

Silfit Z 91 and alternative fillers in sulfur-cured EPDM molded parts

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Objective

To broaden the range of filler options for sulfur-cured EPDM molded-part formulations, alternative fillers are evaluated alongside Silfit Z 91.

Comparative assessment of alternative fillers versus Silfit Z 91 in a sulfur-cured EPDM molded-part formulation.



Experimental details

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

Base formulation

Material	Description	phr
Keltan 2650	Ethylene-propylene-diene rubber, amorphous, ML 1+4 (125 °C): 25 MU	100
Zinkoxyd aktiv	Zinc oxide	3
Edenor C18 98-100 GW	Stearic acid	0.5
Filler	*see "Fillers and characteristics"*	120
Process oil P 460	Paraffinic mineral oil, plasticizer	5
PEG 4000	Polyethylene glycol	1
Rhenogran ZBEC-70	Zinc dibenzyldithiocarbamate, 70 %, accelerator	2
Rhenogran CBS-80	N-cyclohexyl-2-benzothiazolesulfenamide, 80 %, accelerator	0.5
Rhenogran MBTS-80	2-Mercaptobenzothiazole disulfide, 80 %, accelerator	1.3
Rhenogran TP-50	Zinc dithiophosphate, 50 %, accelerator	2
Rhenogran CLD - 80	Caprolactam disulfide, 80 %, sulfur donor	1
Rhenogran S-80	Sulfur, 80 %, curing agent	0.75
Total		**237.05**

Fillers and characteristics

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

Mixing and curing

Compound preparation	
Two-roll mill	Ø 150 x 300 mm
Batch size	approx. 700 g
Roll temperature	50 °C
Mixing time	approx. 10 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
Abrasion loss	DIN ISO 4649, A
Hardness test	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

Results

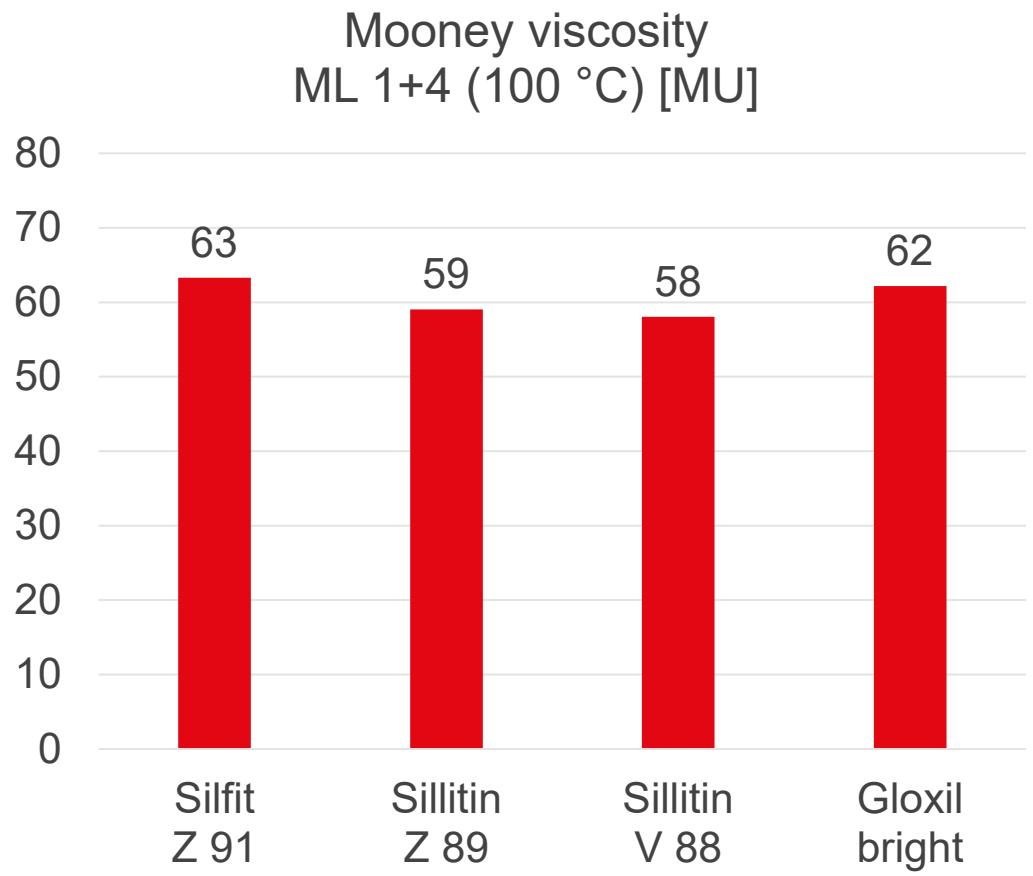
- Rheological properties
- Properties of the vulcanizates
- Aging in hot air 168 h / 70 °C
- Aging in deionized water 168 h / 95 °C

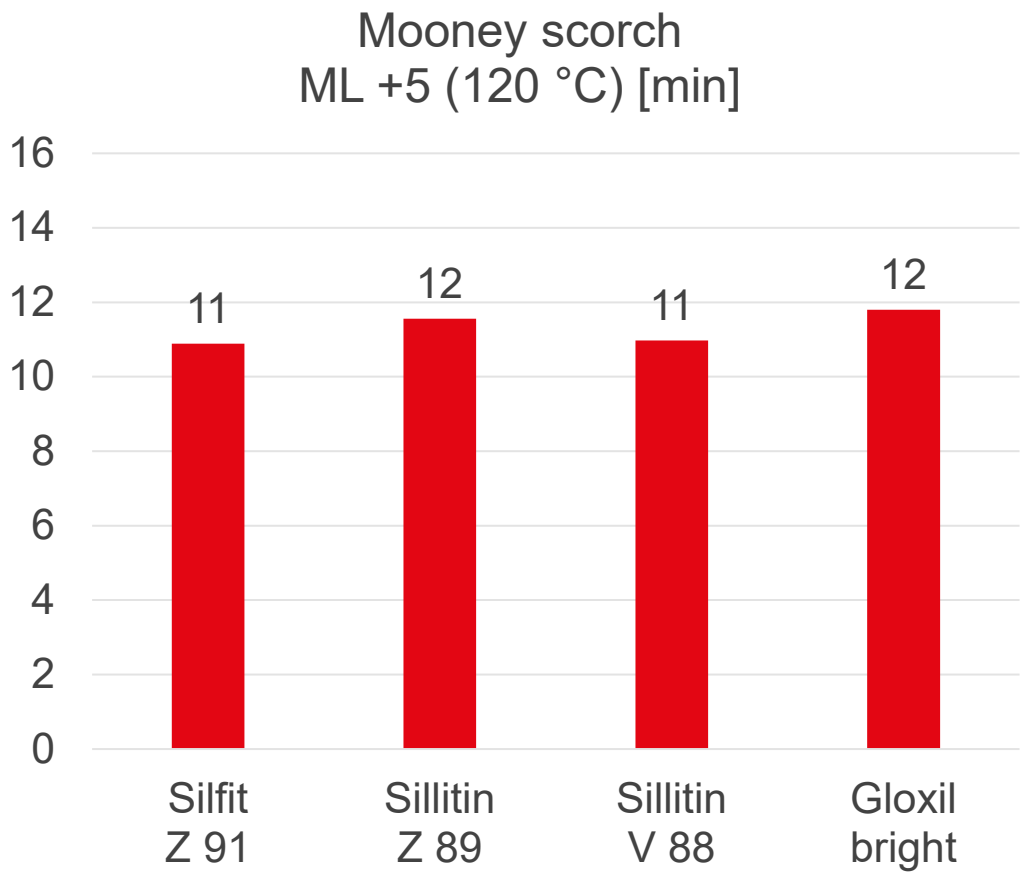
Rheological properties

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

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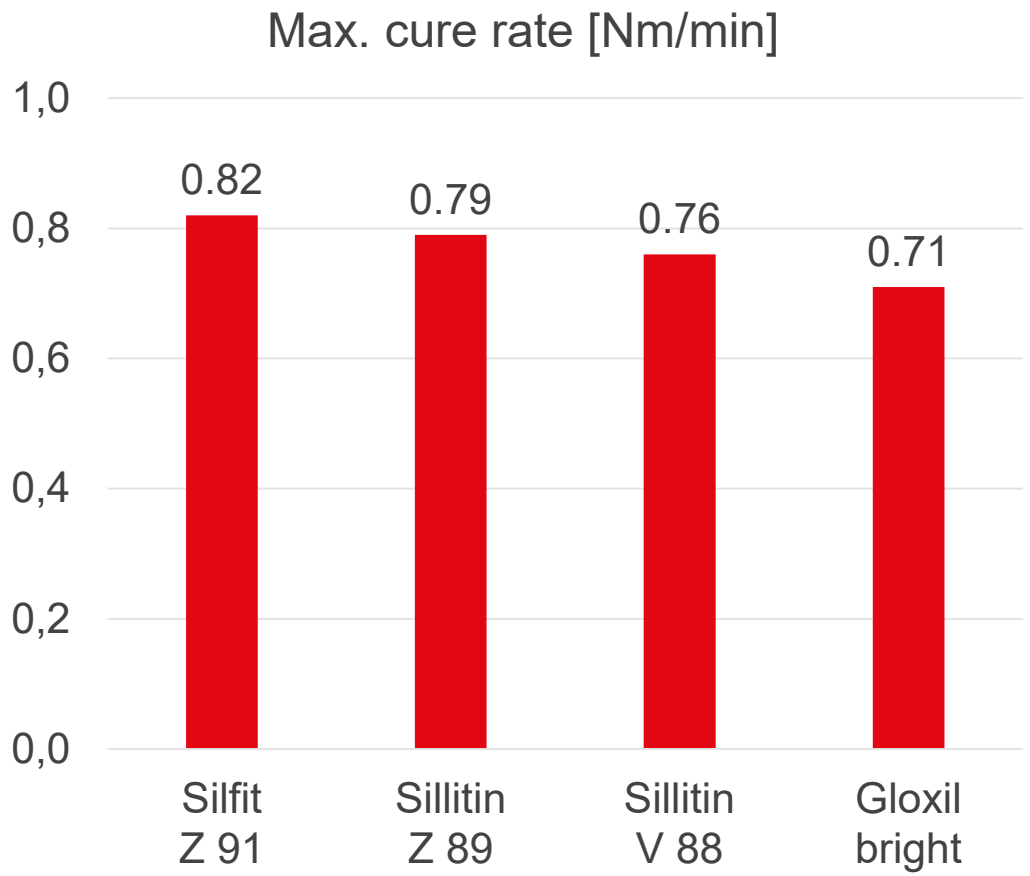
Mooney test

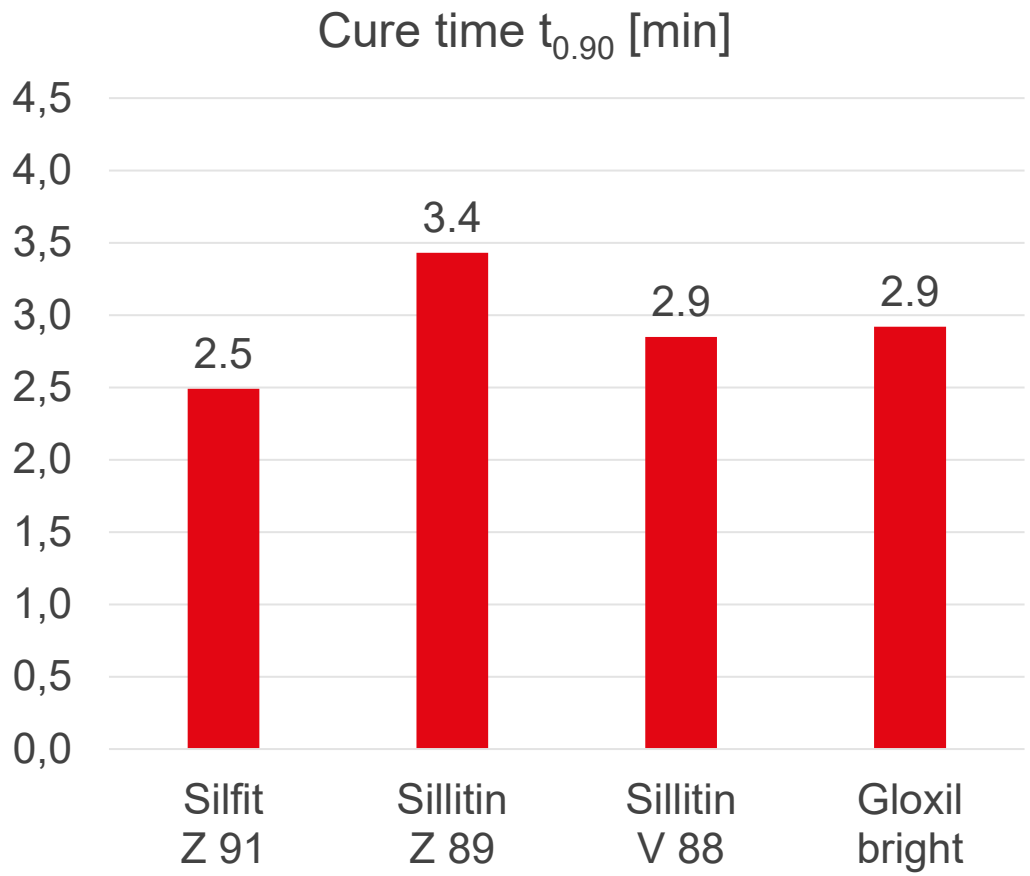




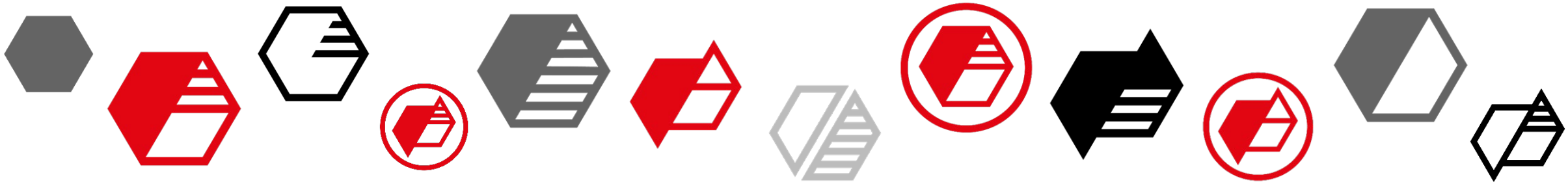
- Slightly lower viscosity for the non-calcined products Sillitin Z 89 and Sillitin V 88.
- Similar scorch time for all products.

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





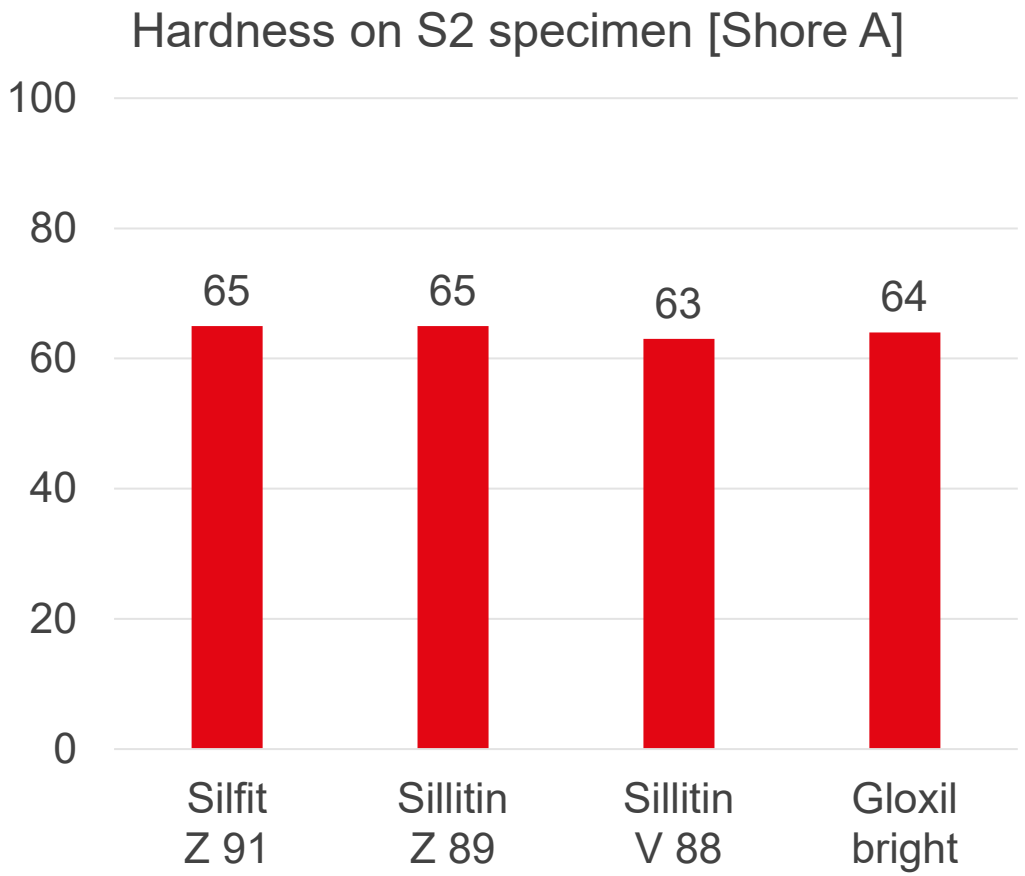
- Similar maximum cure rate among Sillitin-based products.
- Similar optimum cure time $t_{0.90}$ for Sillitin V 88 and Gloxil bright.



Properties of the vulcanizates

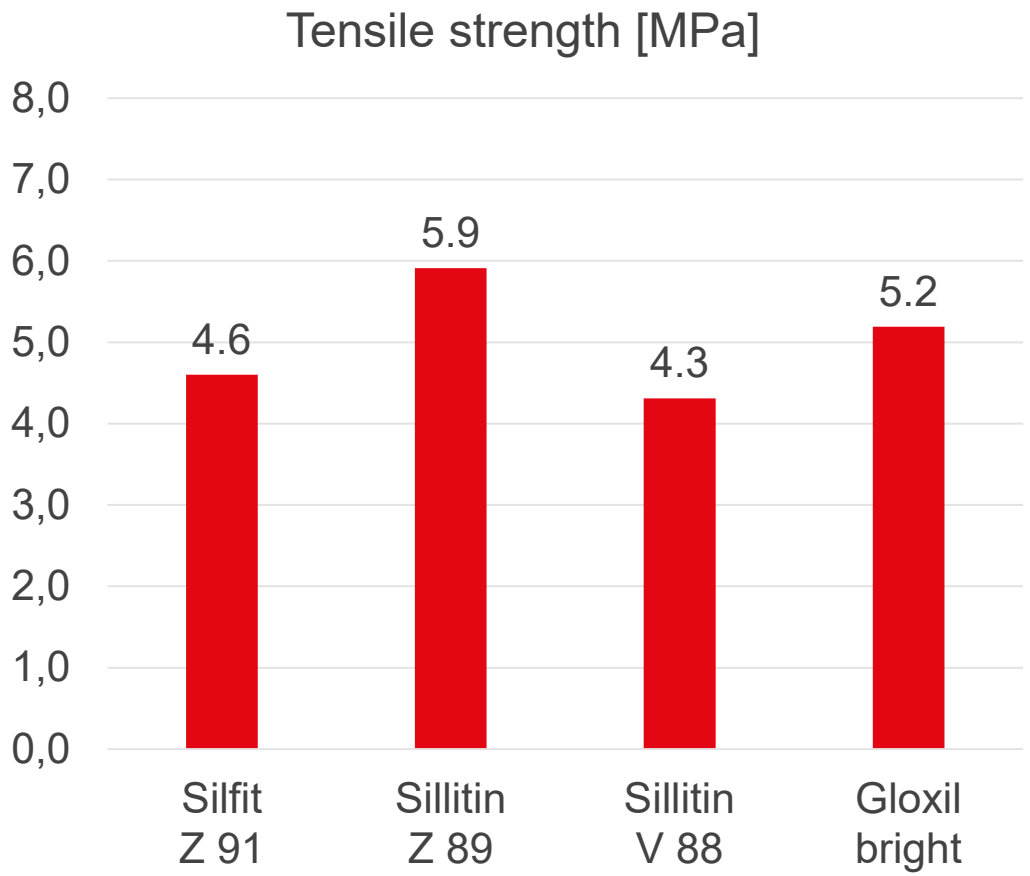
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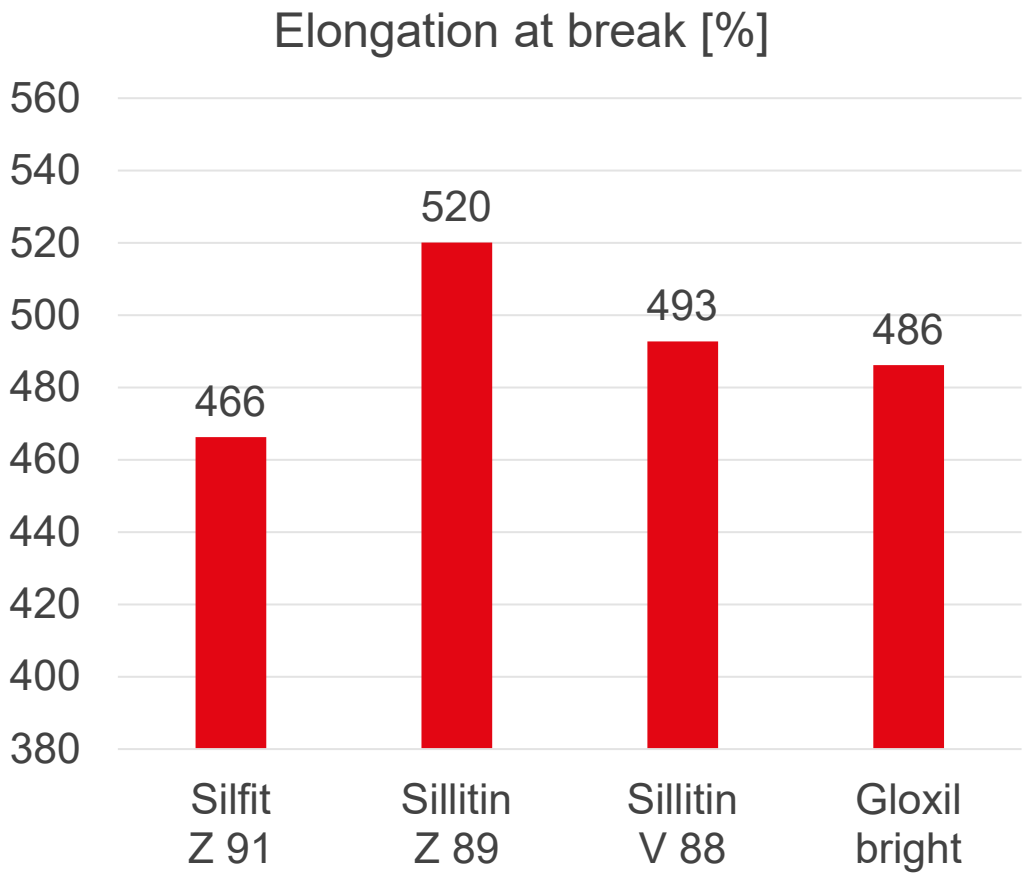
Mechanical properties



- Similar hardness for all products.

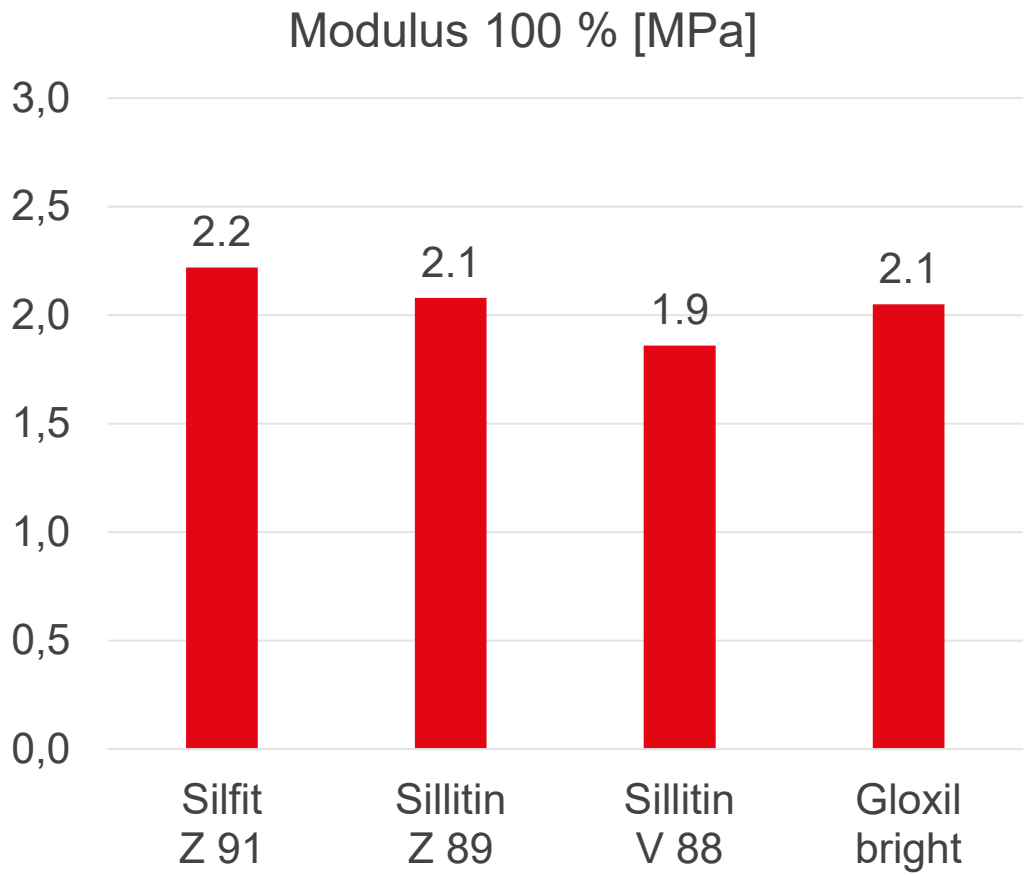
Mechanical properties

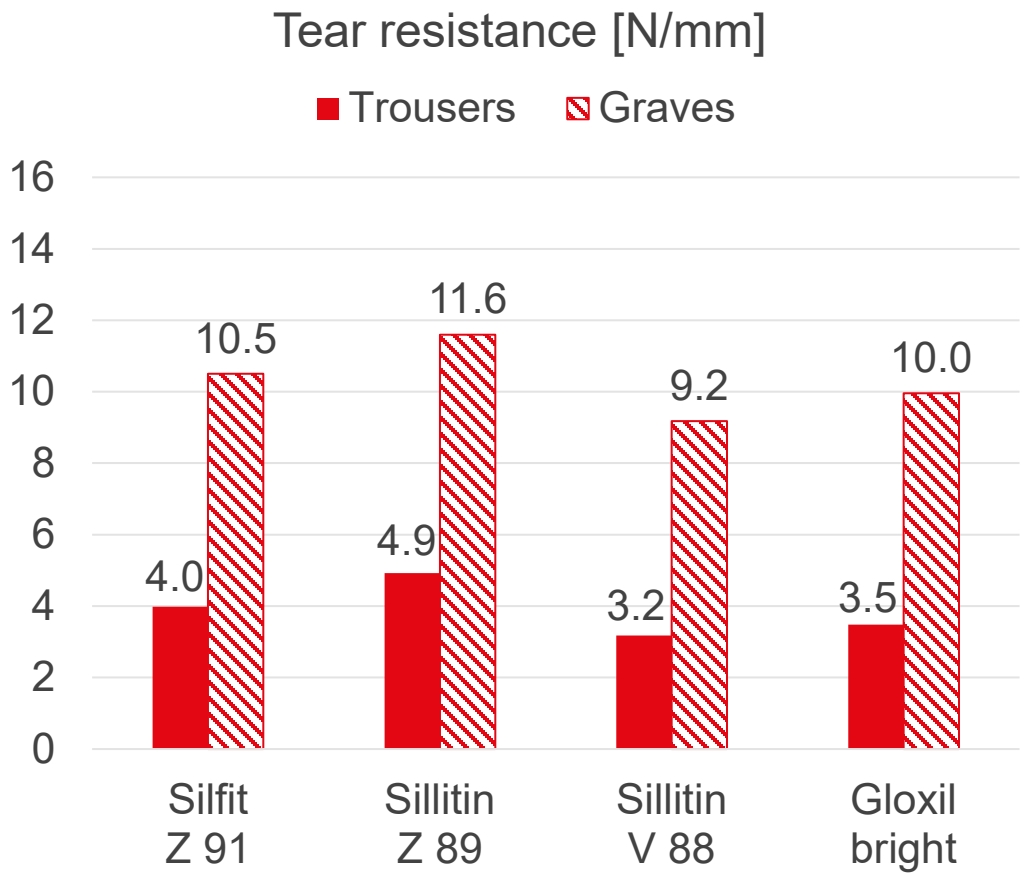




- Similar or improved tensile strength and elongation at break for the alternative products, especially for Sillitin Z 89.

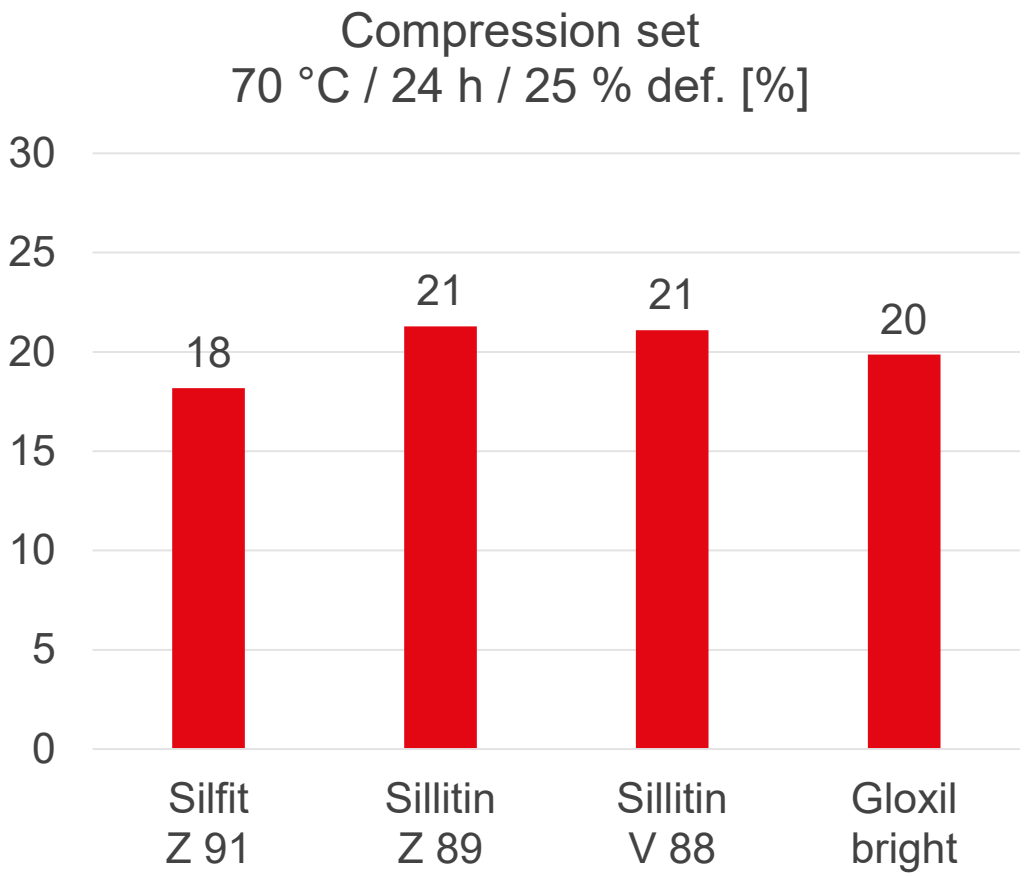
Mechanical properties

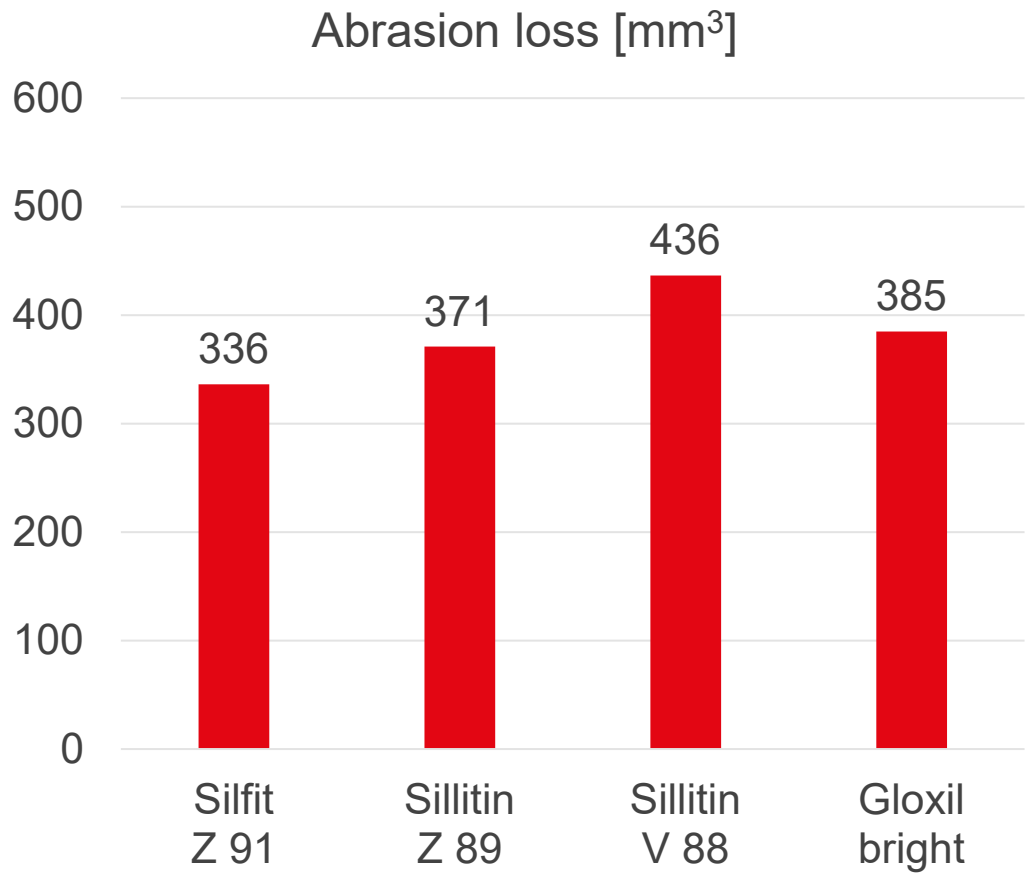




- Similar modulus 100 % for all products.
- Slightly improved tear resistance for Sillitin Z 89.

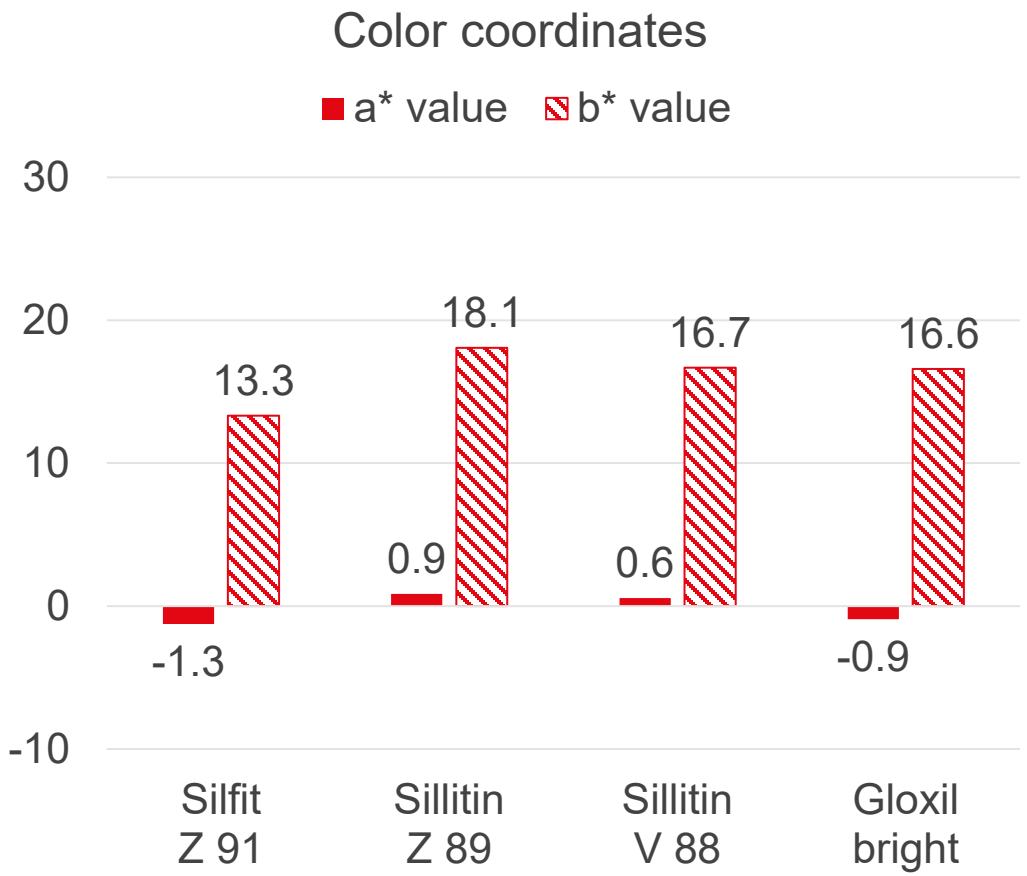
Mechanical properties

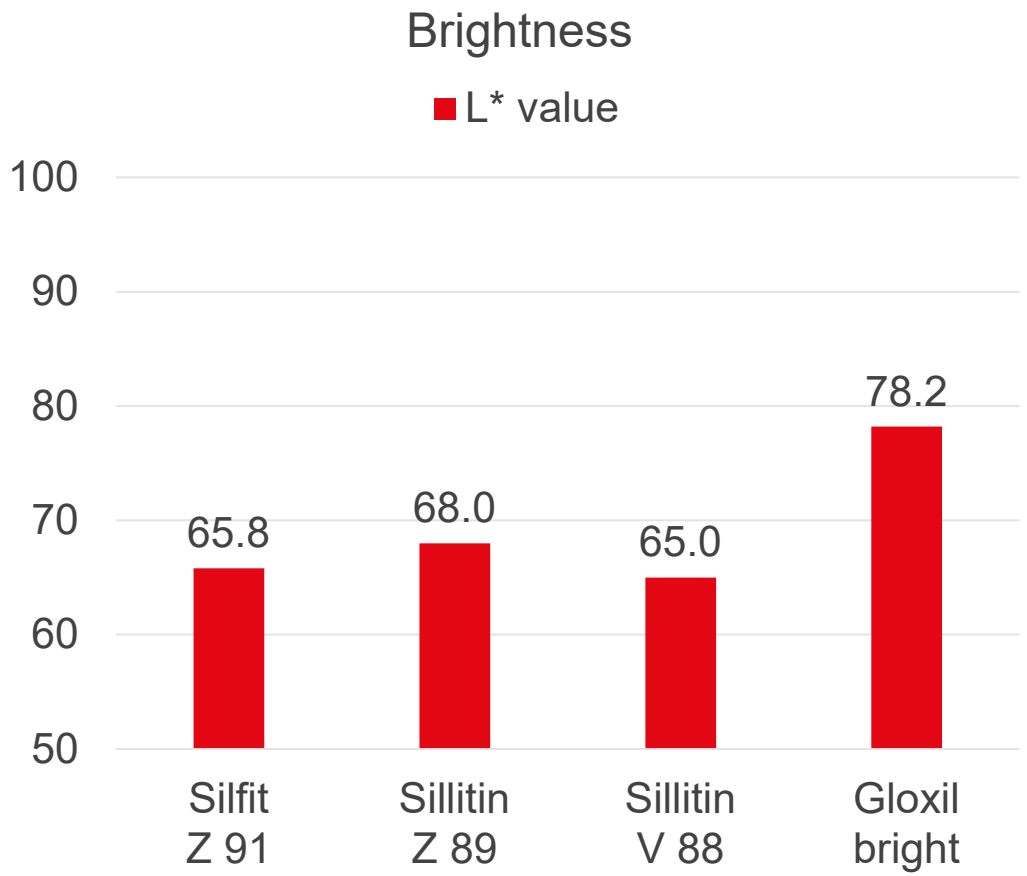




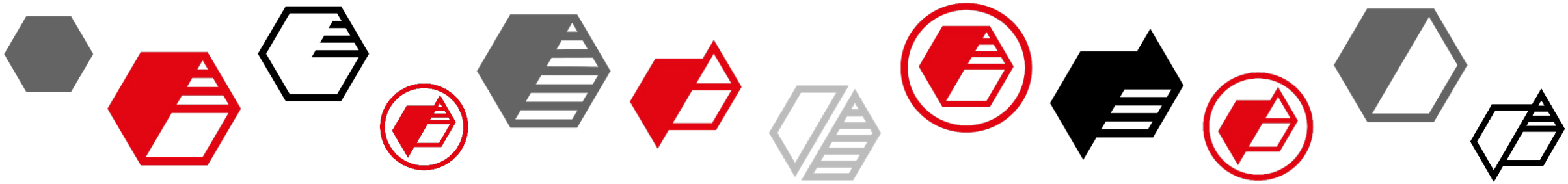
- Similar compression set among the alternative products.
- Sillitin Z 89 offers the best abrasion resistance among the alternative products, followed by Gloxil bright.

Color – Color coordinates and brightness





- Similar color coordinates for Sillitin V 88 and Gloxil bright.
- Similar brightness among Sillitin-based products, while Gloxil bright shows the highest brightness.

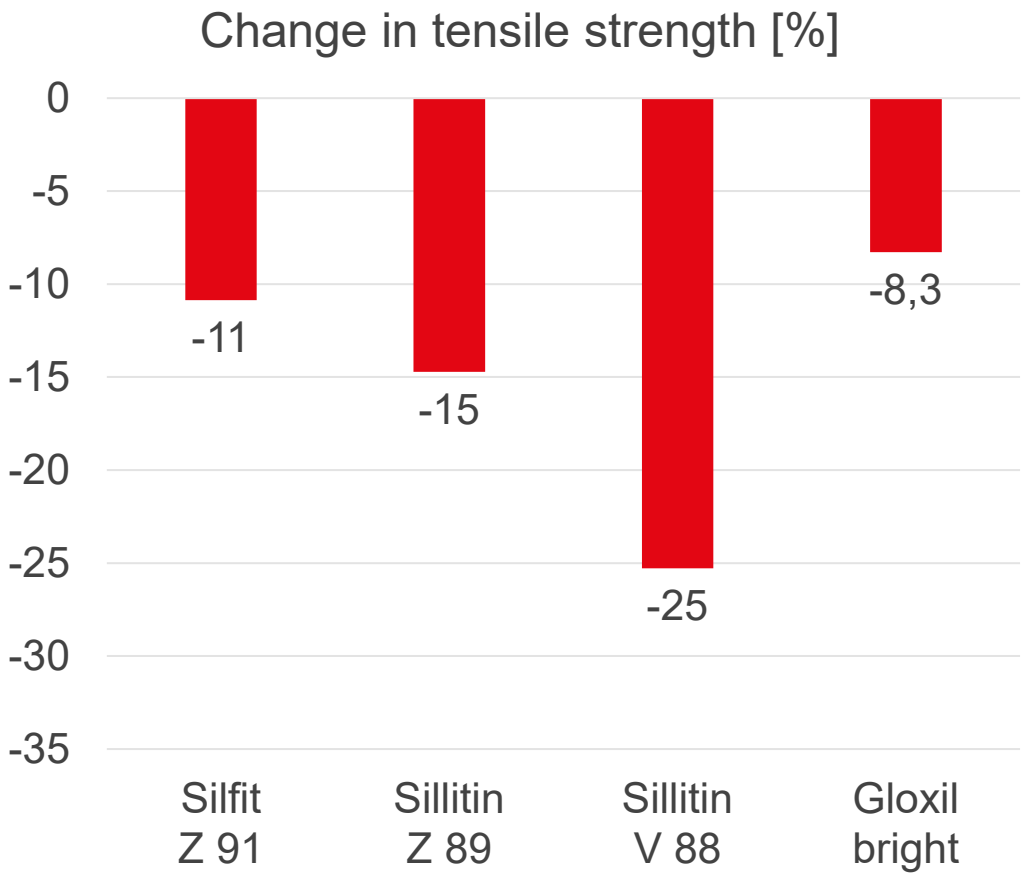


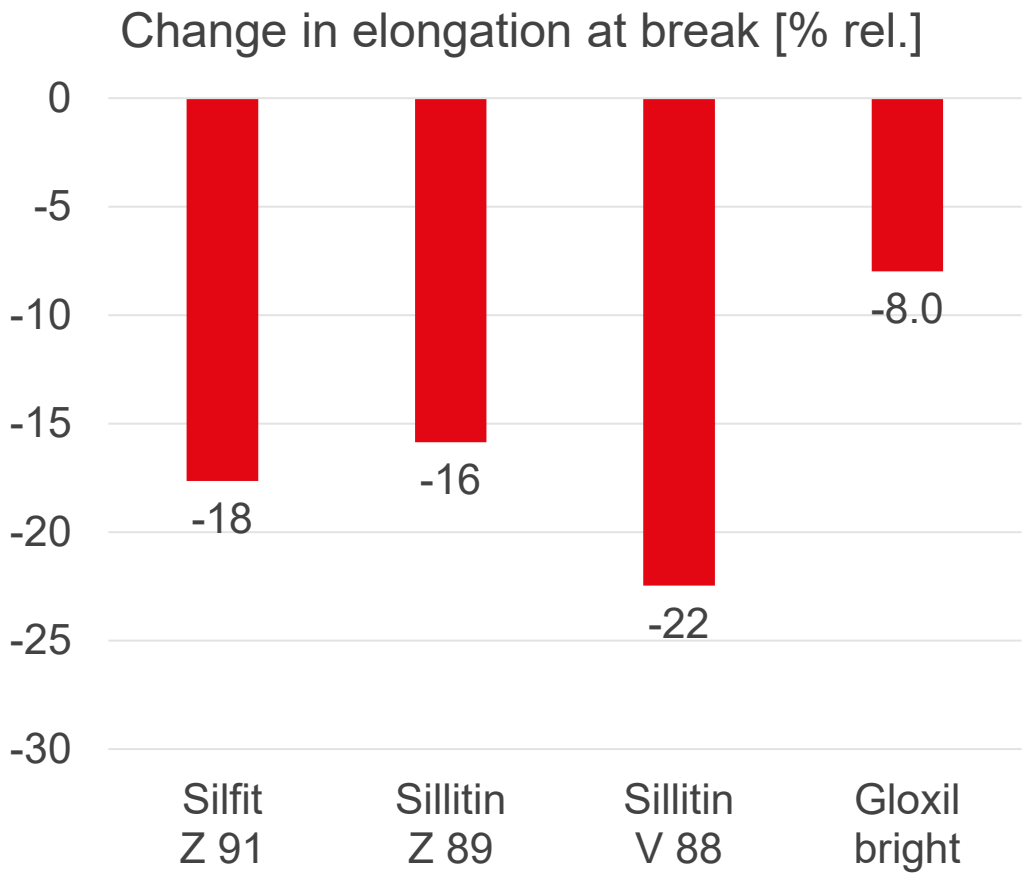
Aging in hot air 168 h / 70 °C

ISO 188, D

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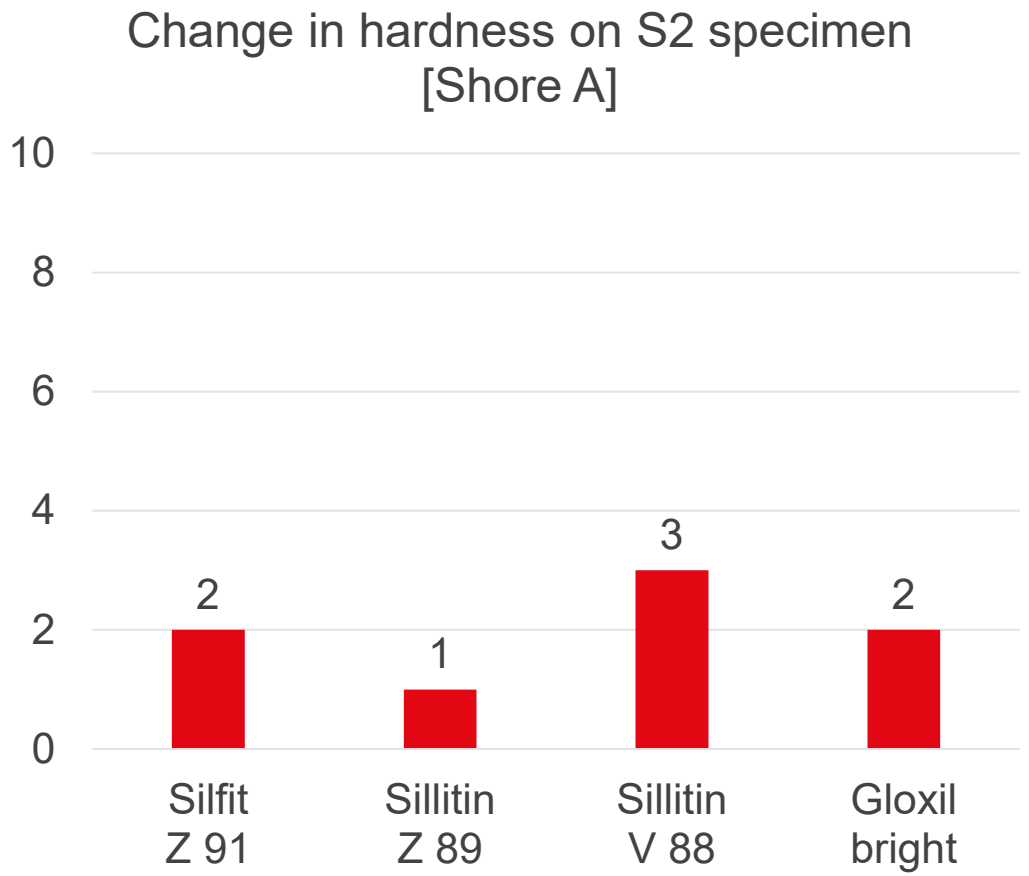
Aging in hot air 168 h / 70 °C



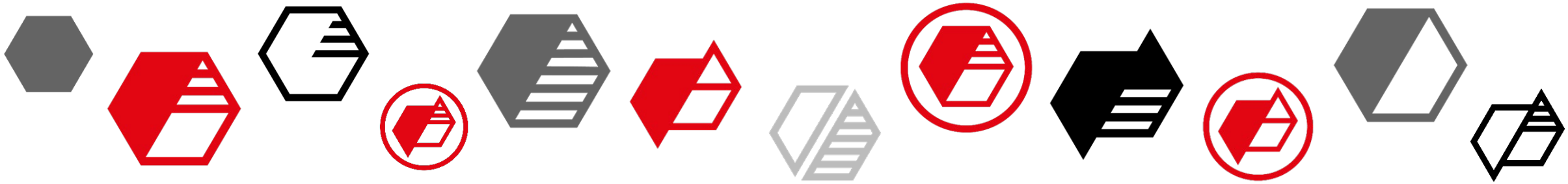


- Similar changes in tensile strength and elongation at break for Sillitin Z 89 and Gloxil bright.

Aging in hot air 168 h / 70 °C



- Similar change in hardness across all products.

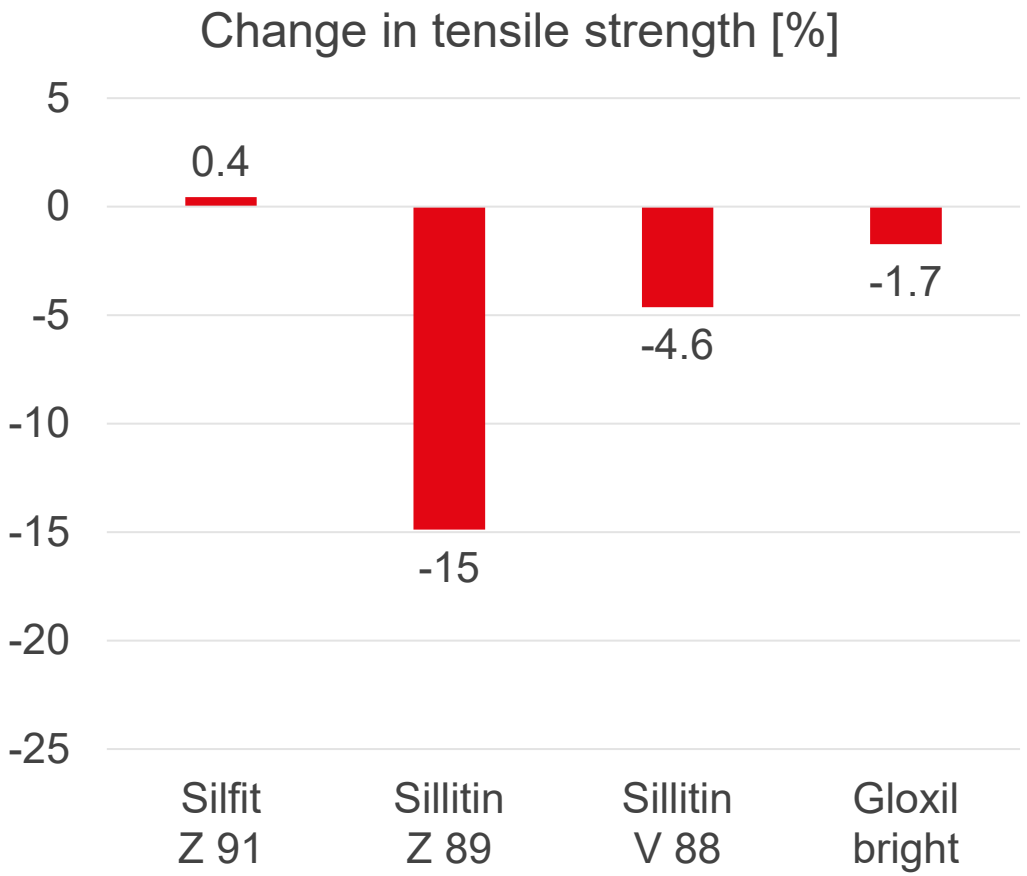


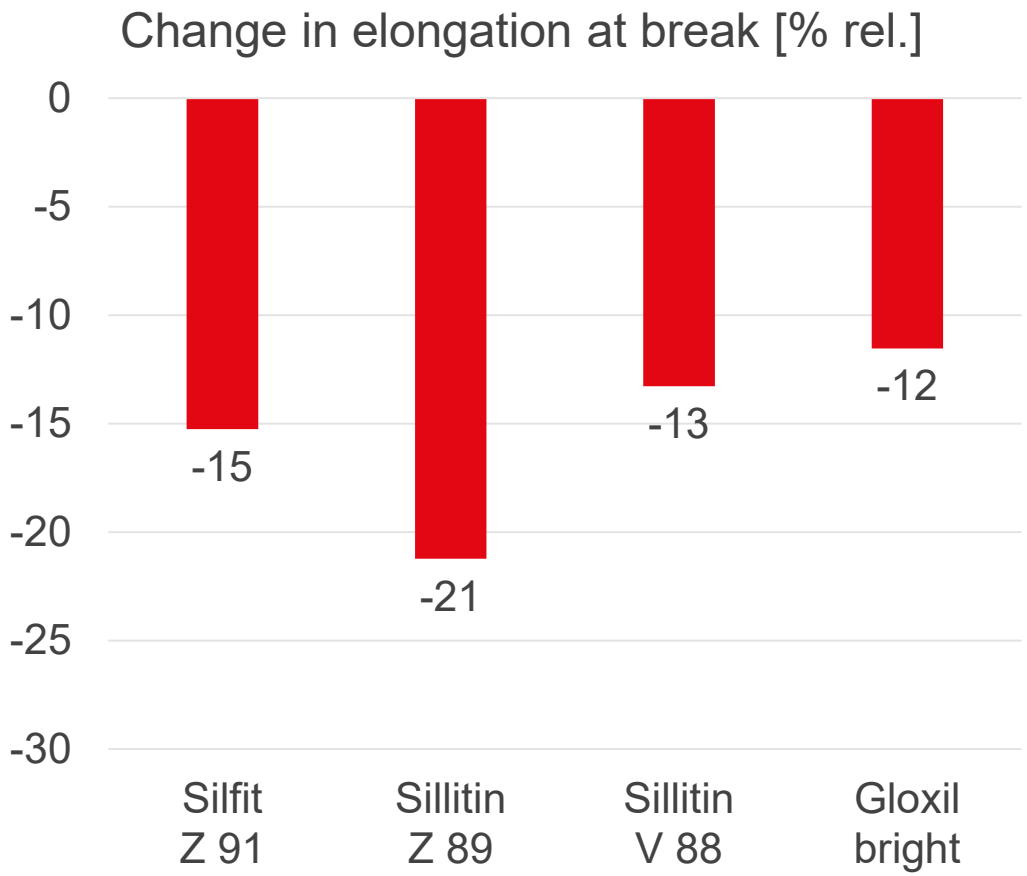
Aging in deionized water 168 h / 95 °C

DIN ISO 1817

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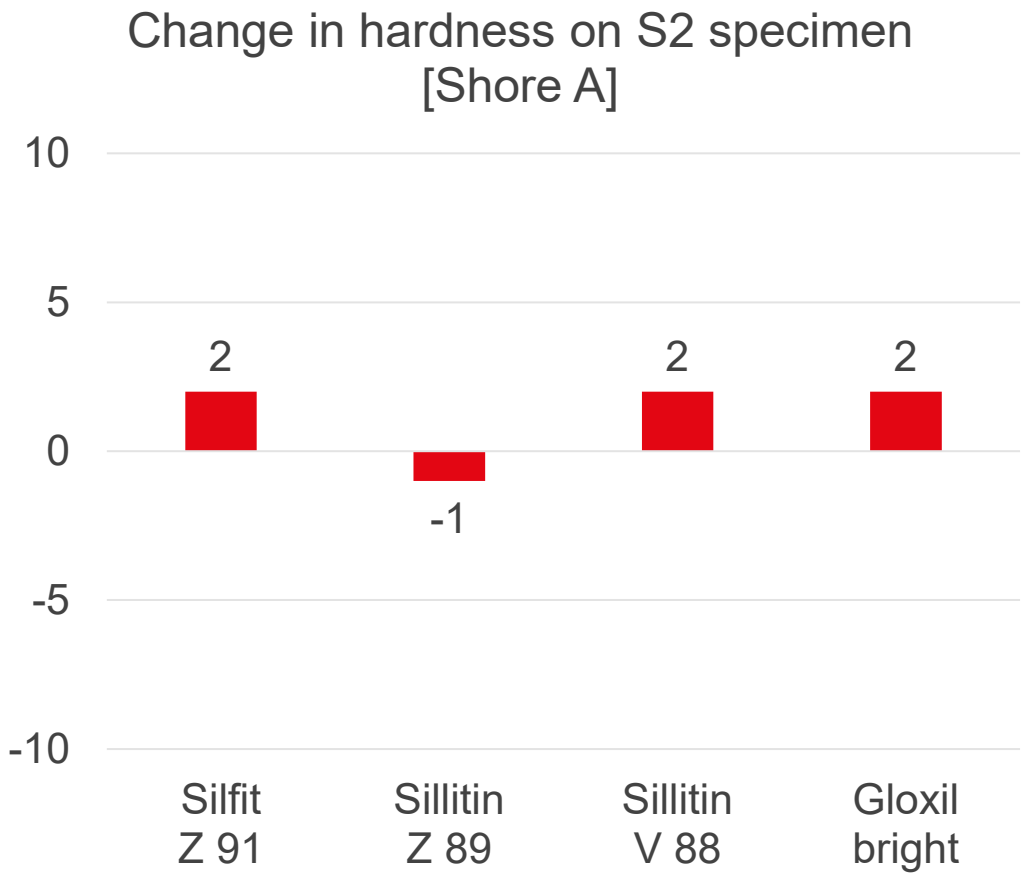
Aging in deionized water 168 h / 95 °C

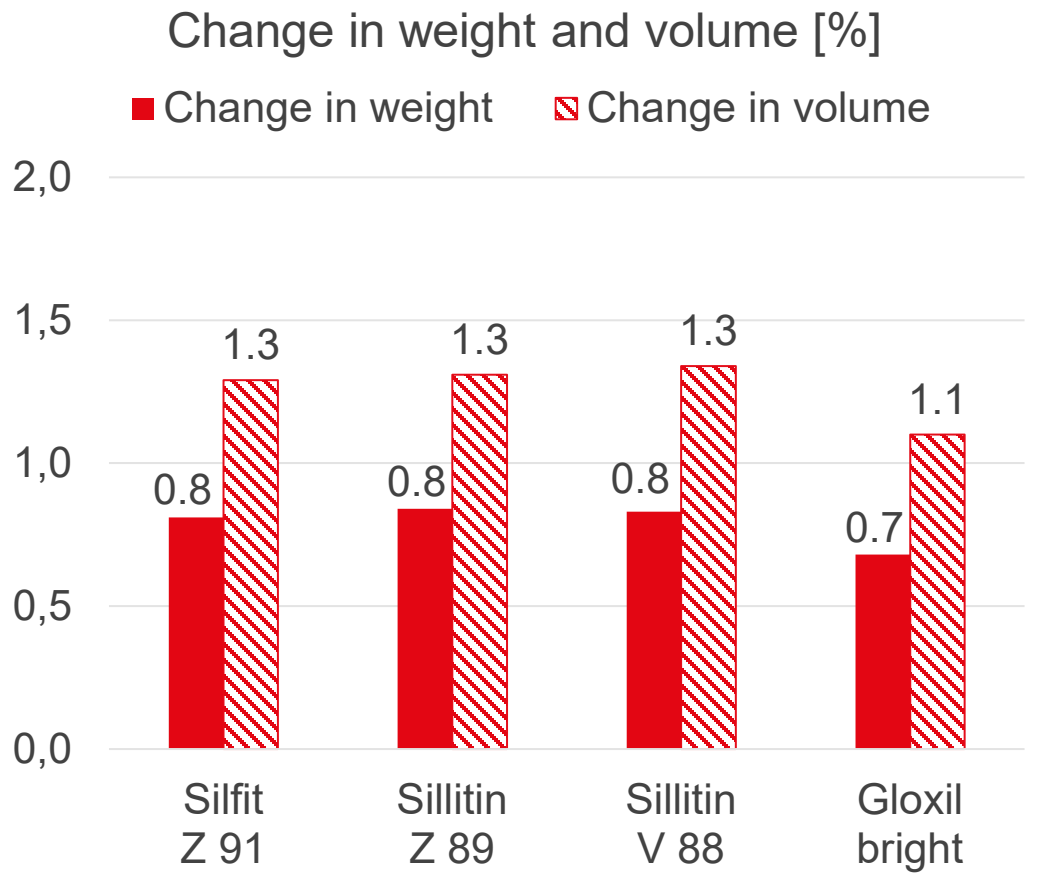




- Similar changes in tensile strength and elongation at break for Sillitin V 88 and Gloxil bright.

Aging in deionized water 168 h / 95 °C





- Similar changes in hardness, weight and volume across all products.

Alternative fillers vs. Silfit Z 91

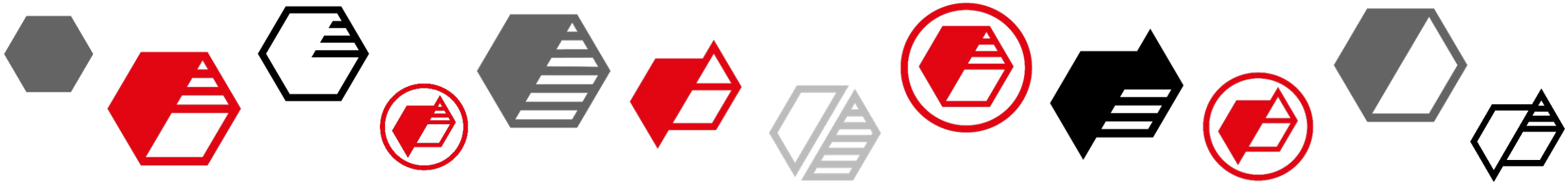
65 Shore A	Sillitin Z 89	Sillitin V 88	Gloxil bright
Mooney viscosity	=	+	=
Scorch time	=	=	=
Max. cure rate	=	=	
Cure time $t_{0.90}$		=	=
Tensile strength	+	=	=
Elongation at break	+	=	=
Modulus 100 %	=	=	=
Tear resistance – Trousers	+		
Tear resistance – Graves	=		=
Compression set 70 °C , 24 h	=	=	=
Abrasion loss	=		
Hot-air resistance 70 °C , 168 h	=		+
Water resistance 95 °C , 168 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	Gloxil bright
Mooney viscosity, ML 1+4, 100 °C	MU	63	59	58	62
Mooney scorch, ML +5, 120 °C	min	11	12	11	12
Max. cure rate, 180 °C	Nm/min	0.82	0.79	0.76	0.71
Cure yield, 180 °C	Nm	0.745	0.751	0.708	0.707
Cure time $t_{0.05}$, 180 °C	min	0.81	0.69	0.70	0.90
Cure time $t_{0.90}$, 180 °C	min	2.5	3.4	2.9	2.9
Tensile strength	MPa	4.6	5.9	4.3	5.2
Elongation at break	%	466	520	493	486
Modulus 100 %	MPa	2.2	2.1	1.9	2.1
Modulus 300 %	MPa	3.2	3.1	2.5	2.8
Hardness	Shore A	65	65	63	64
Tear resistance – Trousers specimen	N/mm	4.0	4.9	3.2	3.5
Tear resistance – Graves specimen	N/mm	10.5	11.6	9.2	10.0
Compression set 24 h / 70 °C / 25 % deformation	%	18	21	21	20
Abrasion loss	mm^3	336	371	436	385

Results in tabular form – Aging in hot air

		Silfit Z 91	Sillitin Z 89	Sillitin V 88	Gloxil bright
Aging in hot air 168 h / 70 °C					
Tensile strength	MPa	4.1	5.0	3.2	4.8
Elongation at break	%	384	438	382	447
Modulus 100 %	MPa	2.5	2.4	2.2	2.2
Hardness	Shore A	67	66	66	66
Δ Tensile strength	%	-11	-15	-25	-8.3
Δ Elongation at break	% rel.	-18	-16	-22	-8.0
Δ Modulus 100 %	%	11	17	16	8.3
Δ Hardness	Shore A	2	1	3	2

Results in tabular form – Aging in deionized water

		Silfit Z 91	Sillitin Z 89	Sillitin V 88	Gloxil bright
Aging in deionized water 168 h / 95 °C					
Tensile strength	MPa	4.6	5.0	4.1	5.1
Elongation at break	%	395	410	427	430
Modulus 100 %	MPa	2.2	2.1	2.0	2.1
Hardness	Shore A	67	64	65	66
Δ Tensile strength	%	0.4	-15	-4.6	-1.7
Δ Elongation at break	% rel.	-15	-21	-13	-12
Δ Modulus 100 %	%	0.9	0.5	5.4	0.0
Δ Hardness	Shore A	2	-1	2	2
Δ Weight	%	0.8	0.8	0.8	0.7
Δ Volume	%	1.3	1.3	1.3	1.1