
Elongation at break	=	=	=	=	=
Moduli	=			=	=
Tear resistance – Trousers				=	
Tear resistance – Graves				=	
Compression set 100 °C , 24 h	=	=	=	=	=
Hot-air resistance 120 °C , 168 h	=			=	
Detergent-solution resistance 100 °C , 100 h	=	=	=	=	=
Color – Color coordinates		=		=	=
Color – Brightness	=	=	=	+	+

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Results in tabular form

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Results in tabular form – Rheological and mechanical properties

		Silfit Z 91	Sillitin Z 89	Sillitin V 88	Sillitin V 85	Gloxil bright	Polestar 200R
Mooney viscosity, ML 1+4, 100 °C	MU	42	38	38	38	41	39
Mooney scorch, ML +5, 120 °C	min	14	14	13	13	14	15
Max. cure rate, 180 °C	Nm/min	0.23	0.24	0.21	0.22	0.20	0.20
Cure yield, 180 °C	Nm	0.196	0.194	0.183	0.185	0.190	0.188
Cure time $t_{0.05}$, 180 °C	min	0.56	0.54	0.55	0.53	0.59	0.62
Cure time $t_{0.90}$, 180 °C	min	2.4	2.3	2.4	2.3	2.6	2.8
Tensile strength	MPa	10.3	10.9	9.0	8.9	11.3	8.2
Elongation at break	%	846	845	847	861	841	804
Modulus 100 %	MPa	0.9	0.9	0.9	0.9	0.9	1.1
Modulus 500 %	MPa	4.8	4.1	3.2	2.9	5.1	5.0
Hardness	Shore A	40	39	38	38	39	41
Tear resistance – Trousers specimen	N/mm	10.8	9.3	7.2	7.2	10.8	8.8
Tear resistance – Graves specimen	N/mm	18.2	16.3	12.6	11.9	19.1	15.7
Compression set 24 h / 100 °C / 25 % deformation	%	29	29	28	29	30	30

Results in tabular form – Aging in hot air

		Silfit Z 91	Sillitin Z 89	Sillitin V 88	Sillitin V 85	Gloxil bright	Polestar 200R
Aging in hot air 168 h / 120 °C							
Tensile strength	MPa	7.6	7.0	4.1	3.9	8.3	5.8
Elongation at break	%	475	540	402	400	481	388
Modulus 100 %	MPa	1.6	1.4	1.5	1.4	1.7	2.0
Hardness	Shore A	48	47	45	45	48	48
Δ Tensile strength	%	-26	-36	-54	-57	-27	-30
Δ Elongation at break	% rel.	-44	-36	-52	-53	-43	-52
Δ Modulus 100 %	%	78	51	57	66	81	82
Δ Hardness	Shore A	8	8	7	7	9	7

Results in tabular form – Aging in detergent solution

		Silfit Z 91	Sillitin Z 89	Sillitin V 88	Sillitin V 85	Gloxil bright	Polestar 200R
Aging in 2 % Persil detergent solution 100 h / 100 °C							
Tensile strength	MPa	9.2	10.2	8.8	7.1	9.9	7.4
Elongation at break	%	756	812	807	794	762	718
Modulus 100 %	MPa	1.0	0.9	0.9	0.9	1.0	1.1
Hardness	Shore A	39	39	38	38	41	41
Δ Tensile strength	%	-11	-6.4	-2.5	-20	-12	-9.6
Δ Elongation at break	% rel.	-11	-3.8	-4.7	-7.7	-9.3	-11
Δ Modulus 100 %	%	17	-3.2	-2.2	1.2	5.5	0.9
Δ Hardness	Shore A	-1	0	0	0	2	0
Δ Weight	%	-0.6	-0.1	-0.3	-0.3	-0.4	-0.5
Δ Volume	%	-0.7	0.0	-0.3	-0.2	-0.4	-0.6