Filler comparison

Non black fillers in sulfur cured NBR-Rubber

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Content

Status Quo

A hardness of approx. 70 Shore A was targeted.

The accelerator system was adapted by contemporary components that do not cause any critical nitrosamines.

Experimental

- Formulation
- Fillers
  - Neuburg Siliceous Earth (NSE)
  - Tailored Filler Solutions (TFS)
  - Competitors
- Compounding and vulcanization
- Test standards - overview

Formulation

Ingredients	Description	phr
Perbunan 3446 F	Acrylonitrile butadiene rubber, acrylonitrile content: approx. 35 % ML 1+4 (100 °C): 42 MU	100
Zinkoxyd aktiv	Zinc oxide active	5
Edenor C18 98-100 GW	Stearic acid	1
Filler	*Please see slides „Fillers“*	variable 120 / 80 / 70 / 60 / 45 / 40
Mediaplast NB 500	Ester plasticizer, phthalate-free	5
Rhenogran S-80	Sulfur, 80 %, crosslinking agent	1
Rhenogran CBS-80	N-Cyclohexylbenzothiazole-2-sulfenamide, 80 %, accelerator	1,25
Rhenogran TBzTD-70	Tetrabenzylthiuram disulphide, 70 %, accelerator	3,00
Total:		**max. 236,25 / min. 156,25**

Fillers – Neuburg Siliceous Earth

	phr
Sillitin V 85	120
Sillitin V 88	120
Sillitin N 82*	120
Sillitin N 85	120
Sillitin Z 86	120
Sillitin Z 89	120
Sillikolloid P 87	120

***Sillitin N 82 will be replaced by Sillitin N 75**

	Basic material	Calcination	Functionalization	phr
Silfit Z 91	Sillitin Z 86	✓	-	120
Aktifit AM	Silfit Z 91	✓	Amino	120
Aktisil AM	Sillitin Z 86	-	Amino	120
Aktisil PF 216	Sillitin Z 86	-	Tetrasulfane	120
Aktisil VM 56	Sillitin Z 86	-	Vinyl	120
Aktisil VM 56/89	Sillitin Z 89	-	Vinyl	120
Aktisil Q	Sillitin V 90 *internal product quality	-	Methacrylic	120
Aktisil PF 777	Sillitin Z 86	-	Alkyl	120

Fillers – Tailored Filler Solutions

	Basic material	Calcination	Functionalization	phr
Struktosil 45 AM	Talc	-	Amino	120
Struktosil 45 MAM	Talc	-	Methacrylic	120

Fillers – Competitors

	Calcination	Functionalization	phr
Carbon black N 550	-	-	60
Precipitated silica 180 m²/g	-	-	40
Precipitated silica 130 m²/g	-	-	45
Precipitated aluminum silicate	-	-	70
Precipitated calcium silicate	-	-	80
French Hard Clay	-	-	120
English Hard Clay	-	-	120
English Clay	-	-	120
English Soft Clay	-	-	120
English calcined Clay	✓	-	120
American calcined Clay	✓	-	120
American calcined Clay, amino functionalized	✓	Amino	120
English calcined Clay, amino functionalized	✓	Amino	120
American calcined Clay, vinyl functionalized	✓	Vinyl	120
Whiting	-	-	120
Whiting, stearate functionalized	-	Stearic acid	120
American Talc	-	-	120
American coated Talc, amino functionalized	-	Amino	120

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Compounding and vulcanization

Compounding	
Open mill	Ø 150 x 300 mm
Batch weight	1000 g 500 g for Mooney testing
Mill temperature	40 °C
Mixing time	NSE: approx. 10 - 15 min. Competitors: approx. 15 - 30 min.

Vulcanization	
The curing was carried out in a press at 160 °C	
Curing time	5 min. or t_{90} + 10 %

Test standards – overview

Testing	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, part 1 – 4
Tensile test	DIN 53 504, S2
Compression set	DIN ISO 815-1, Typ B
Abrasion loss	DIN ISO 4649, A
Hardness	DIN ISO 7619-1
Rebound elasticity	DIN 53 512
Tear resistance - Trousers specimen	DIN ISO 34-1, A
Tear resistance - Graves specimen	DIN ISO 34-1, Bb
Resistance to liquid media	DIN ISO 1817
Resistance to air	ISO 188, D

Results

→ back to content

- Properties of raw compound
  - Mooney Viscosity ML 1+4 (100 °C)
  - Mooney Scorch ML +5 (120 °C)
  - Rotorless Cure Meter, 160 °C
- Properties of vulcanizate
- Hot air aging 168 h / 70 °C
- Hot air aging 168 h / 100 °C
- Immersion in deionized water 168 h / 95 °C
- Immersion in reference oil IRM 903 168 h / 100 °C

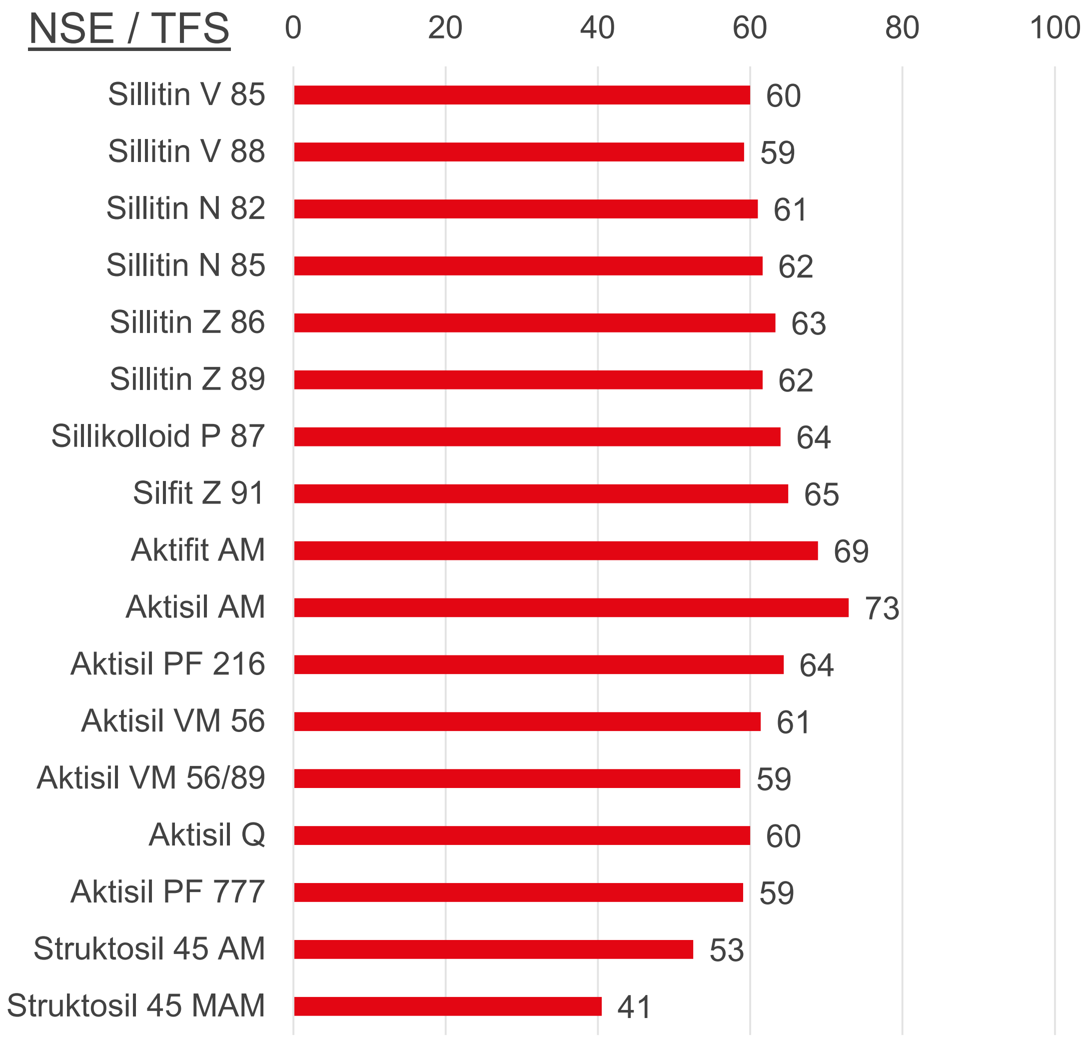
→ back to results

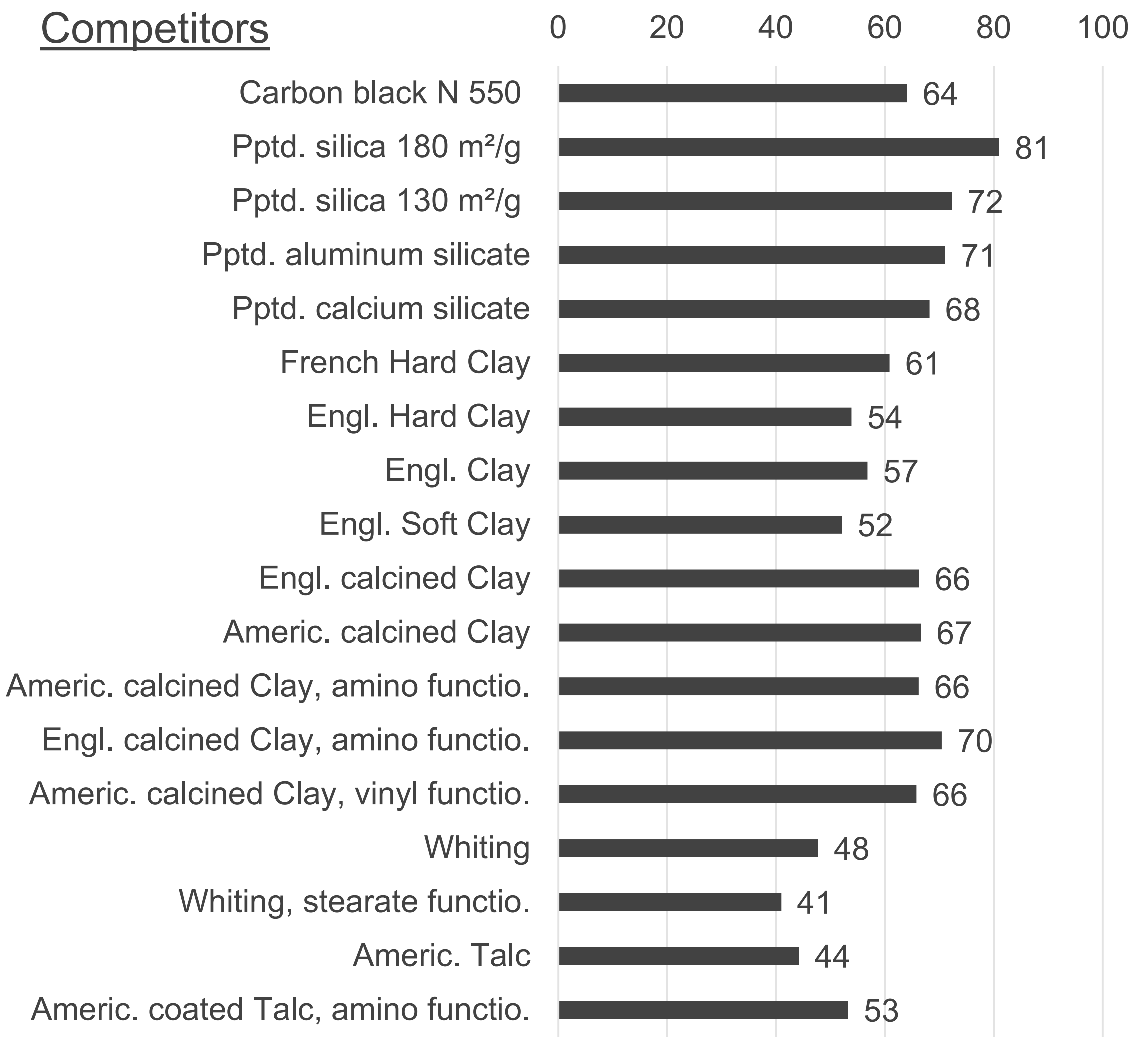
Properties of raw compound

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

Mooney Viscosity ML 1+4 (100 °C) in MU

DIN ISO 289-1

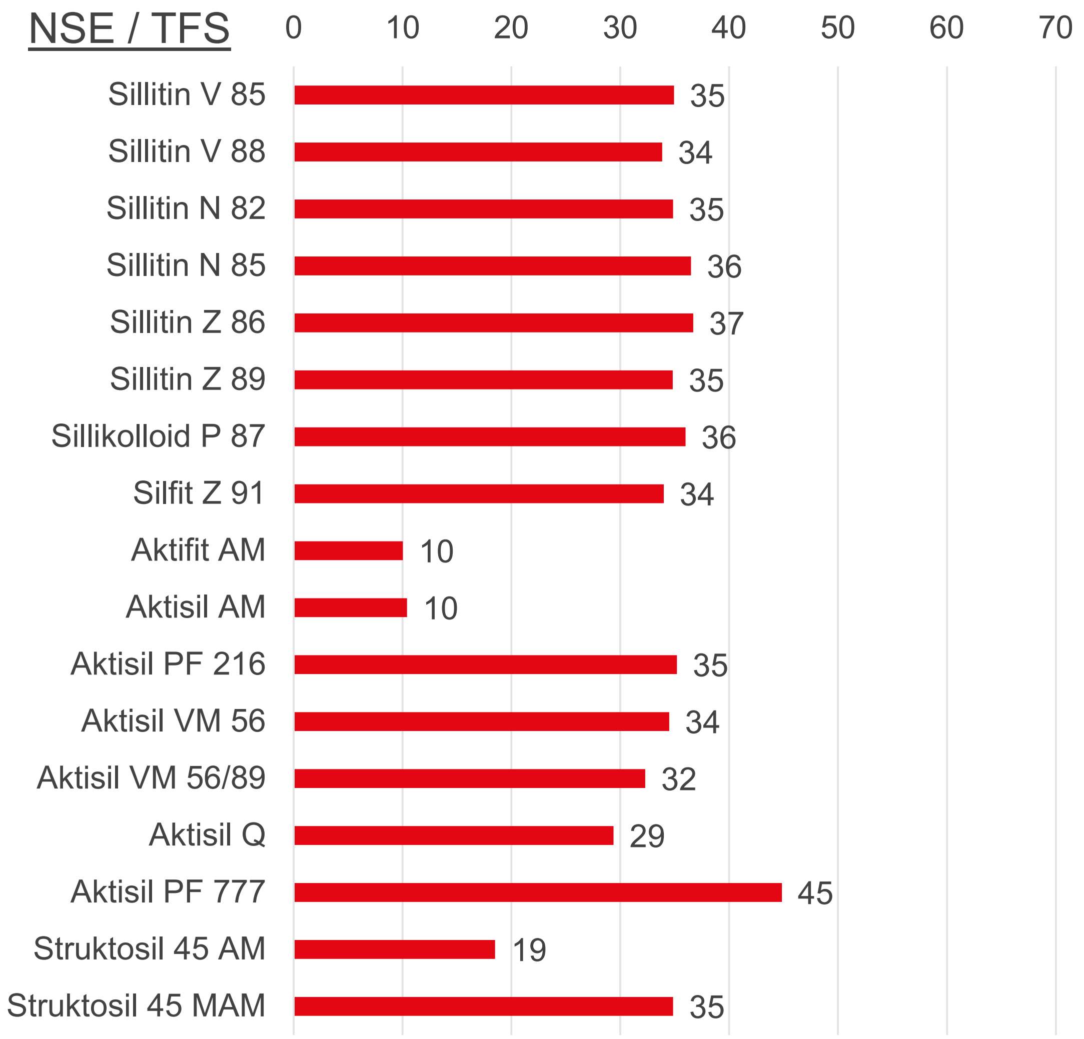


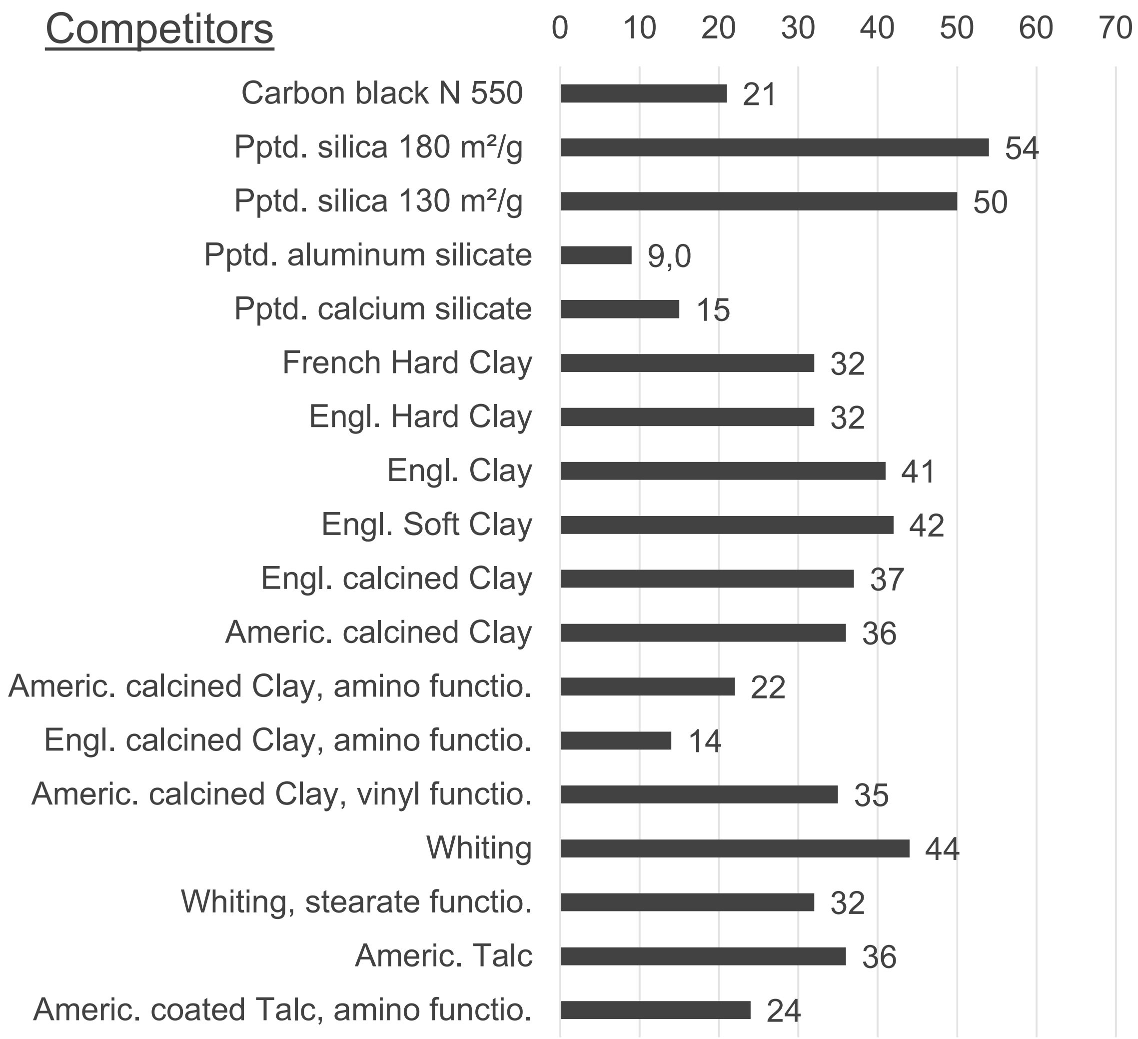


Note: Sillitin N 82 will be replaced by Sillitin N 75

Mooney Scorch ML +5 (120 °C) in min.

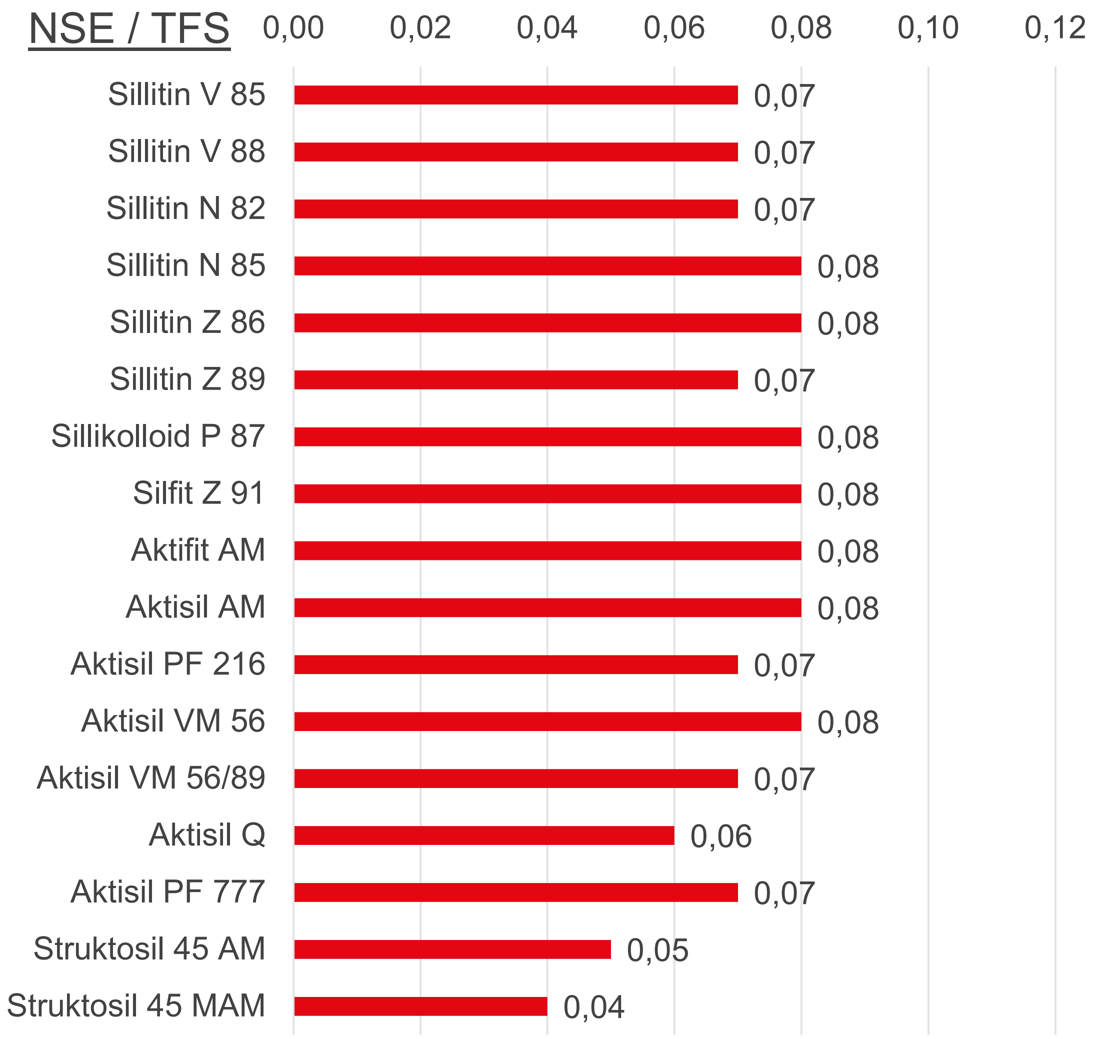
DIN ISO 289-2

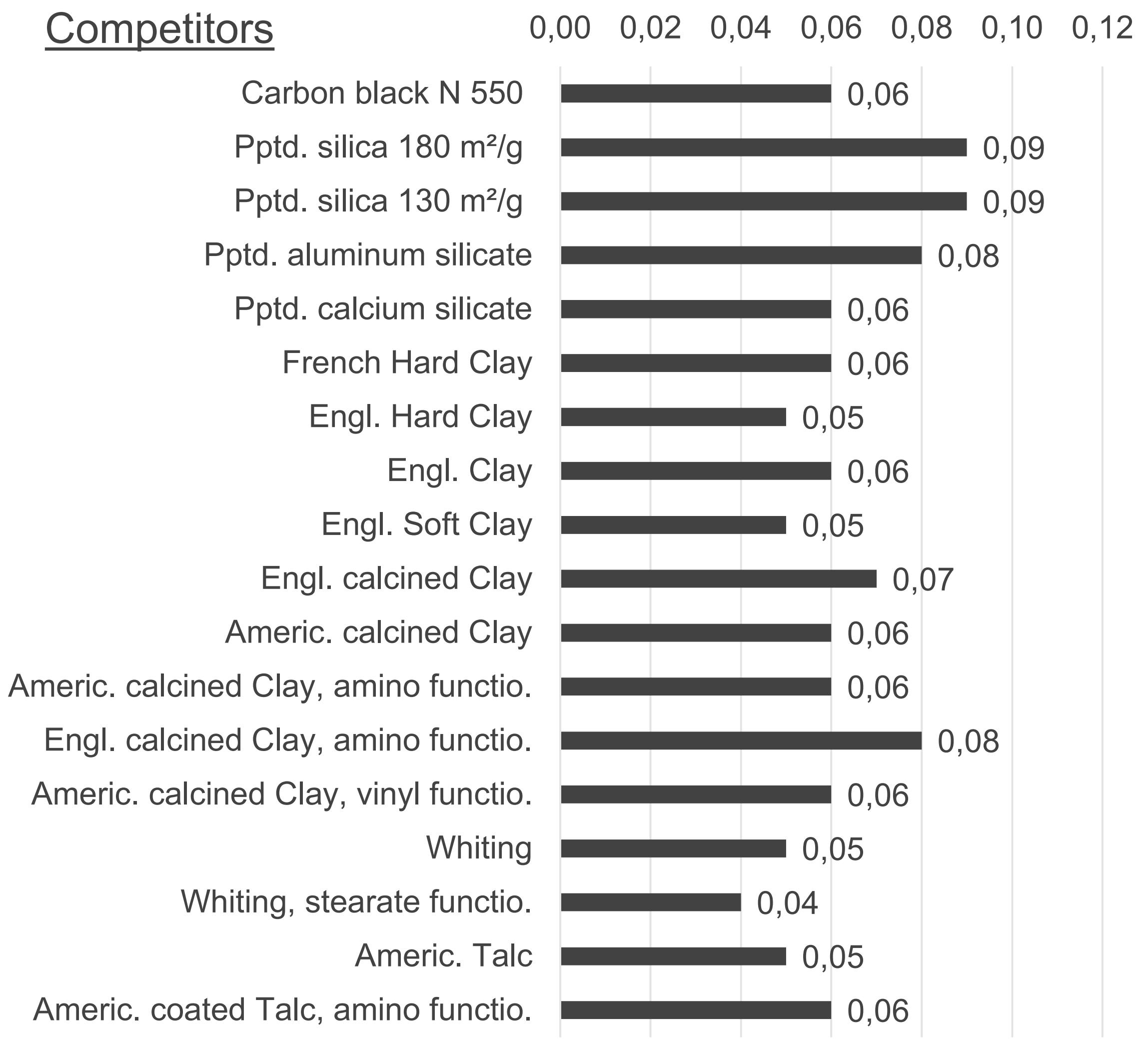




Note: Sillitin N 82 will be replaced by Sillitin N 75

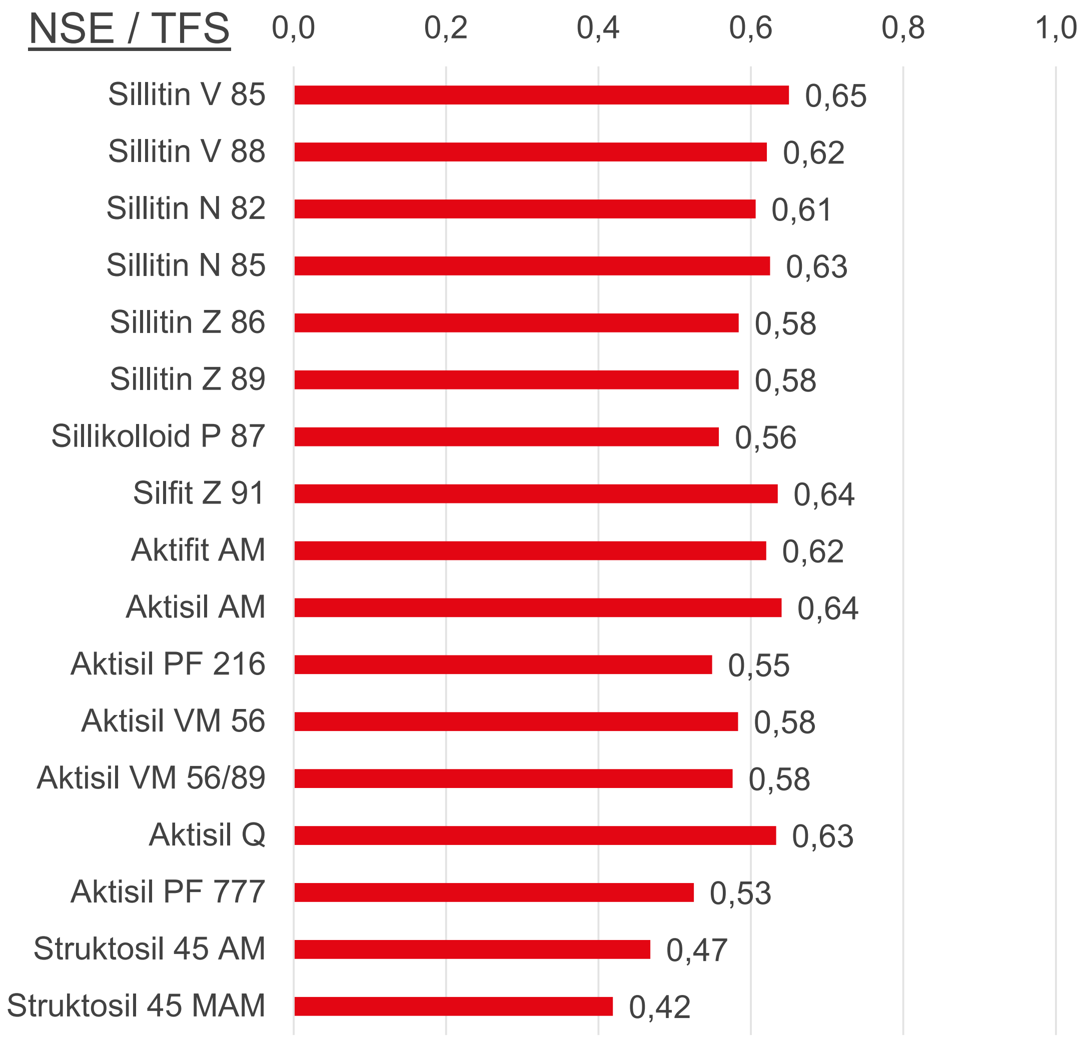
Rotorless curemeter, 160 °C
Torque minimum in Nm

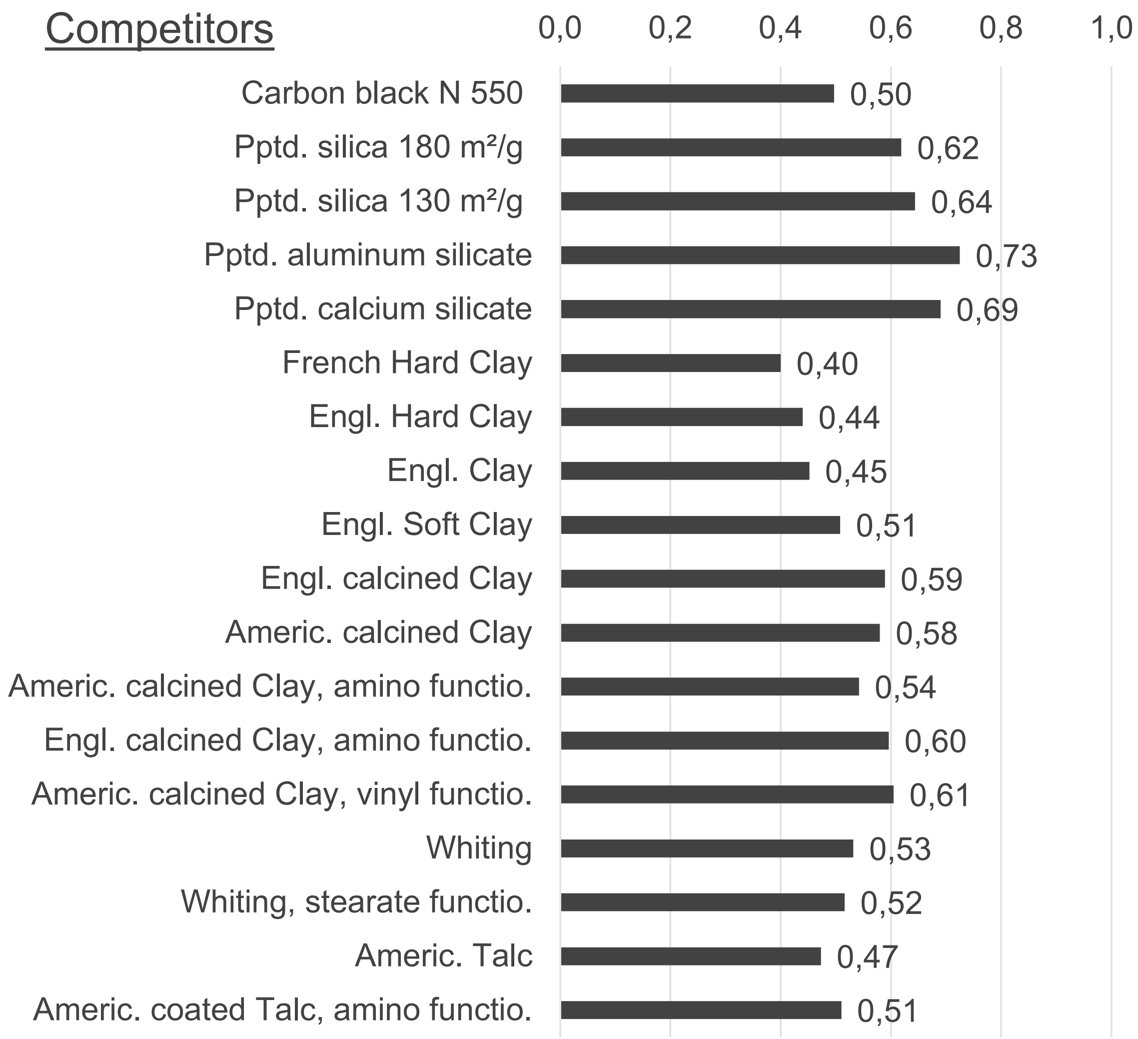




Note: Sillitin N 82 will be replaced by Sillitin N 75

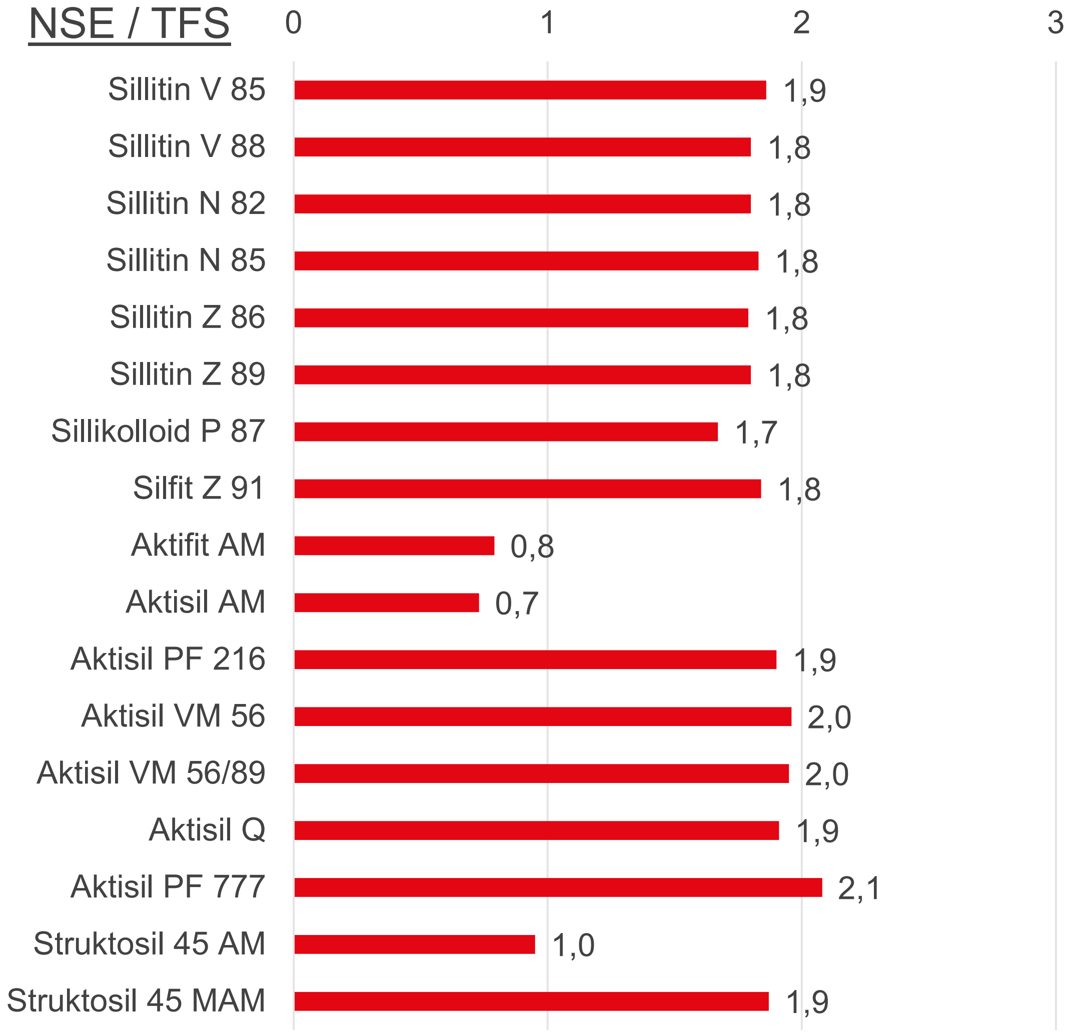
Rotorless curemeter, 160 °C
Cure yield in Nm

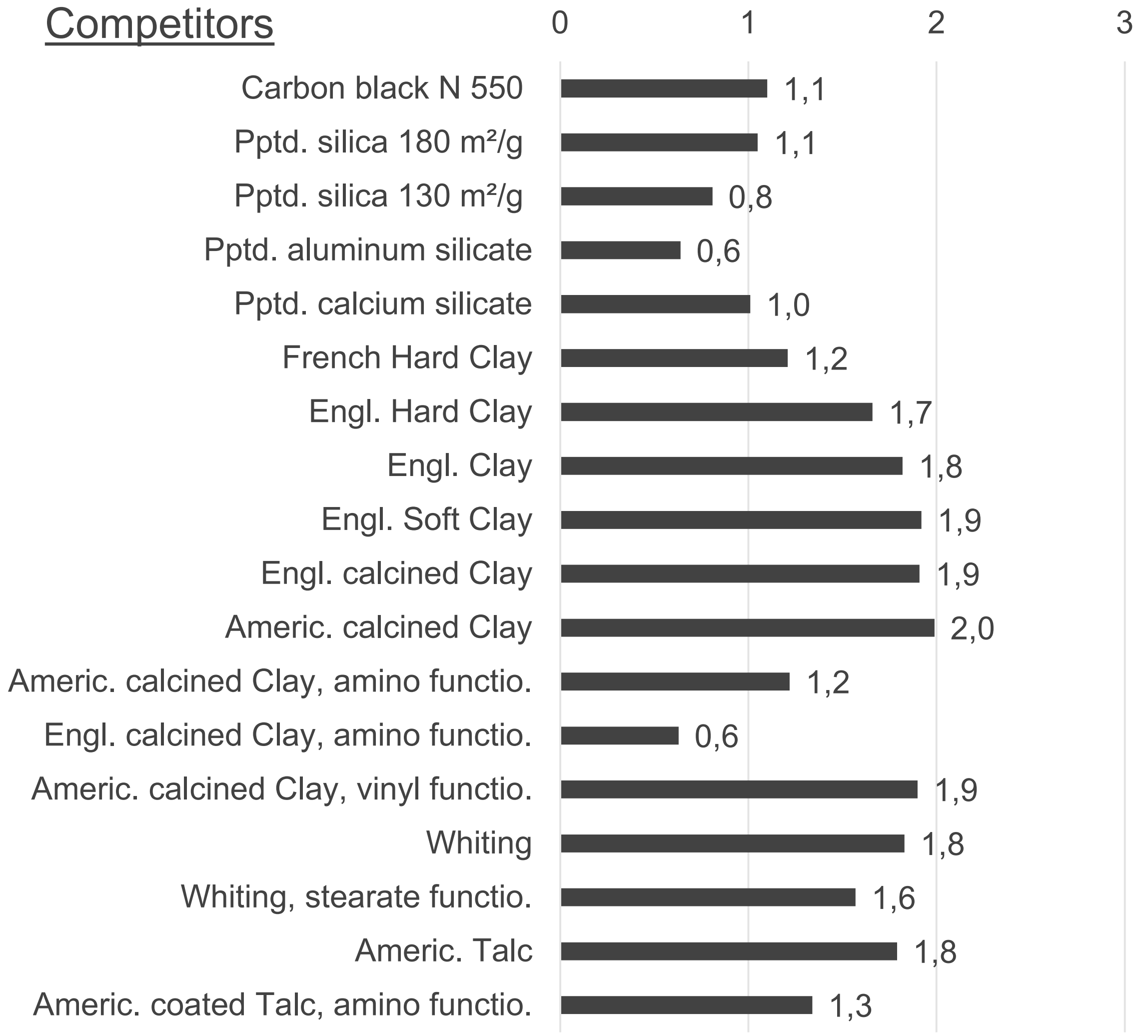




Note: Sillitin N 82 will be replaced by Sillitin N 75

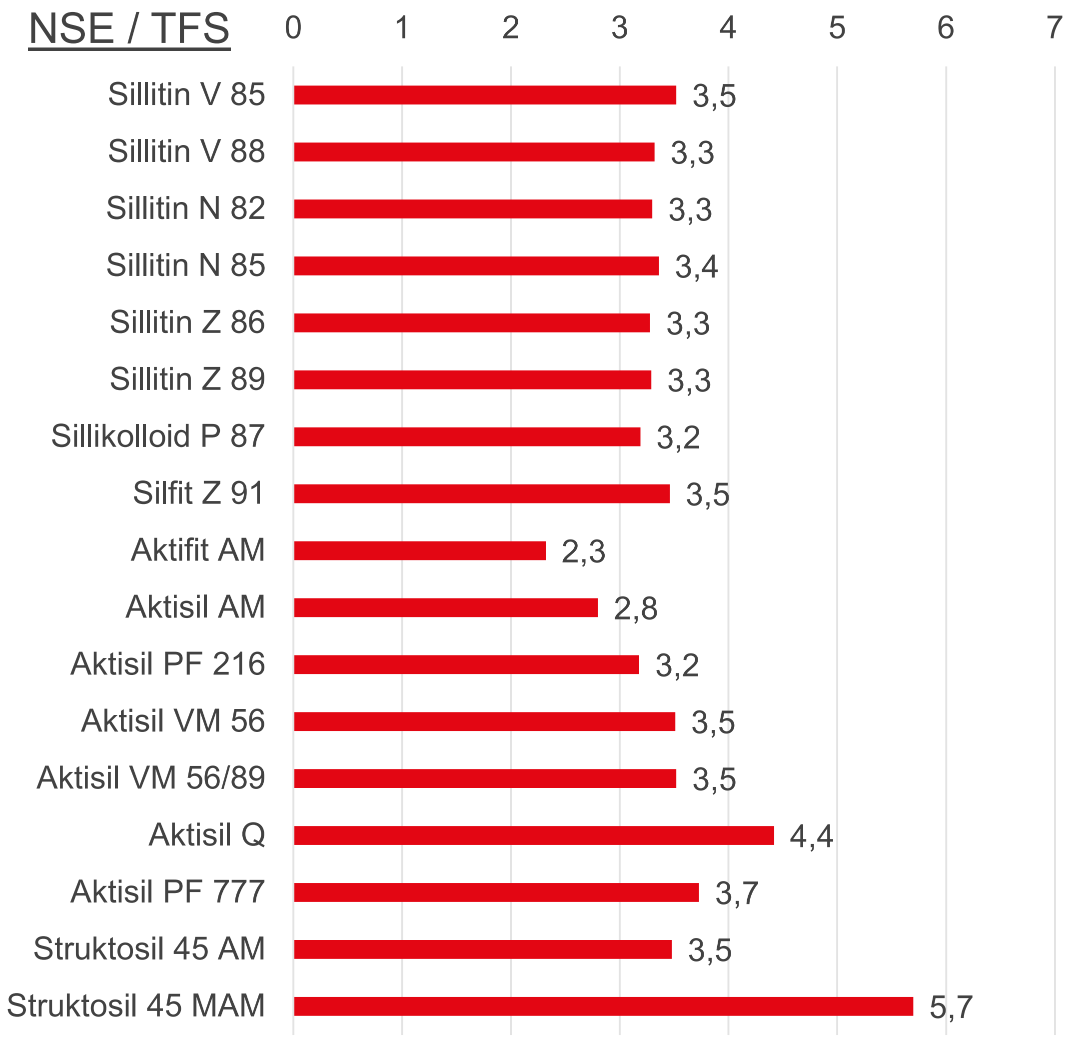
Rotorless curemeter, 160 °C
Conversion time t_5 in min.

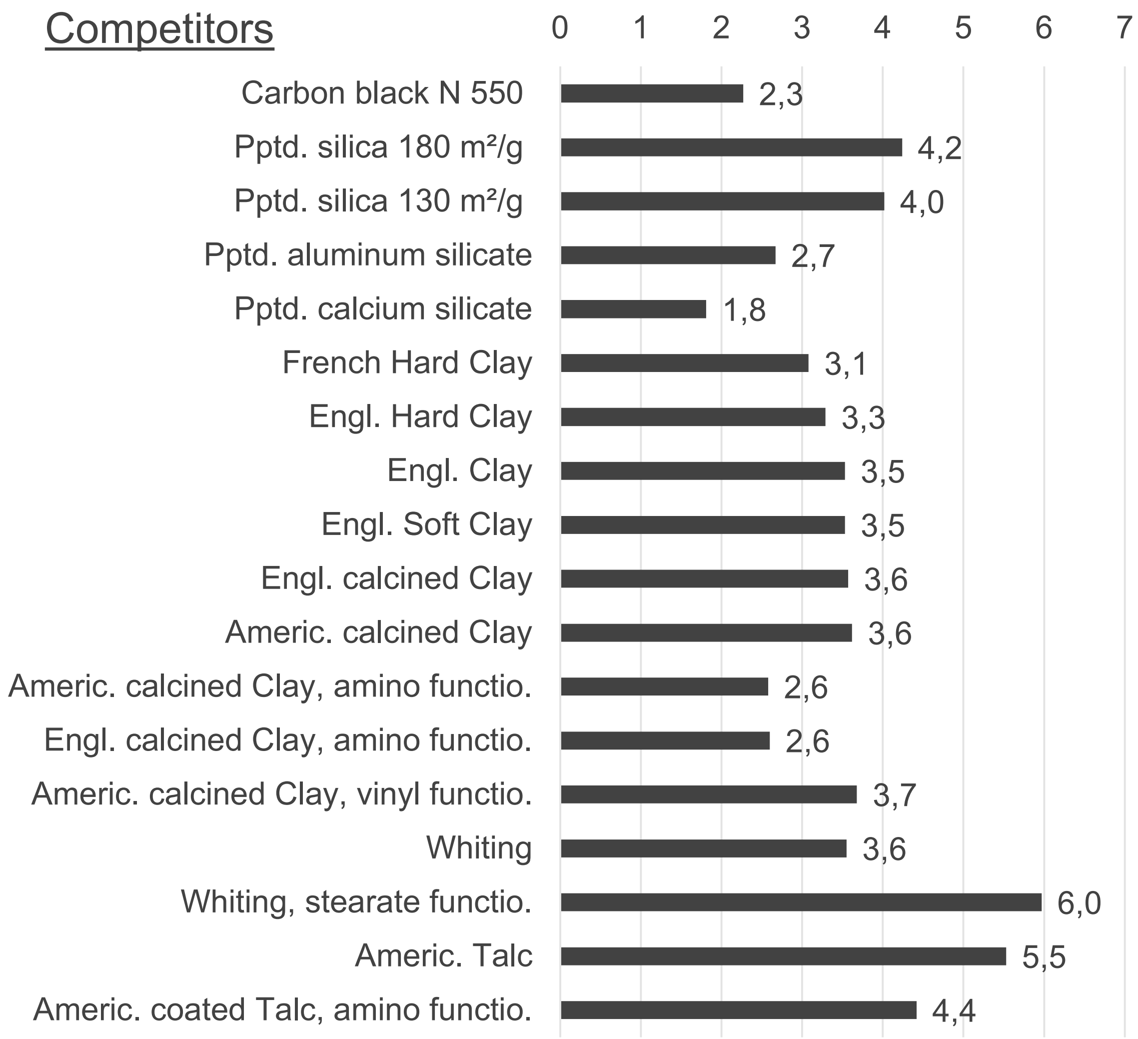




Note: Sillitin N 82 will be replaced by Sillitin N 75

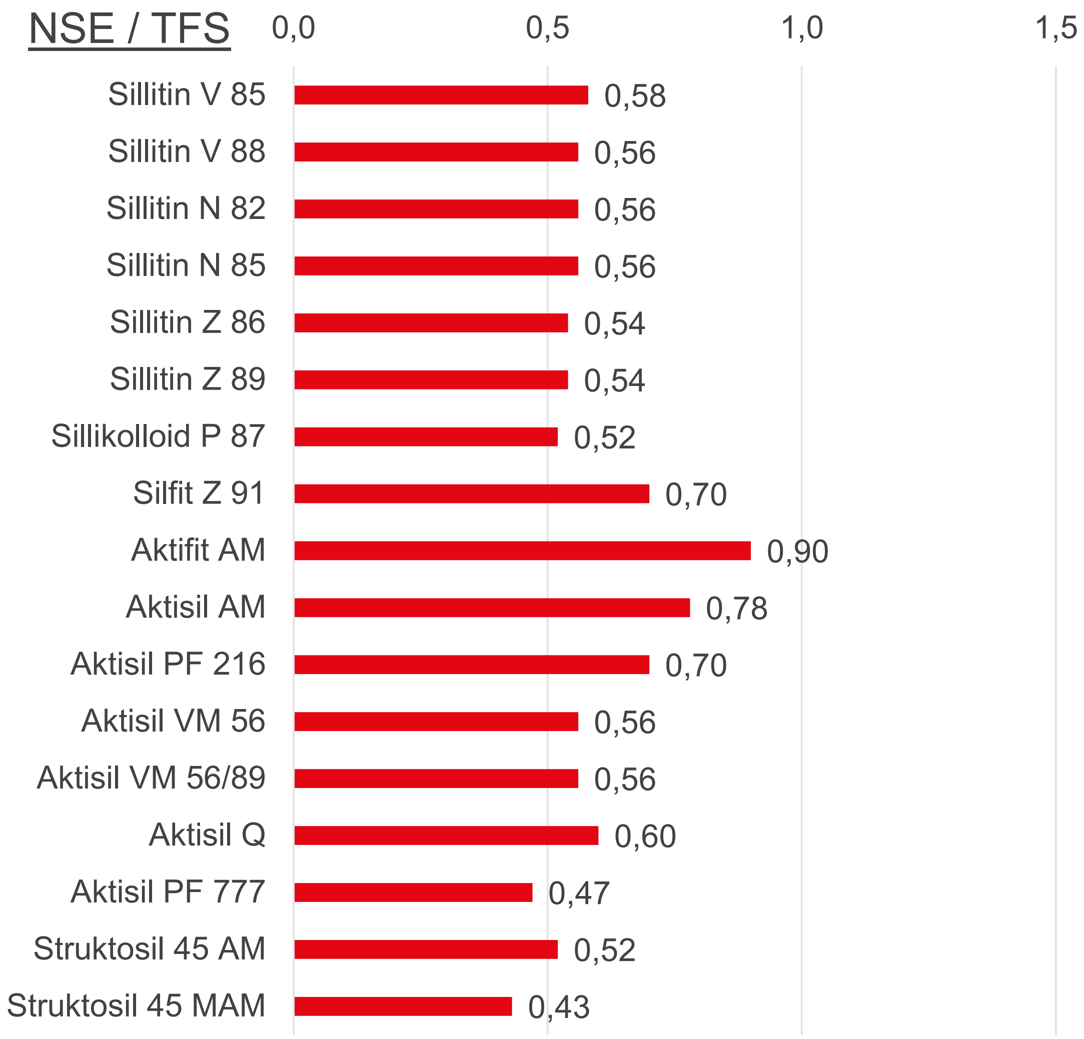
Rotorless curemeter, 160 °C
Conversion time t_{90} in min.

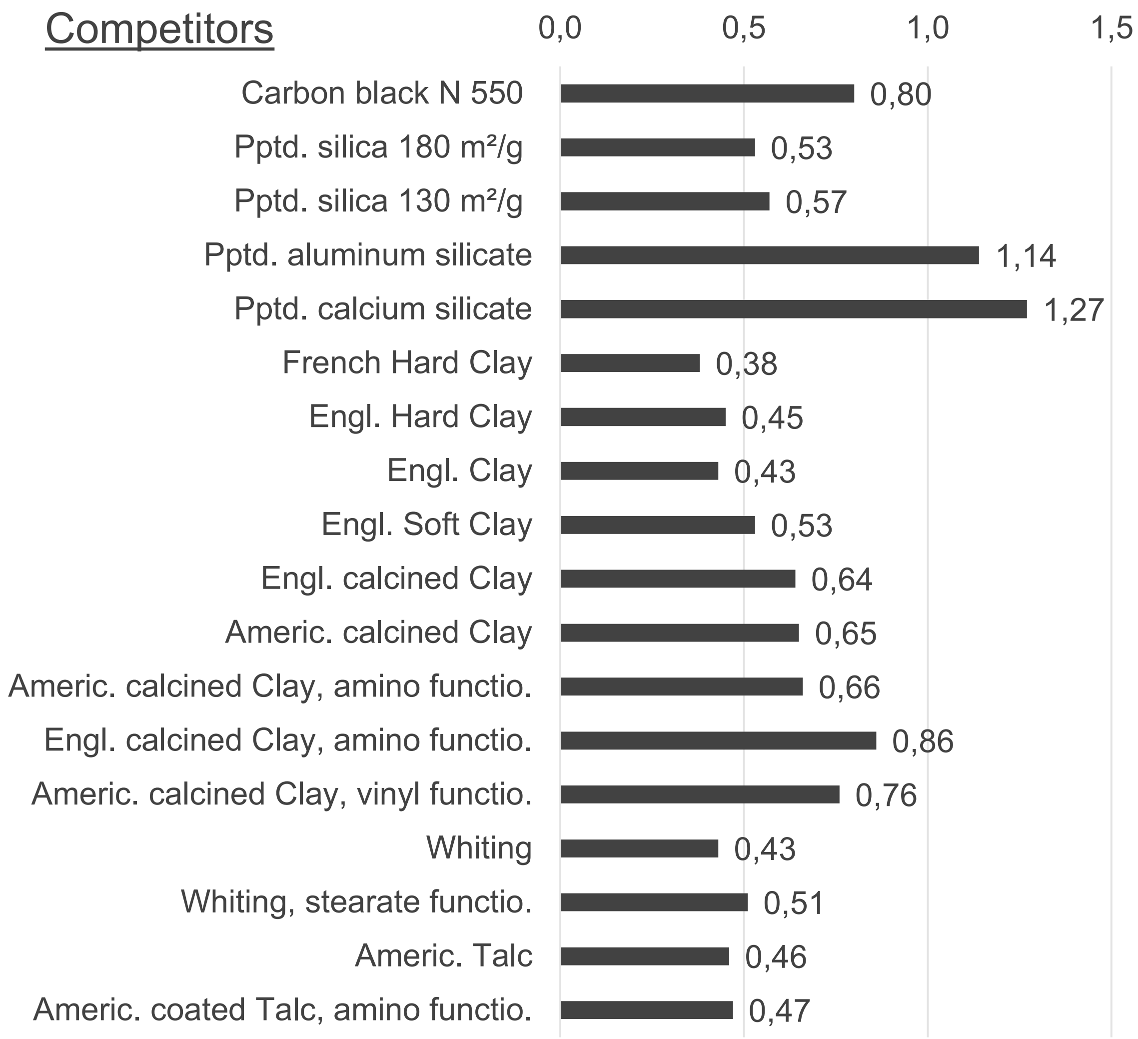




Note: Sillitin N 82 will be replaced by Sillitin N 75

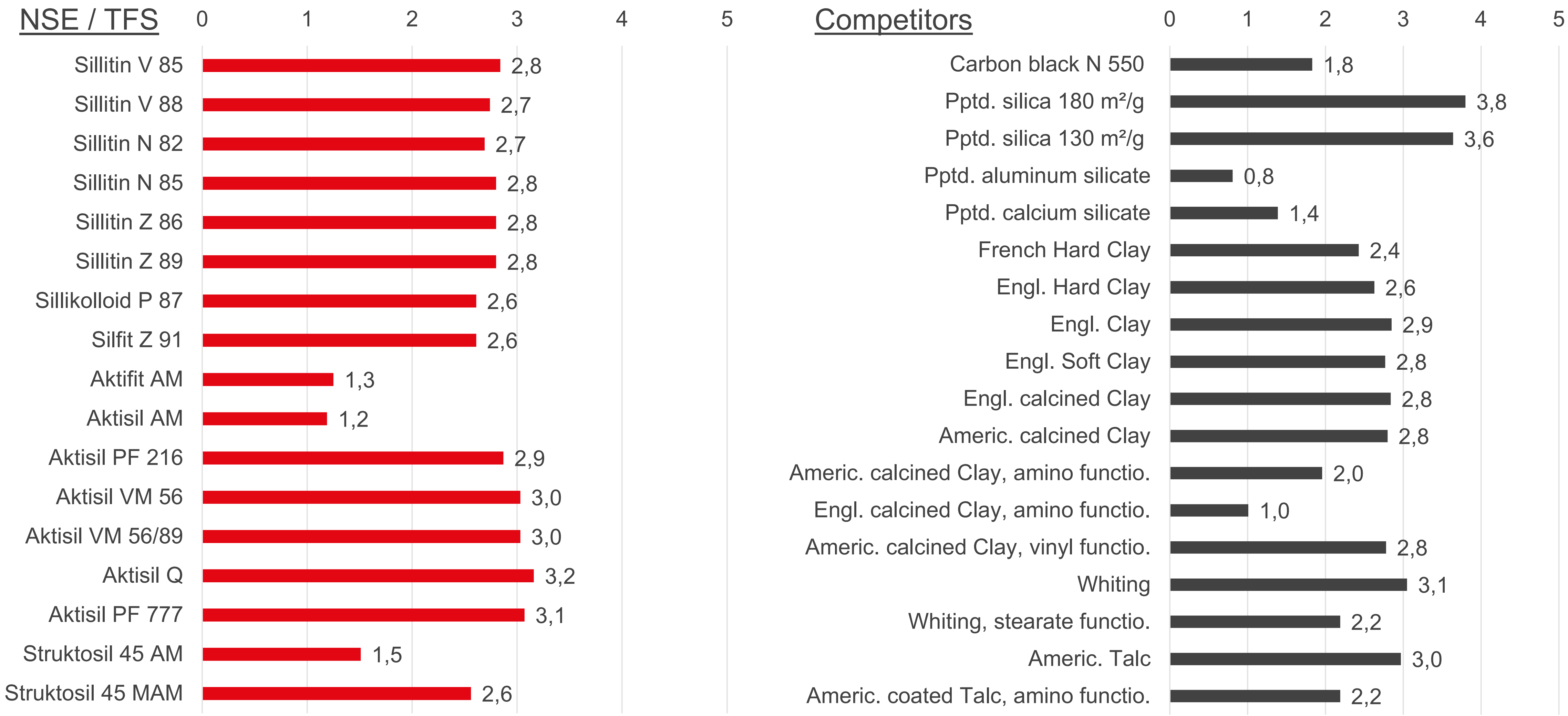
Rotorless curemeter, 160 °C
Max. speed of cure in Nm/min.





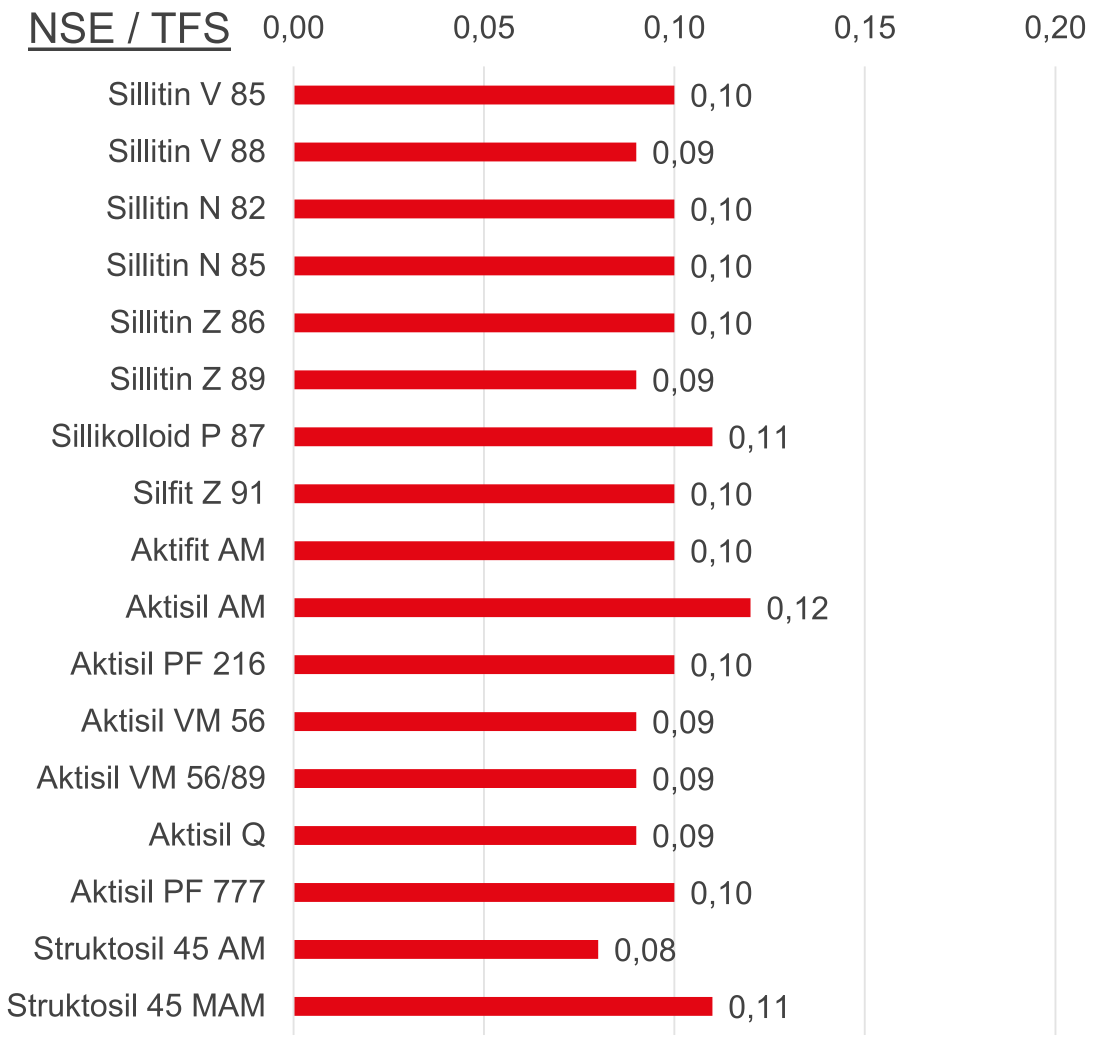
Note: Sillitin N 82 will be replaced by Sillitin N 75

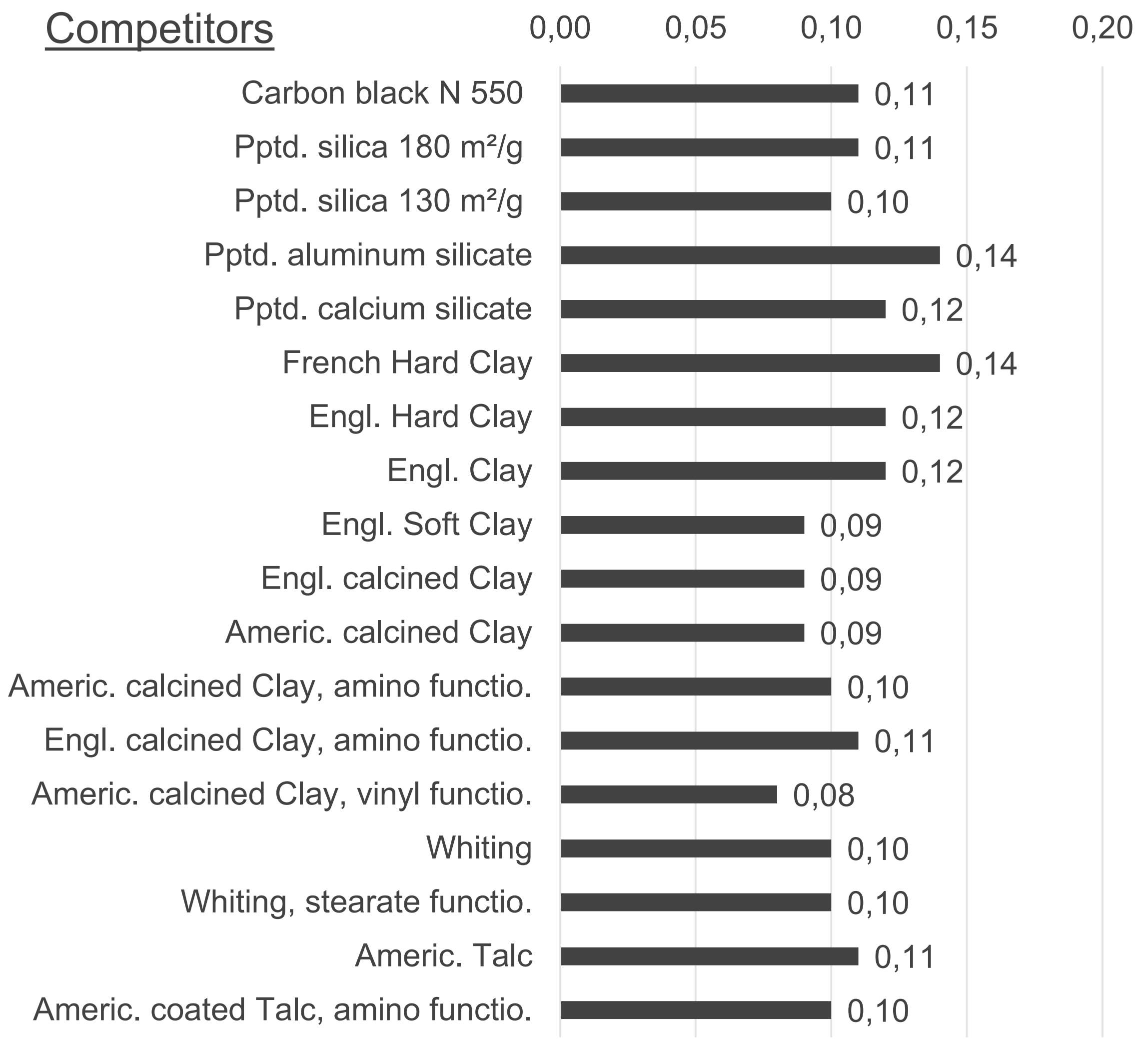
Rotorless curemeter, 160 °C
Time until max. speed of cure in min.



Note: Sillitin N 82 will be replaced by Sillitin N 75

Rotorless curemeter, 160 °C
tan δ, end of test





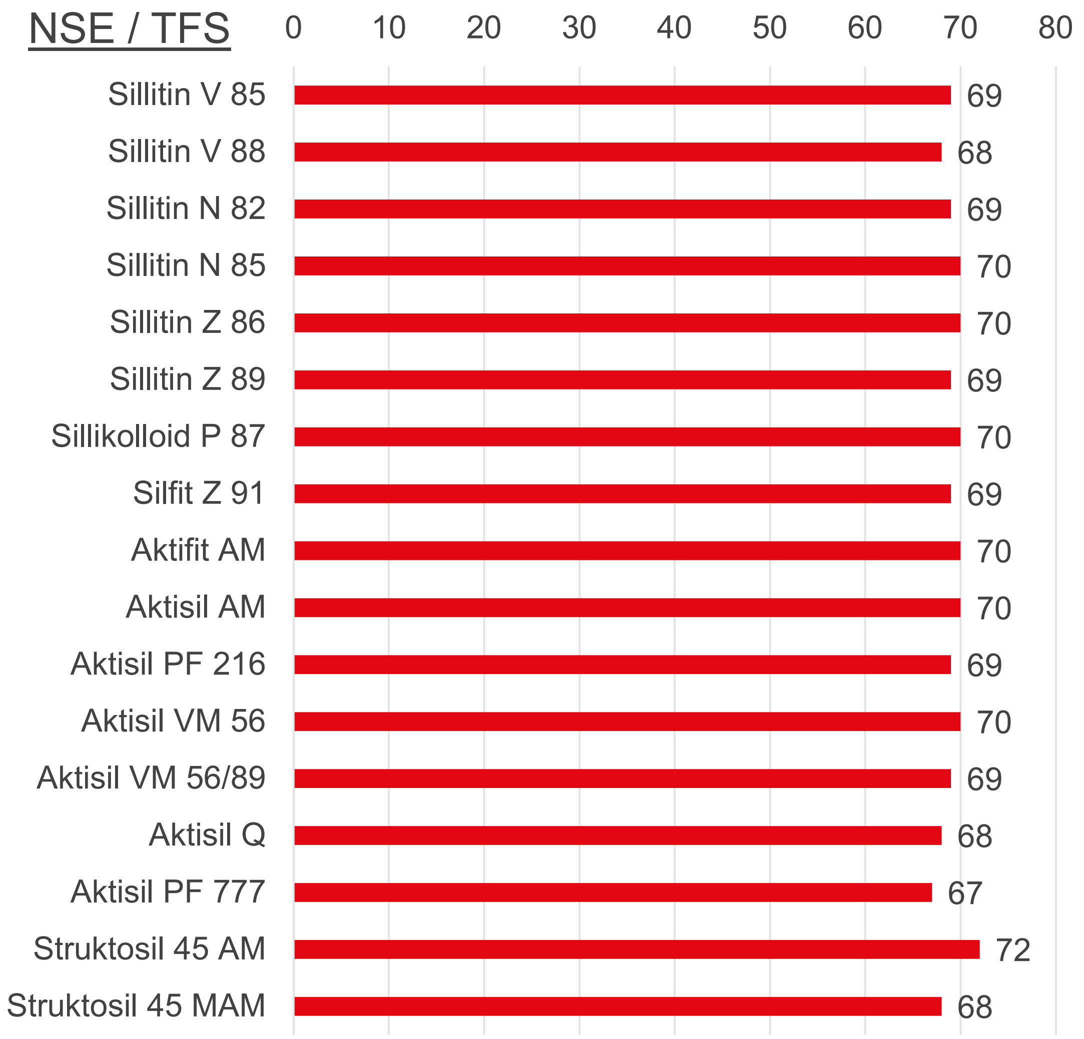
Note: Sillitin N 82 will be replaced by Sillitin N 75

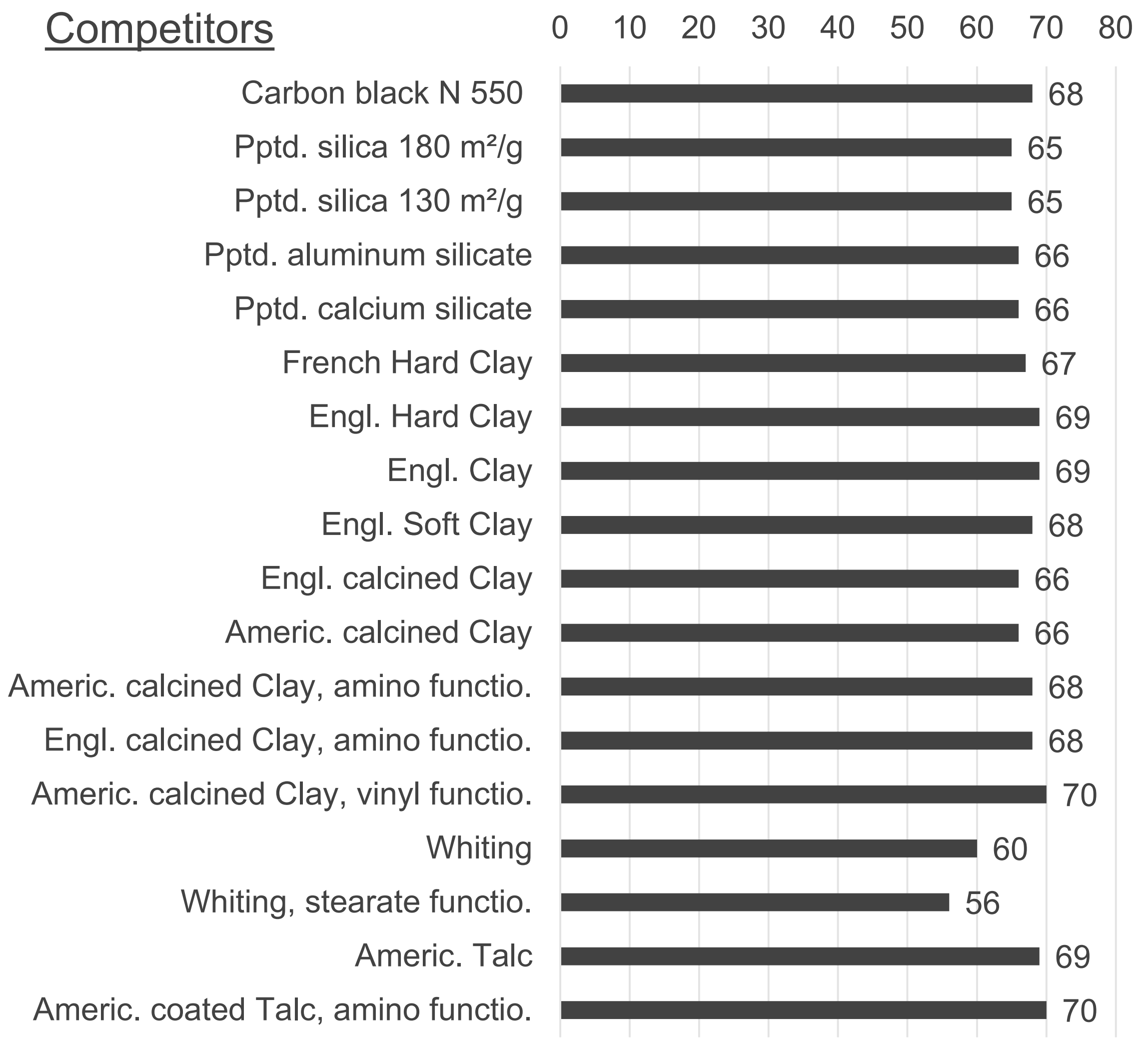
→ back to results

Properties of vulcanizate

Hardness – piled-up S2 dumbbells

DIN ISO 7619-1





Note: Sillitin N 82 will be replaced by Sillitin N 75

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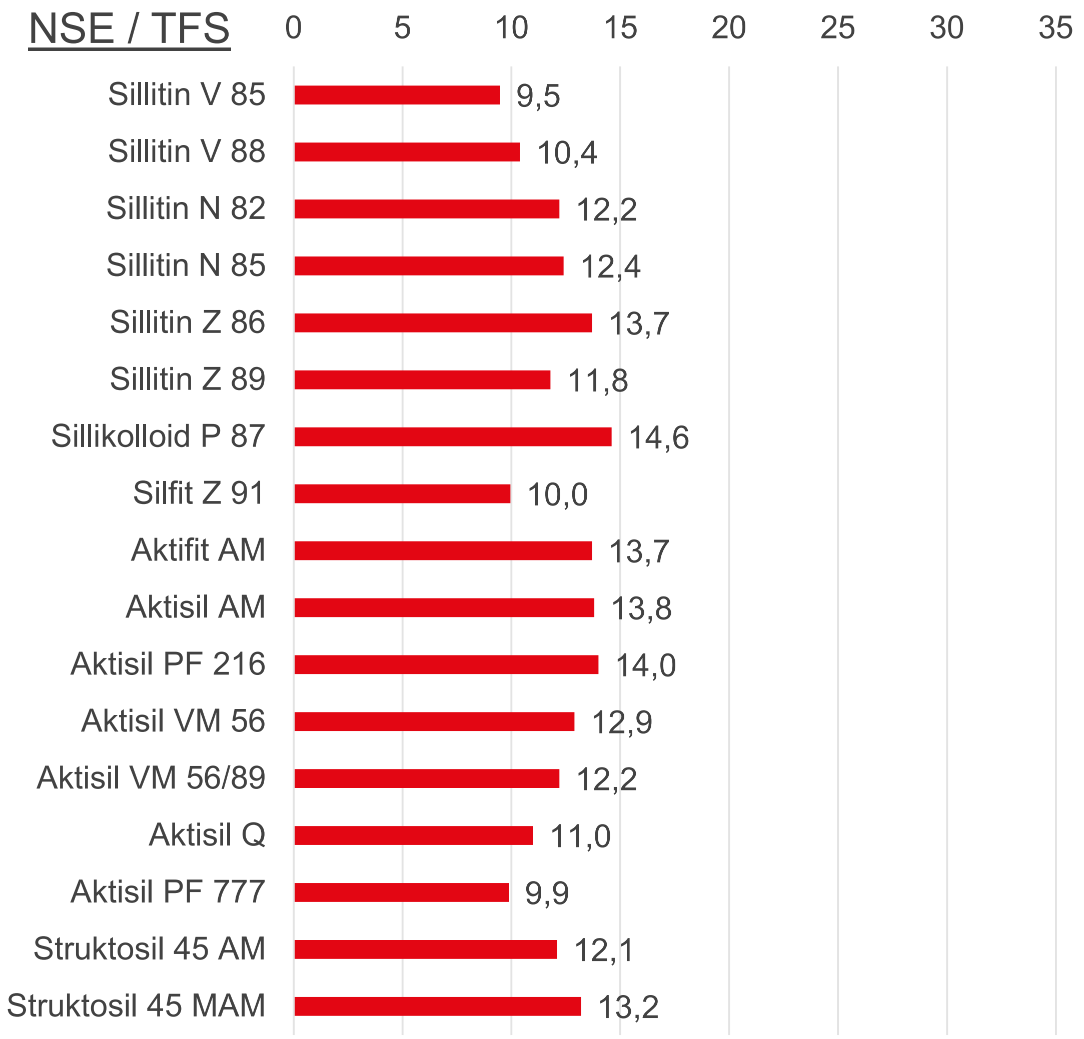
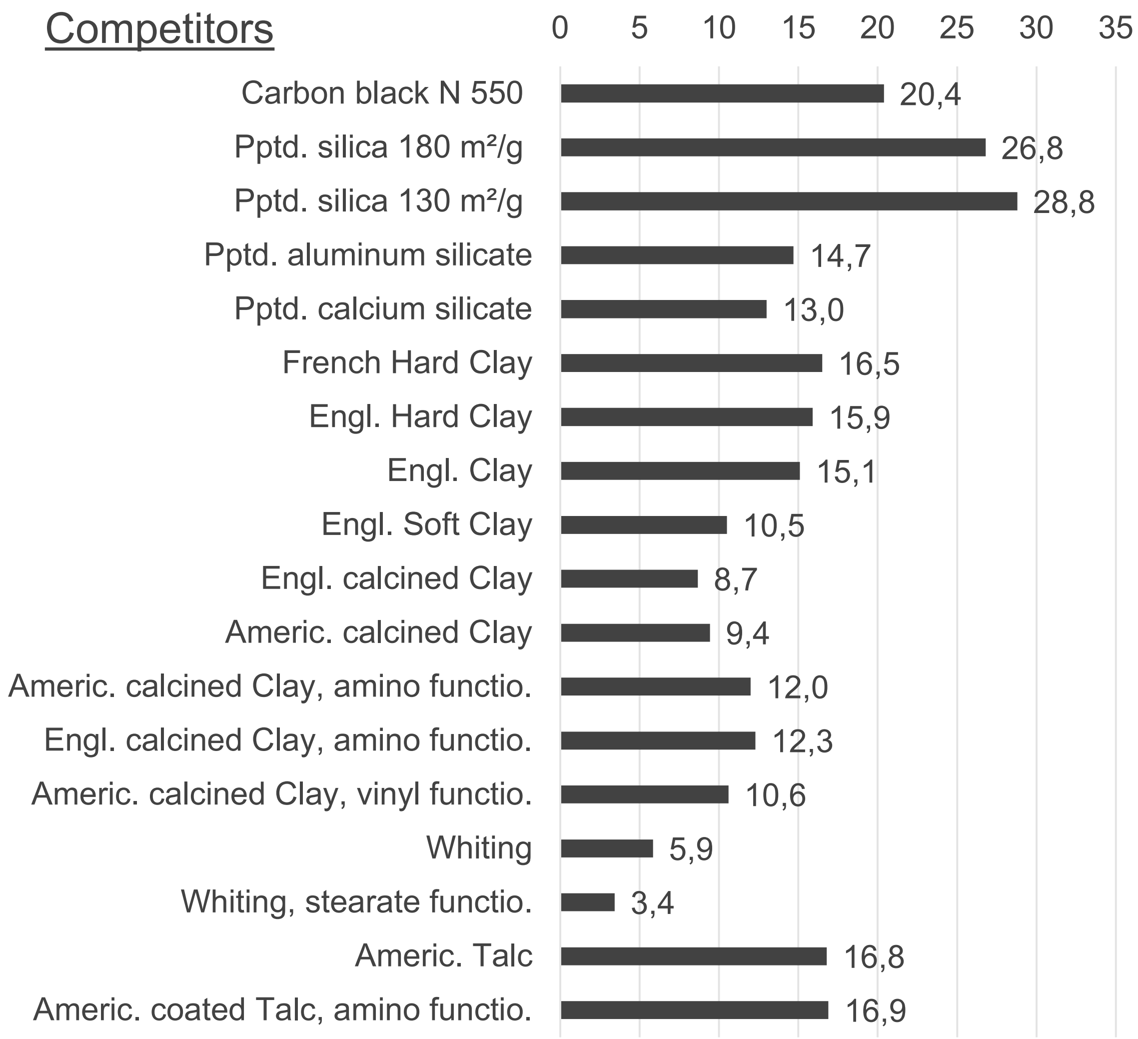
Tensile strength in MPa

DIN 53 504, S2

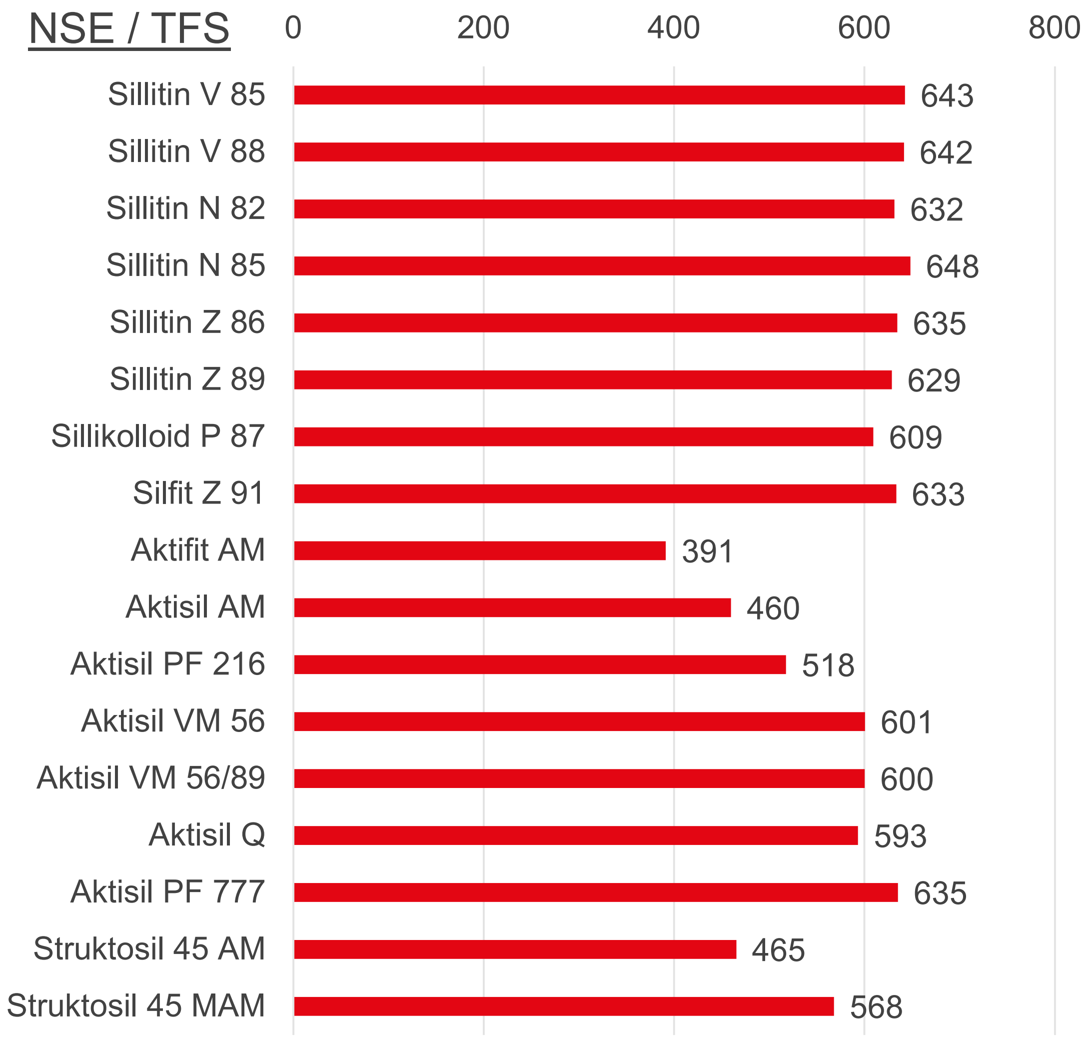


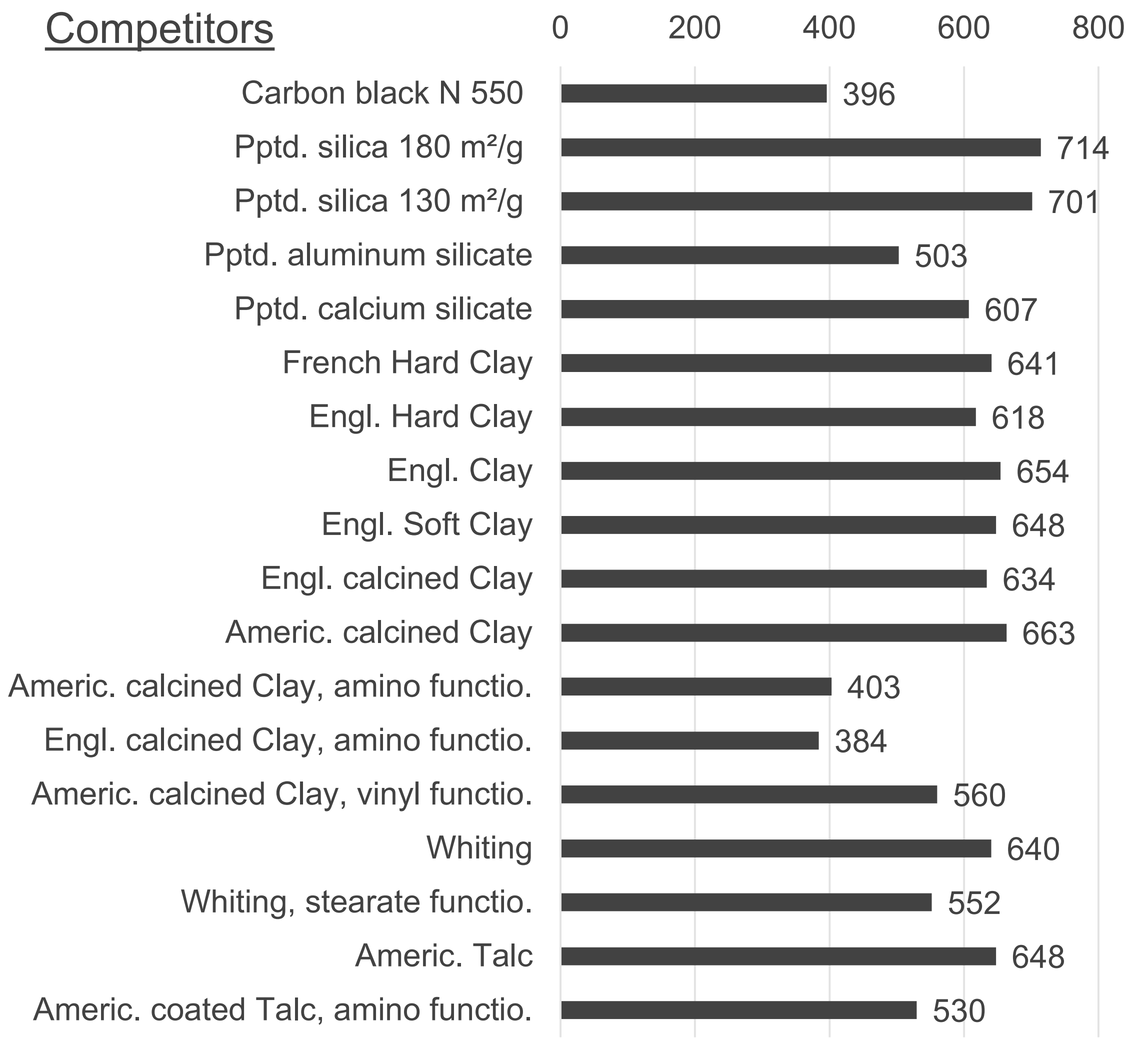


Note: Sillitin N 82 will be replaced by Sillitin N 75

Elongation at break in %

DIN 53 504, S2

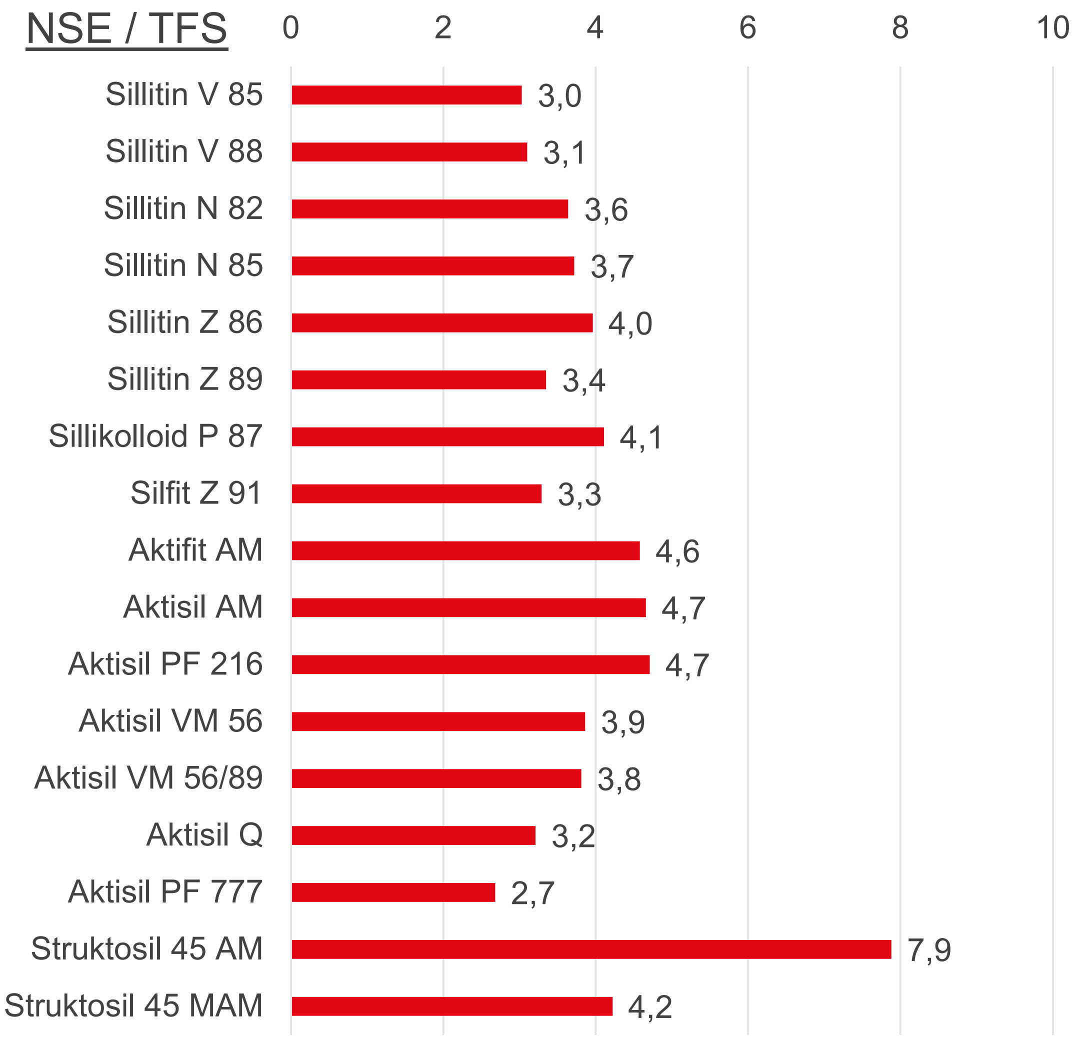


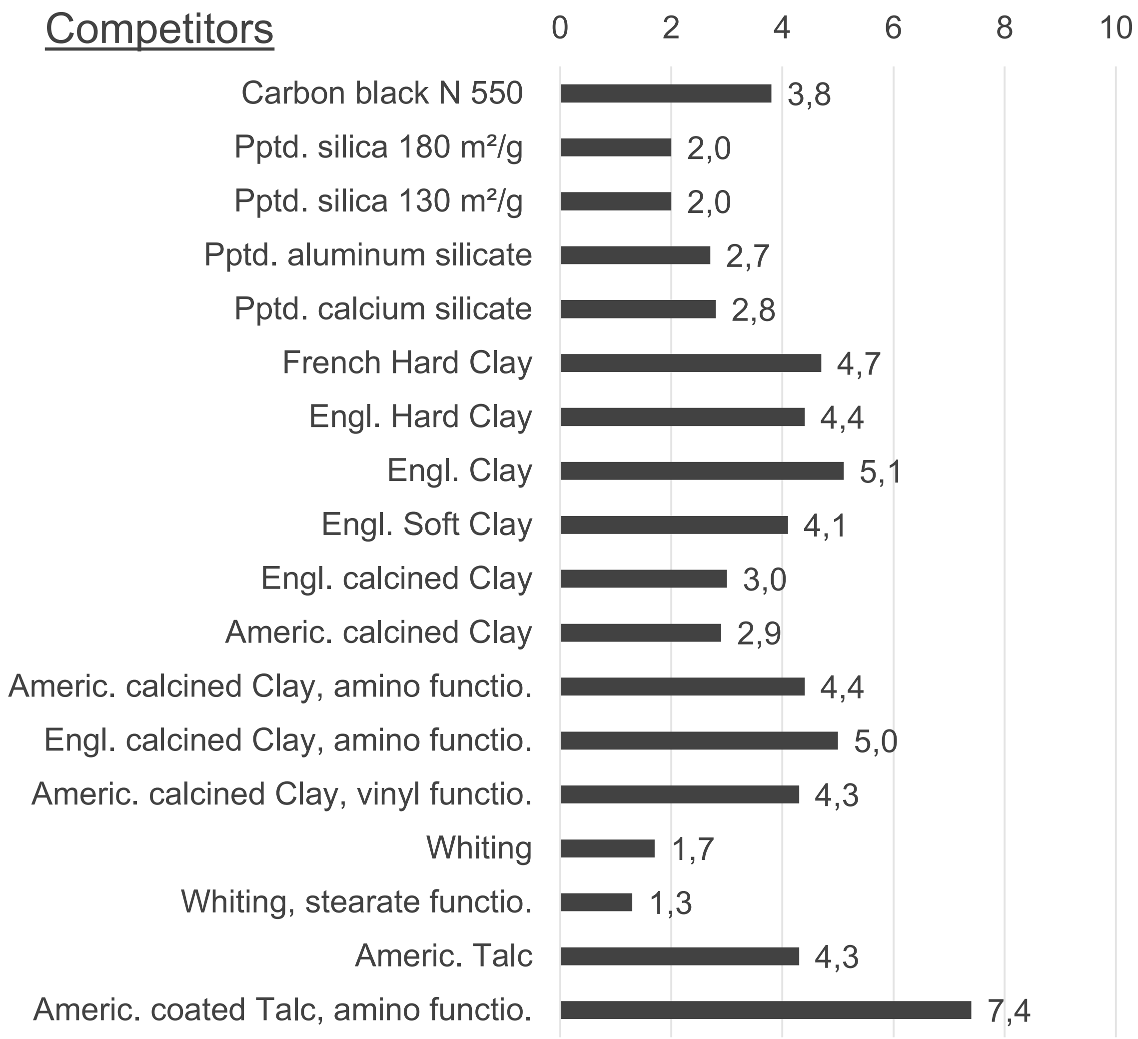


Note: Sillitin N 82 will be replaced by Sillitin N 75

Modulus 100 % in MPa

DIN 53 504, S2

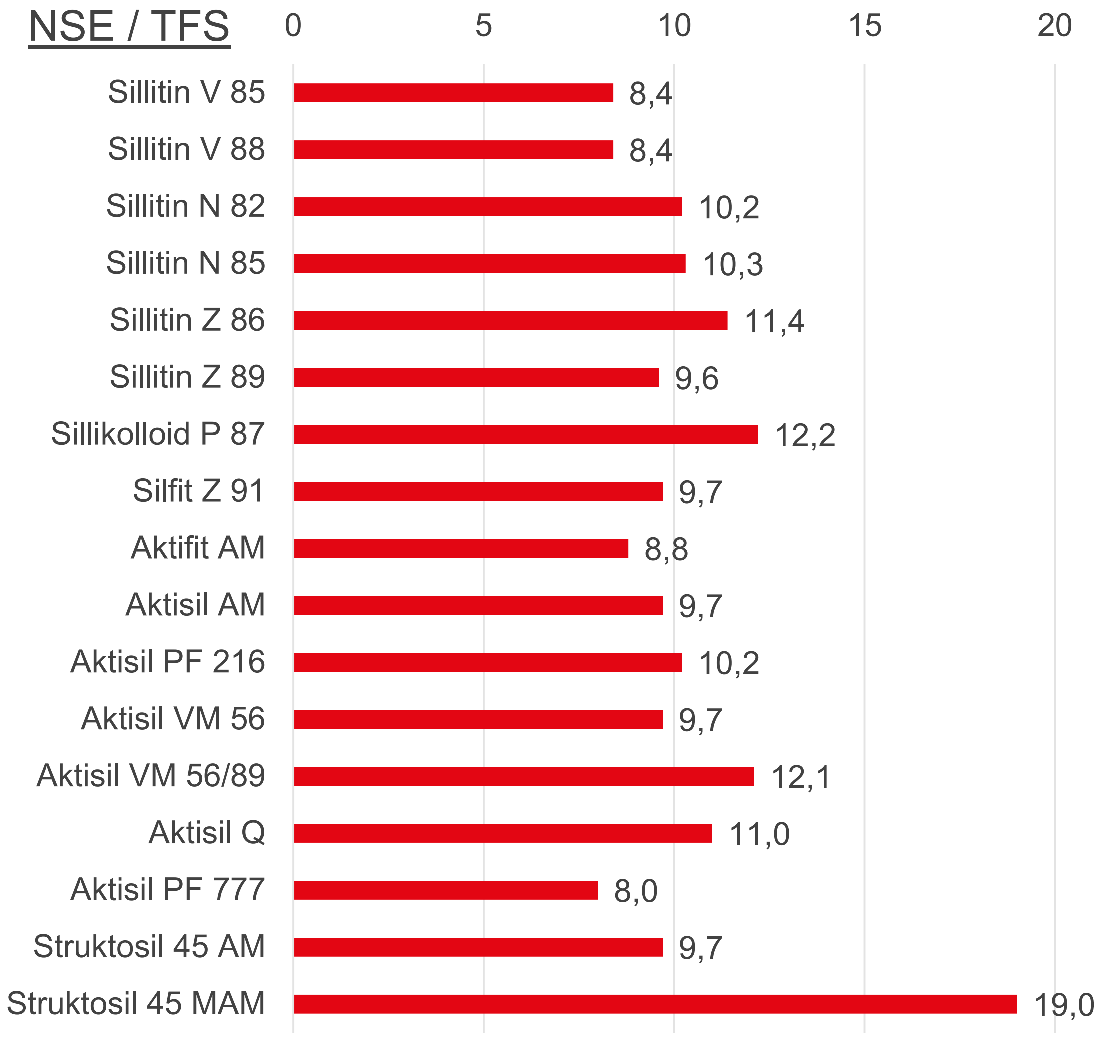


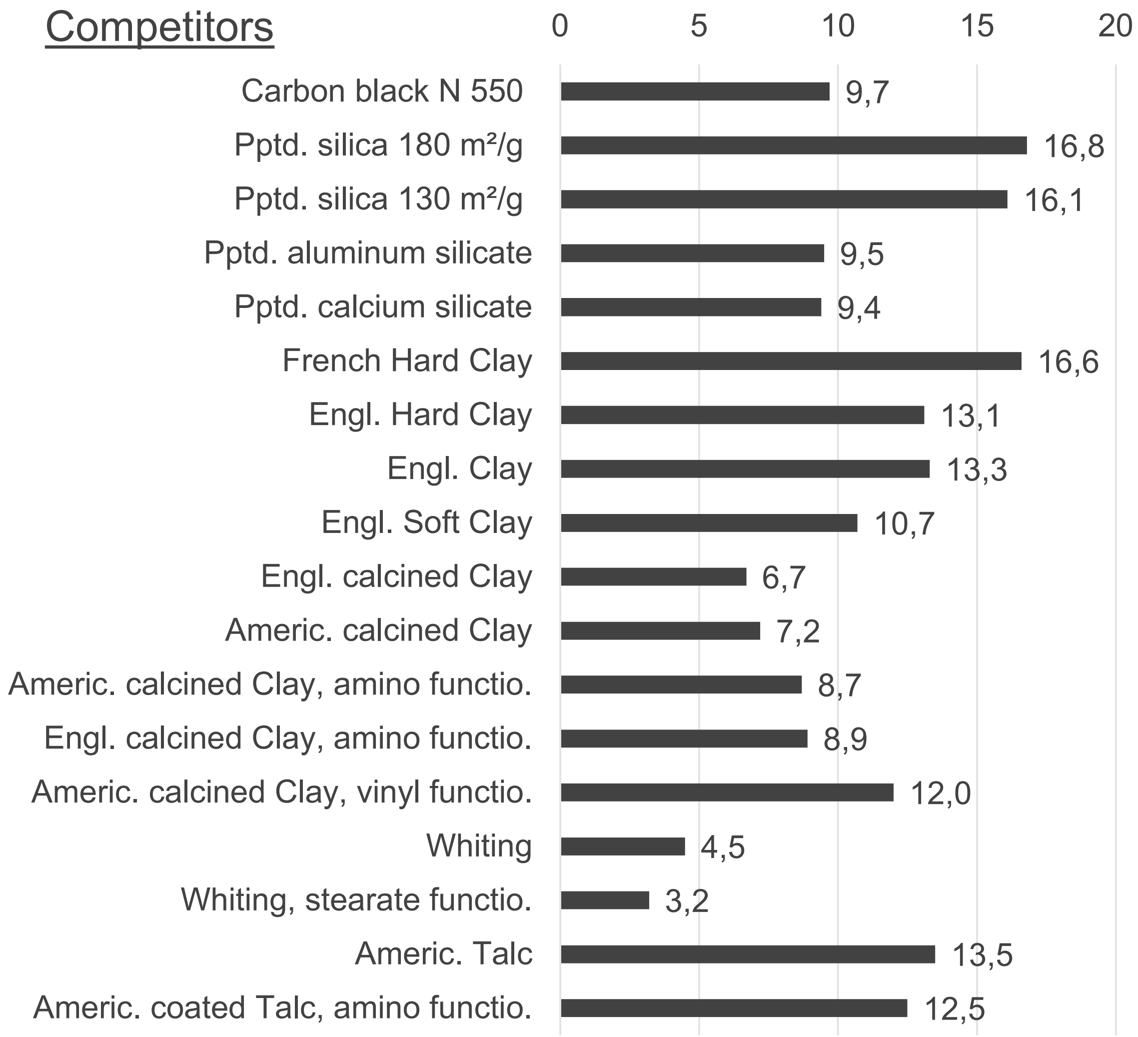


Note: Sillitin N 82 will be replaced by Sillitin N 75

Tear resistance in N/mm – Trousers specimen

DIN ISO 34-1, A

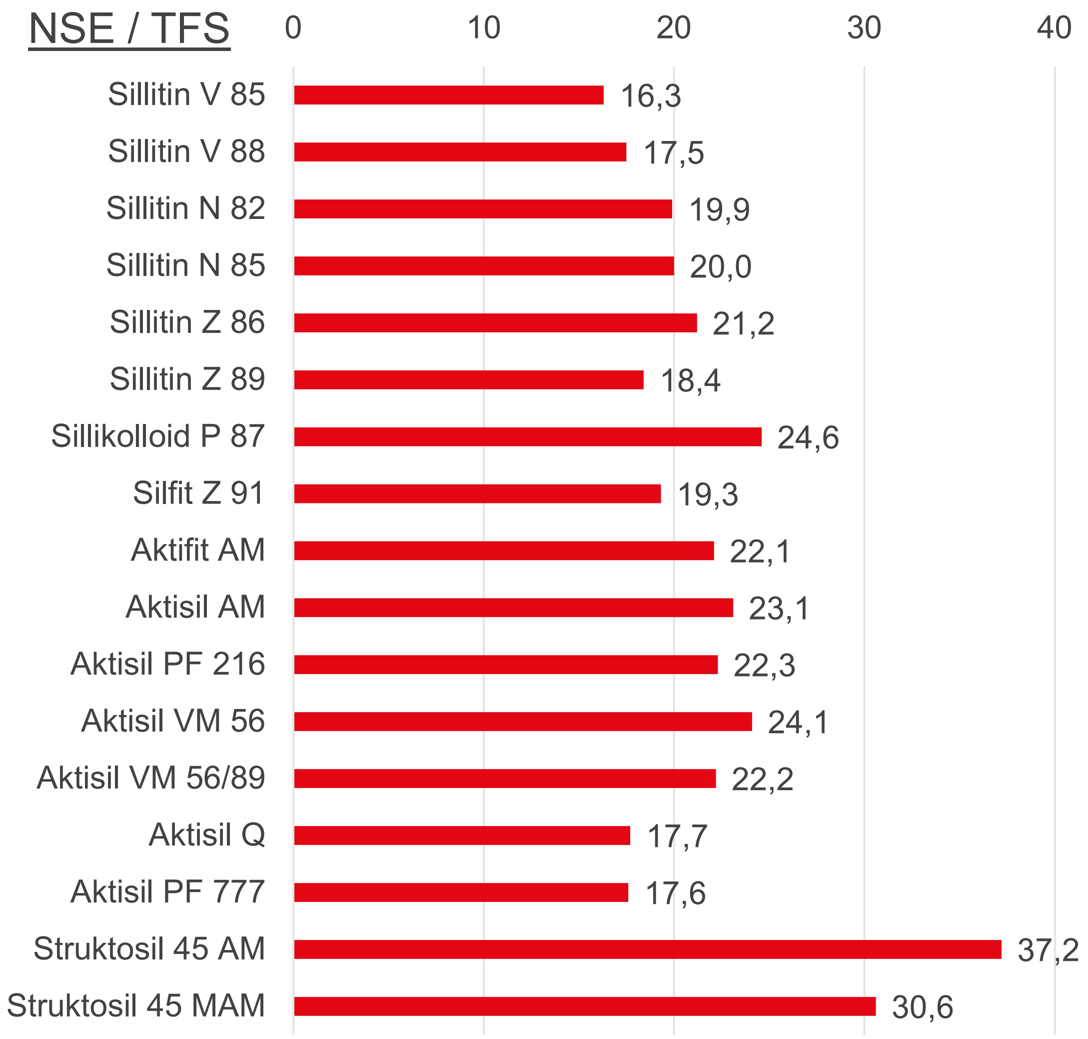


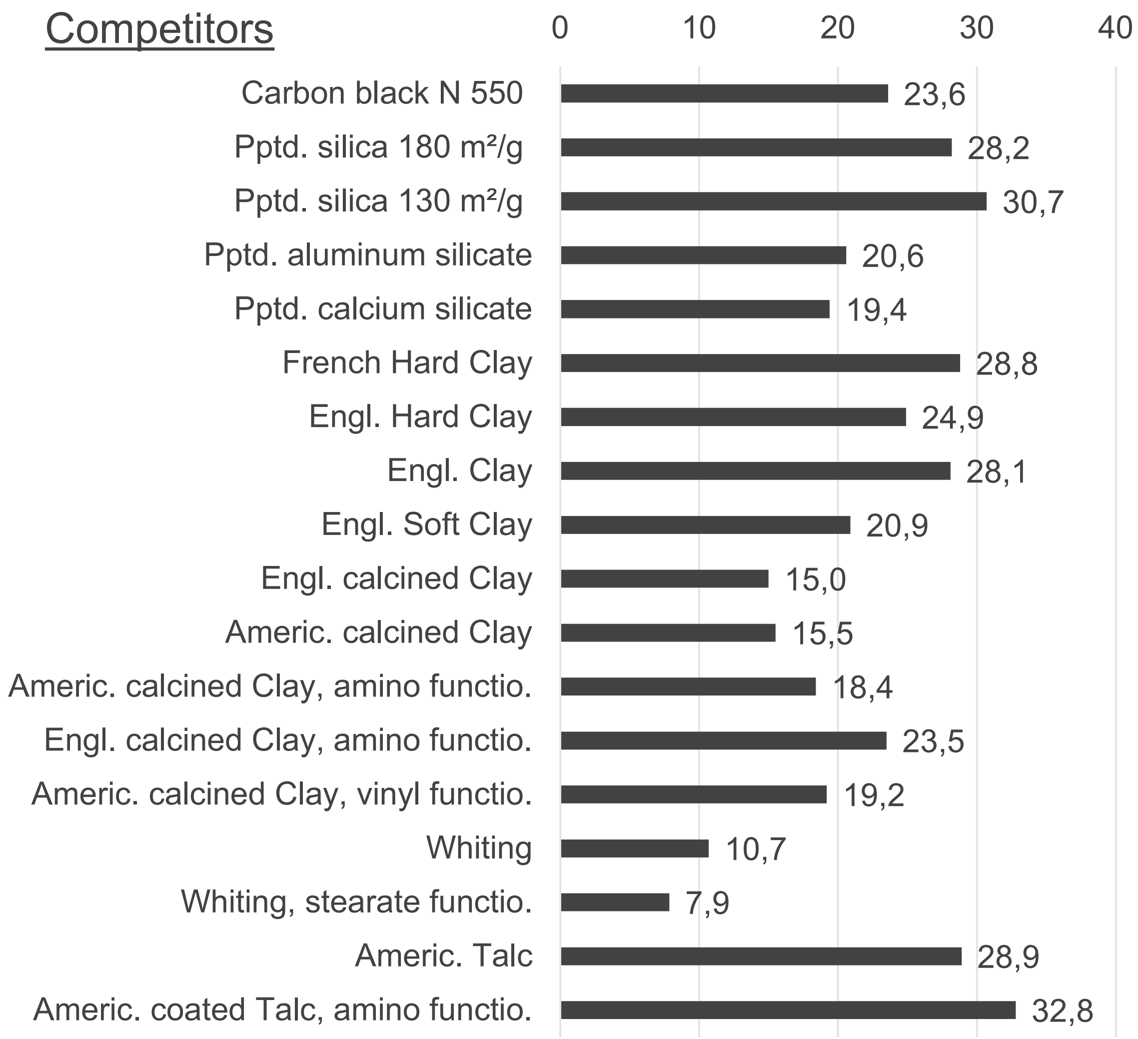


Note: Sillitin N 82 will be replaced by Sillitin N 75

Tear resistance in N/mm – Graves specimen

DIN ISO 34-1, Bb

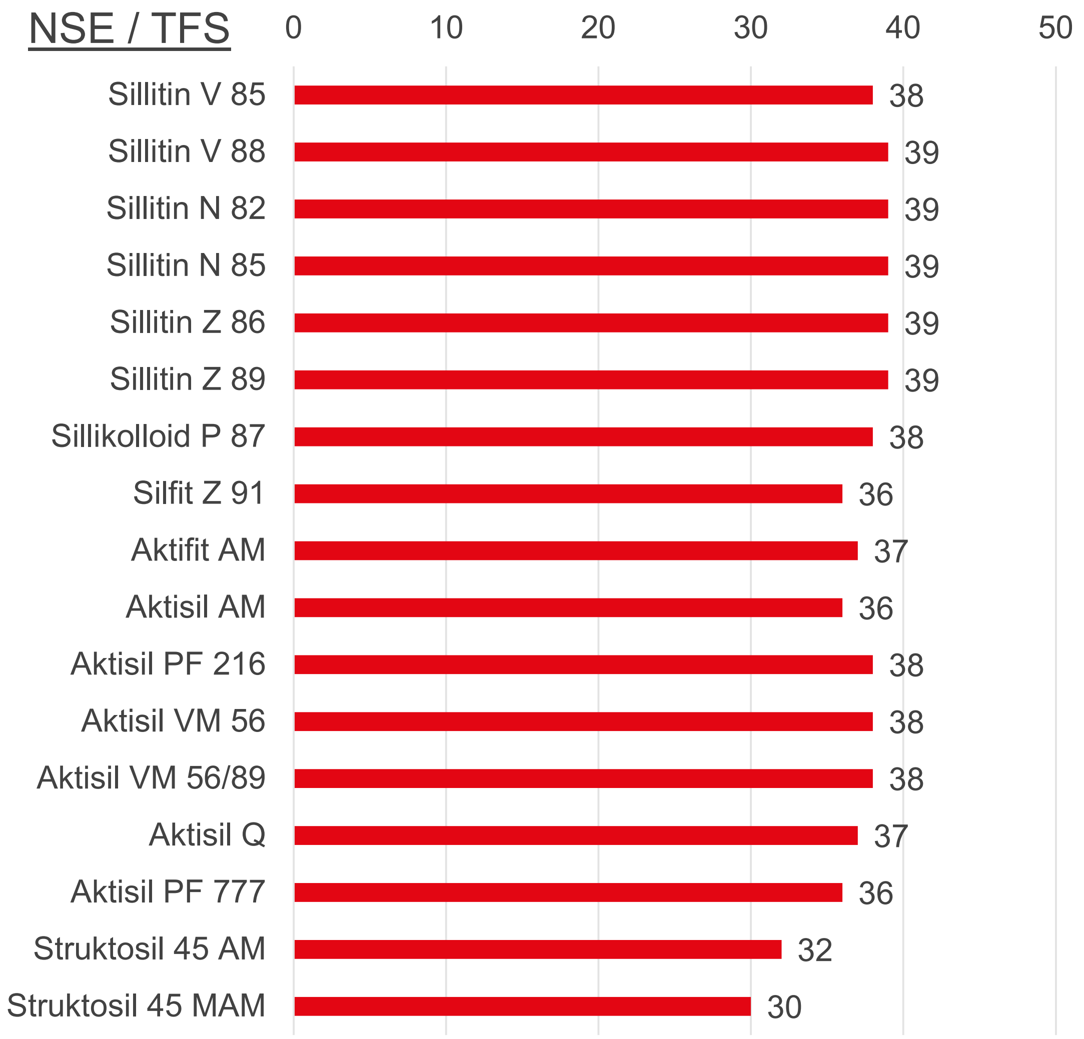


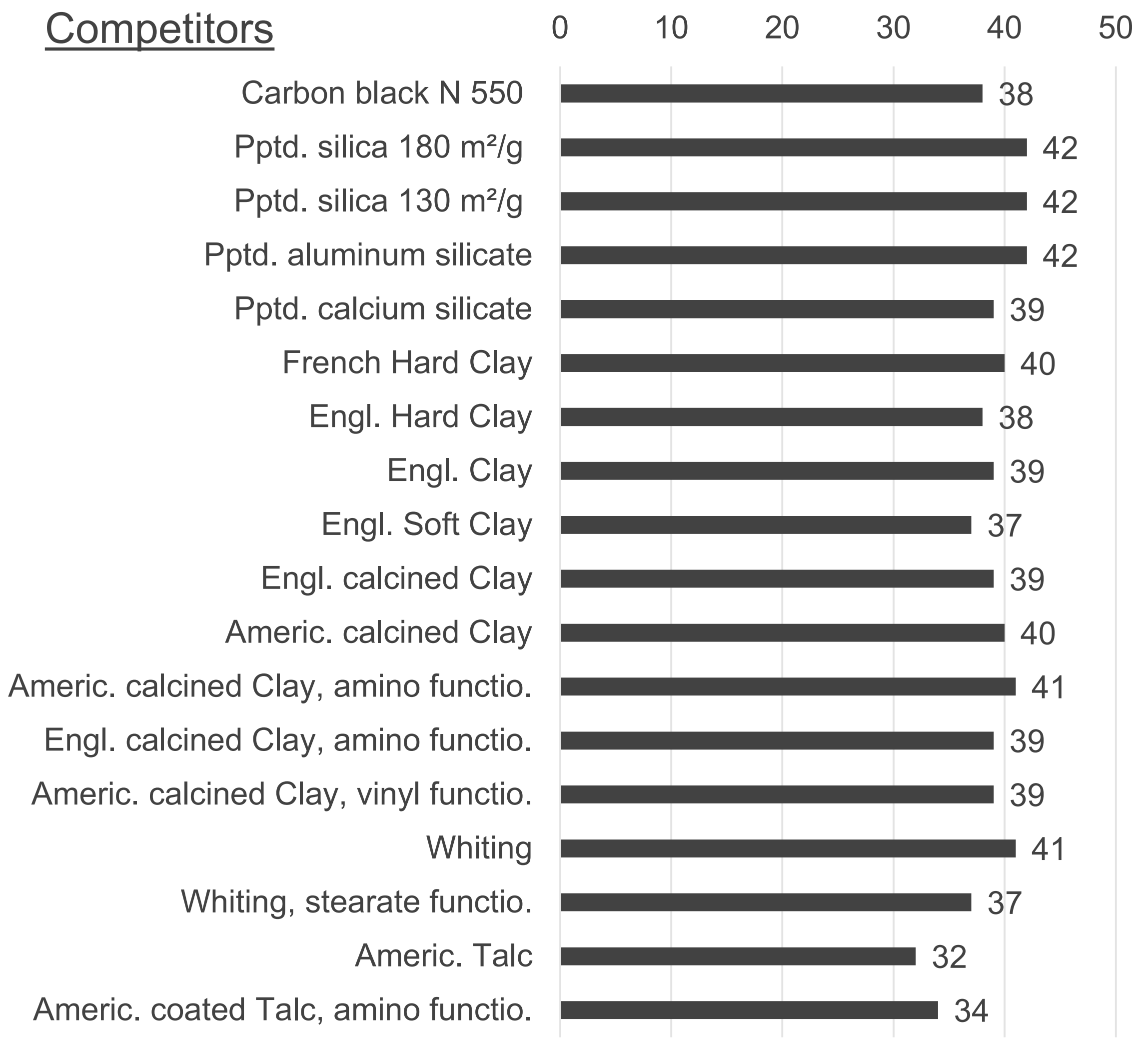


Note: Sillitin N 82 will be replaced by Sillitin N 75

Rebound elasticity in %

DIN 53 512

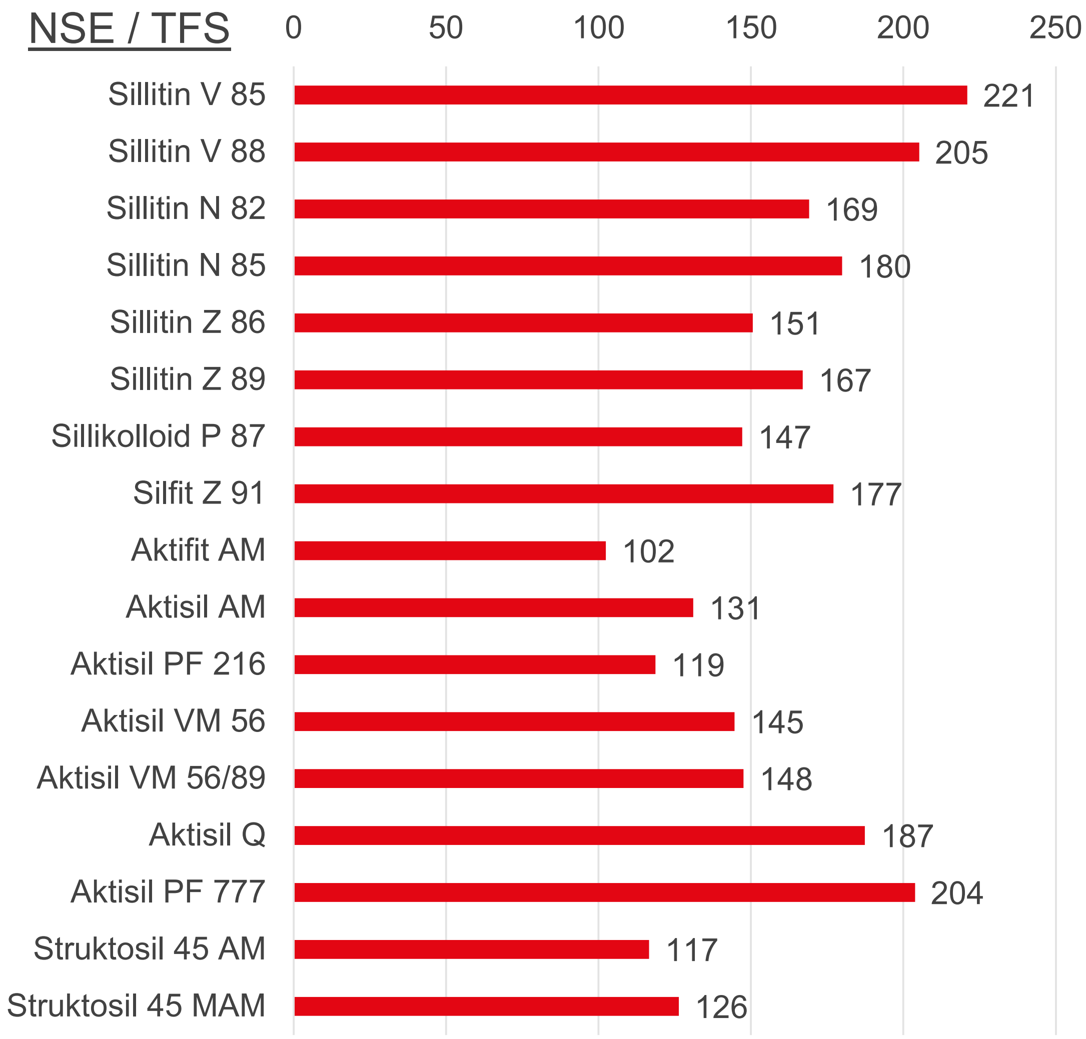


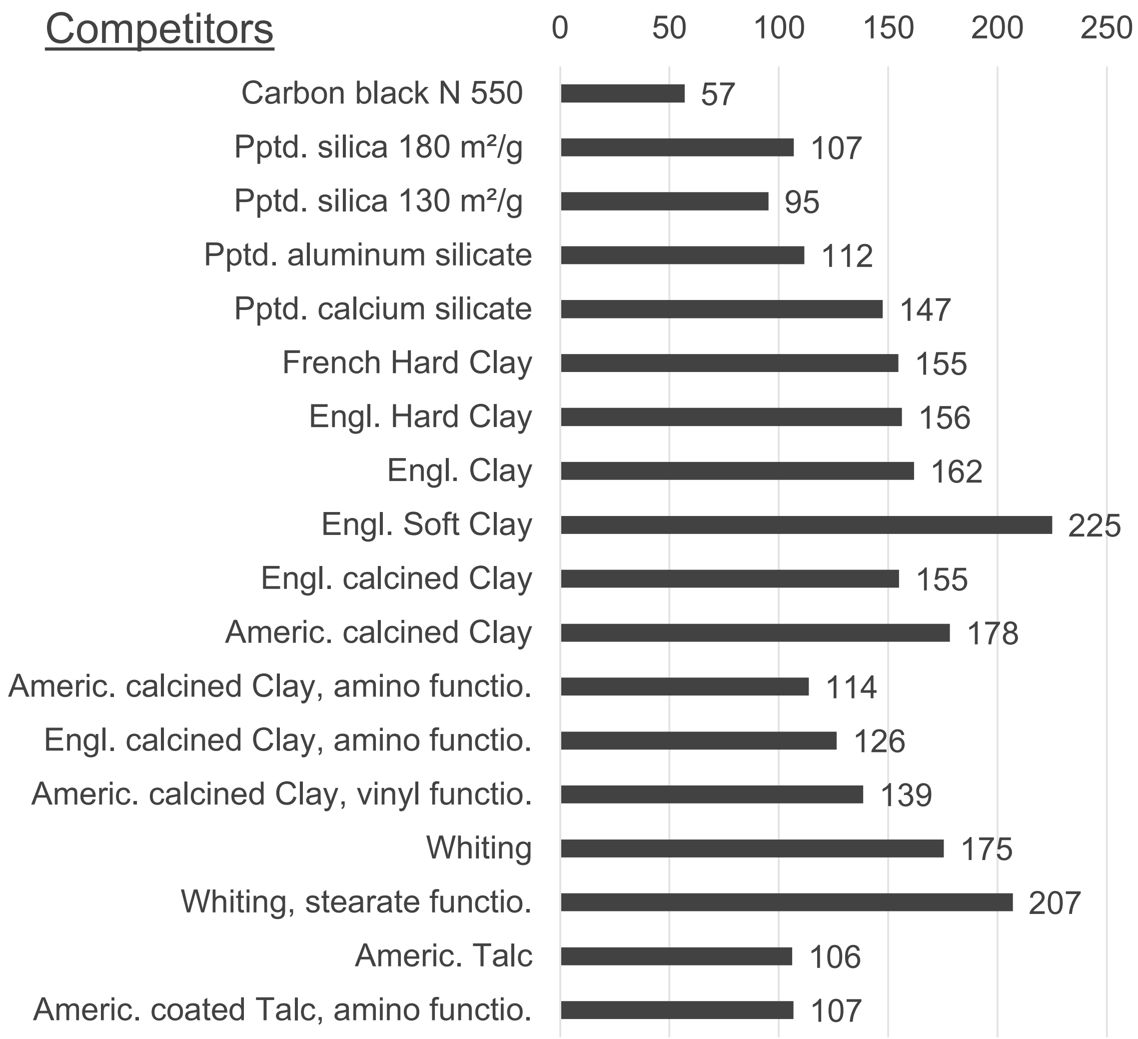


Note: Sillitin N 82 will be replaced by Sillitin N 75

Abrasion loss in mm^3

DIN ISO 4649, A

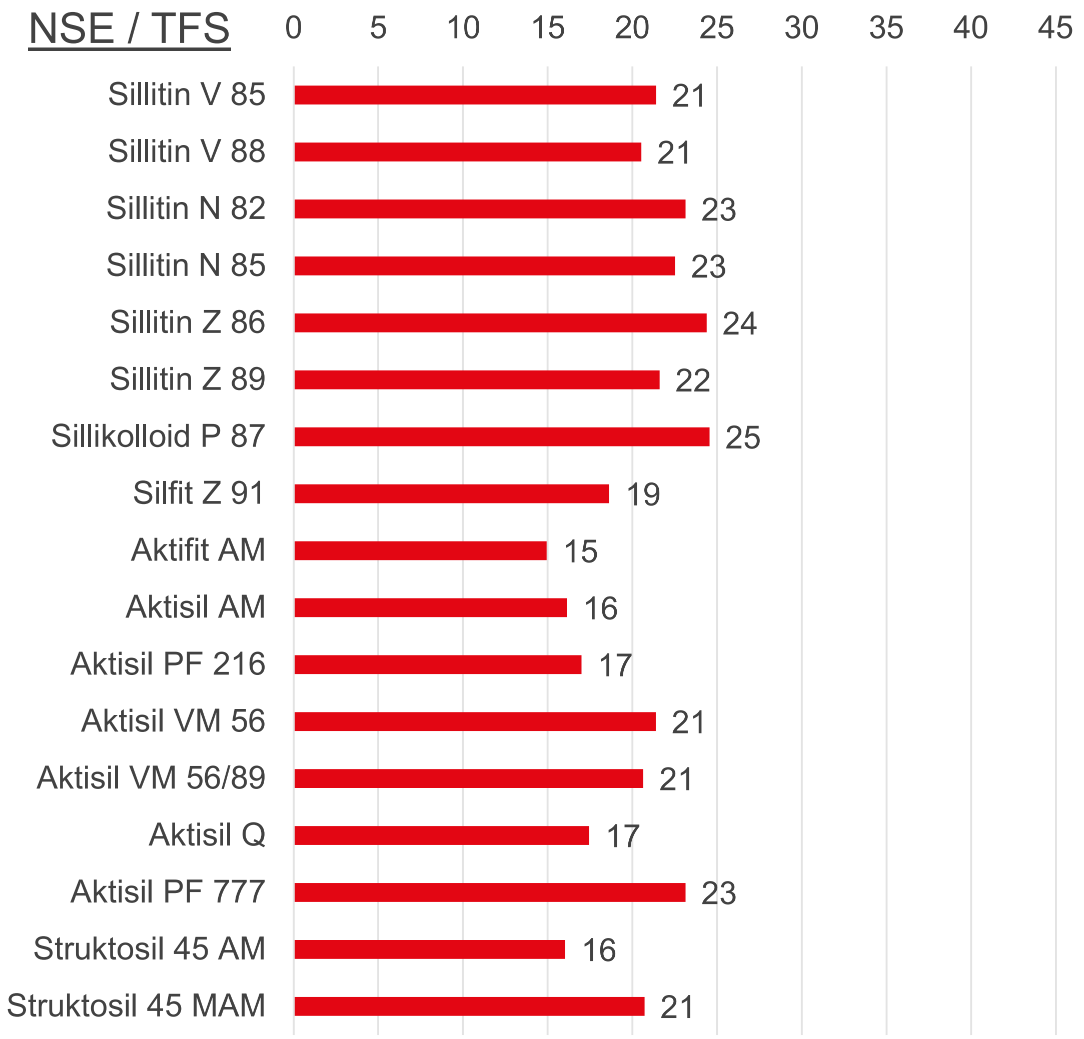


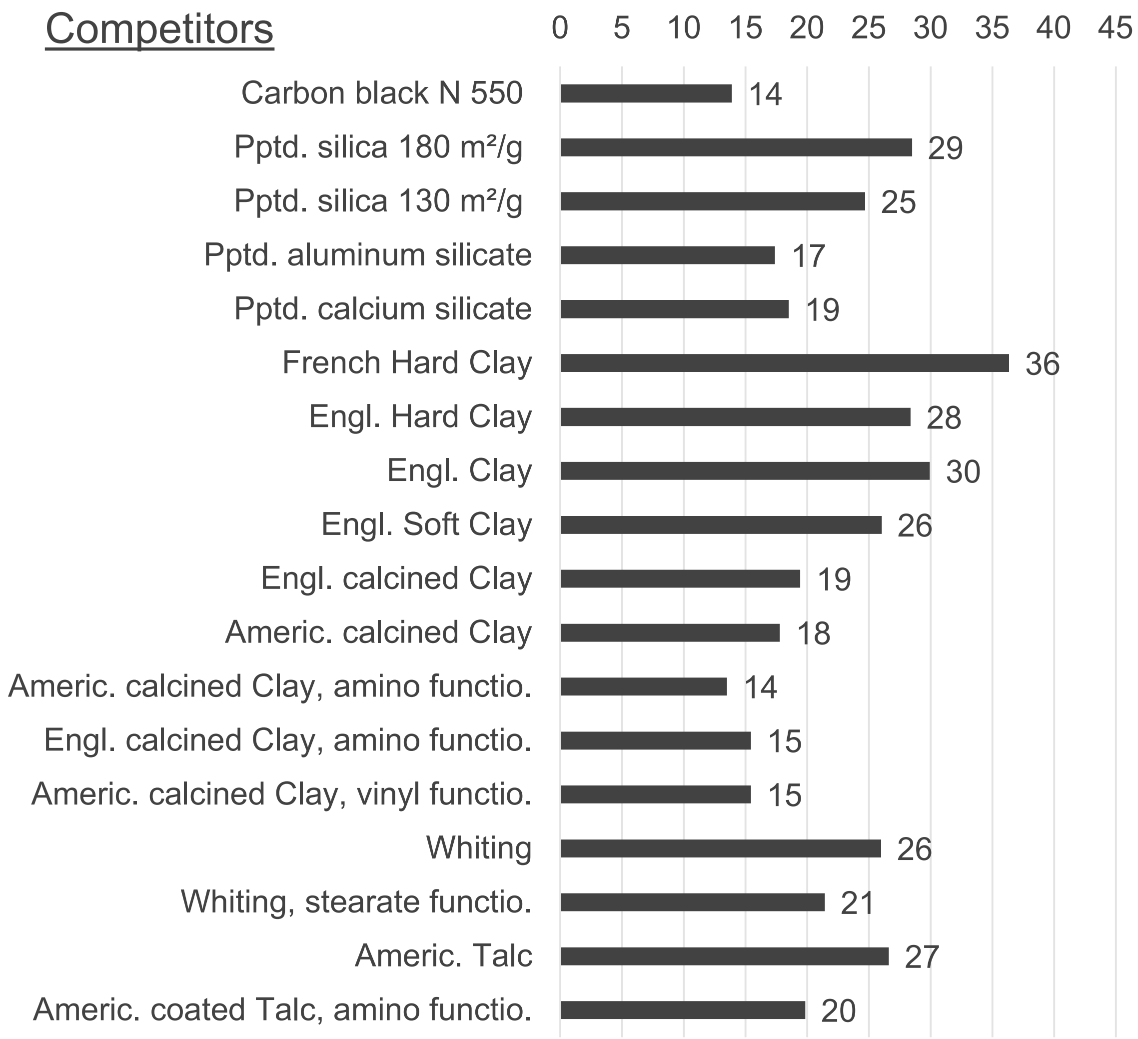


Note: Sillitin N 82 will be replaced by Sillitin N 75

Compression set in % (24 h / 70 °C / 25 % Def.)

DIN ISO 815-1, Typ B





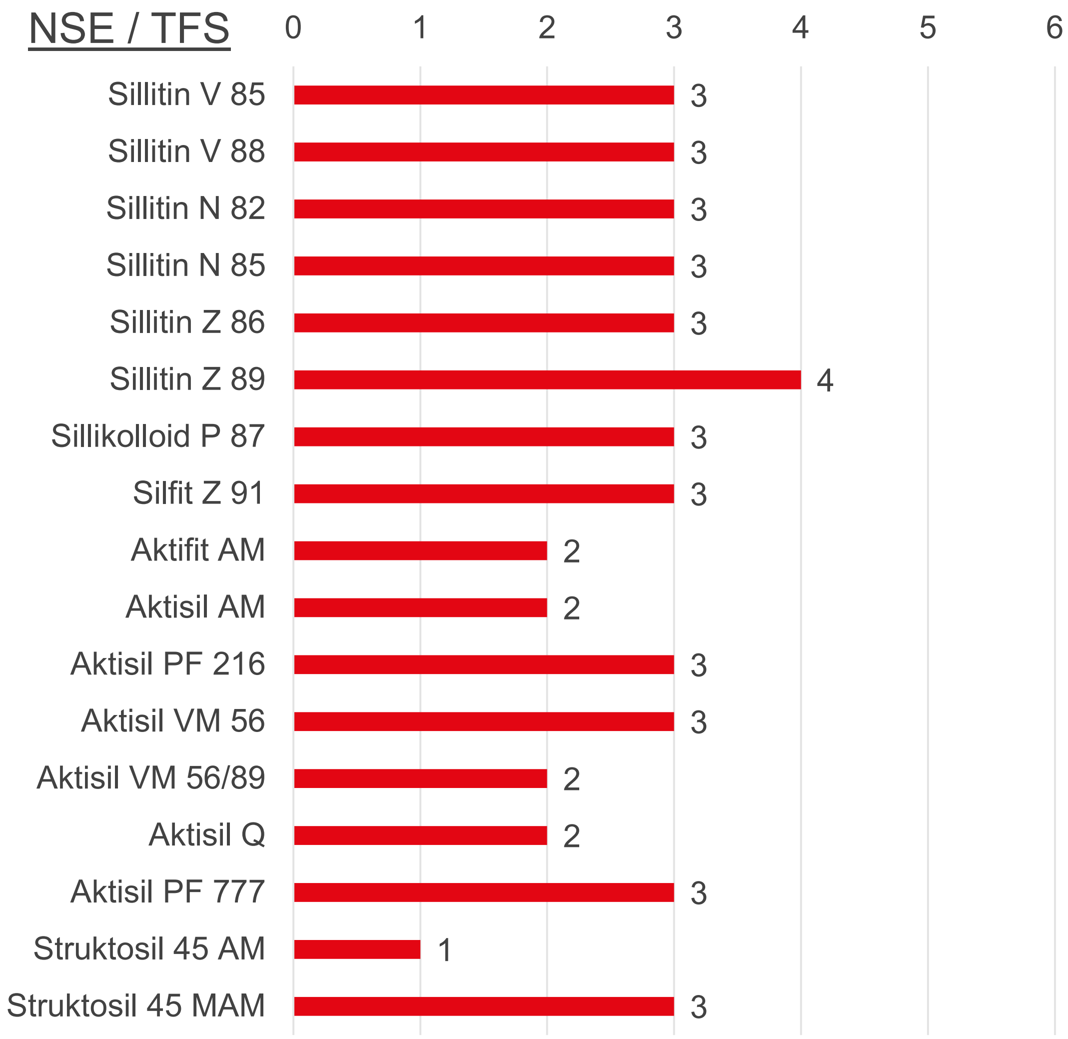
Note: Sillitin N 82 will be replaced by Sillitin N 75

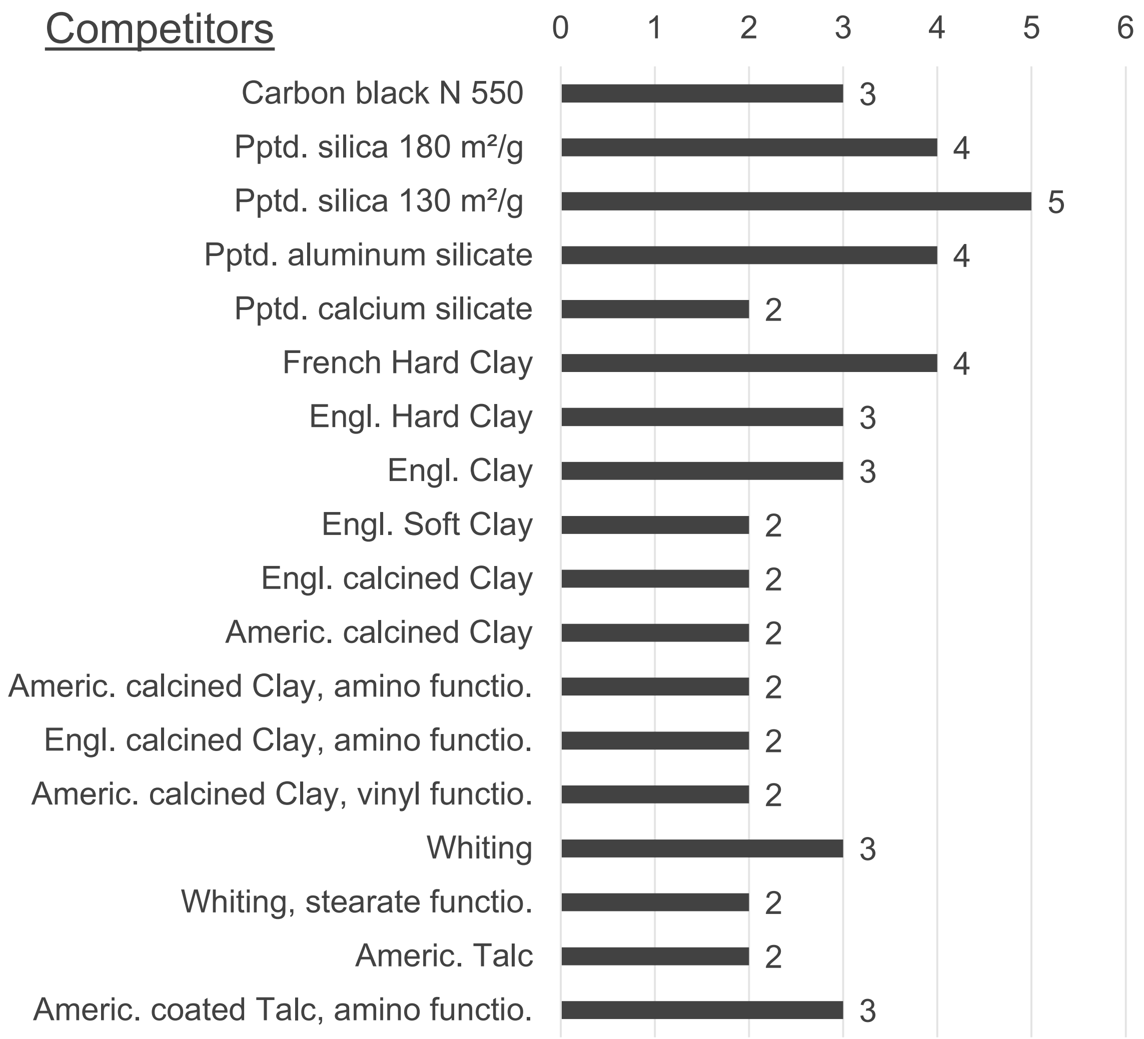
→ back to results

Hot air aging 168 h / 70 °C

ISO 188, D

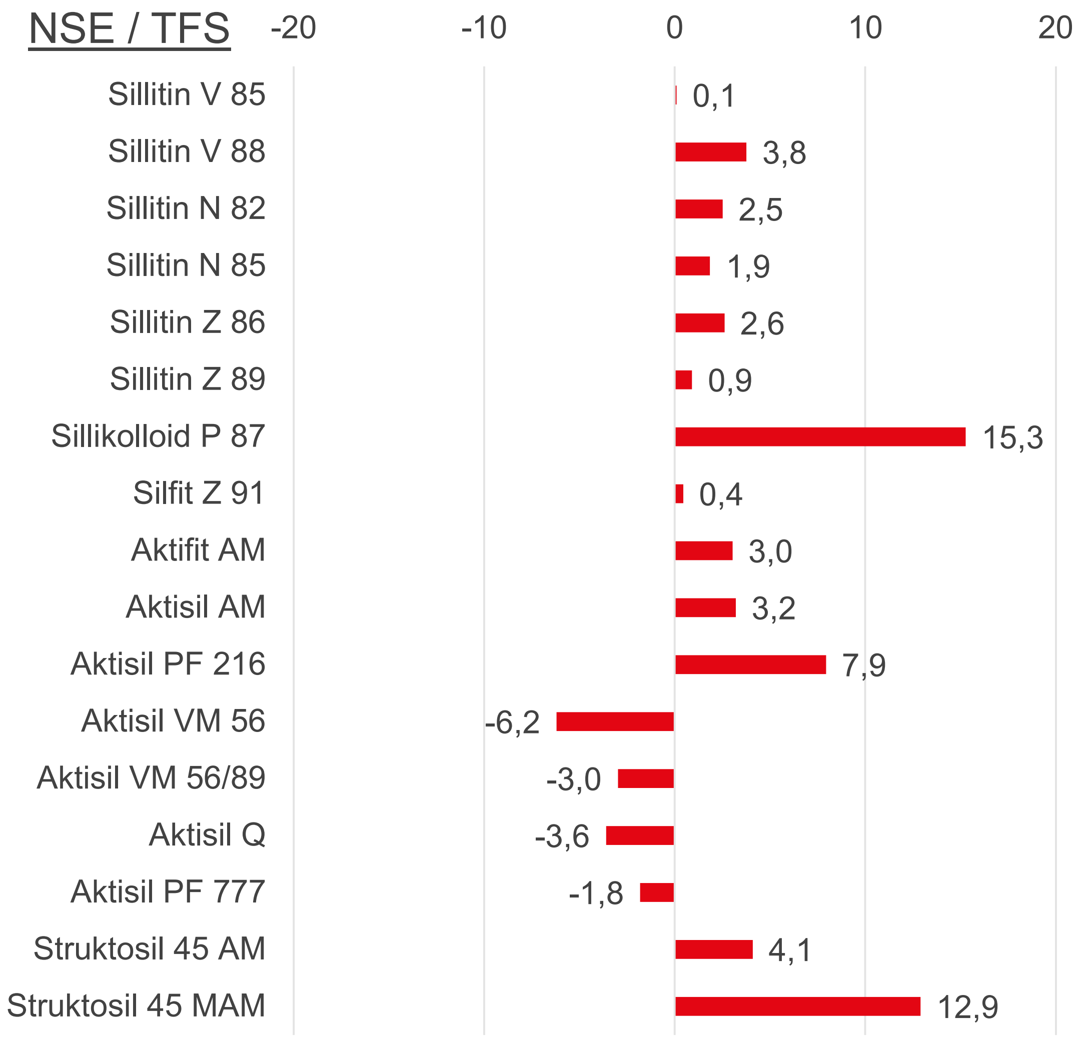
Hot air aging 168 h / 70 °C
Change of hardness in Shore A – piled up S2 dumbbells

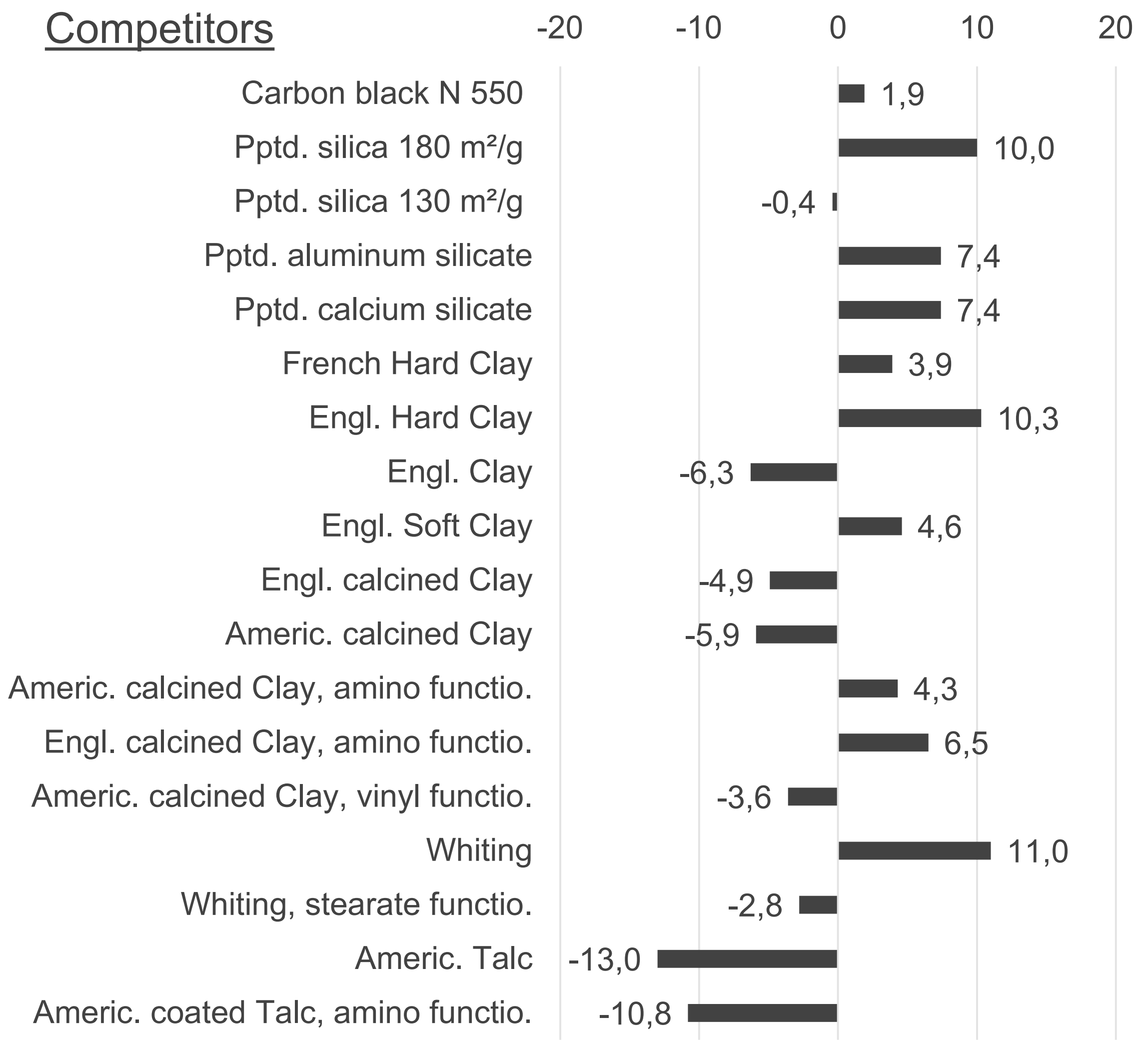




Note: Sillitin N 82 will be replaced by Sillitin N 75

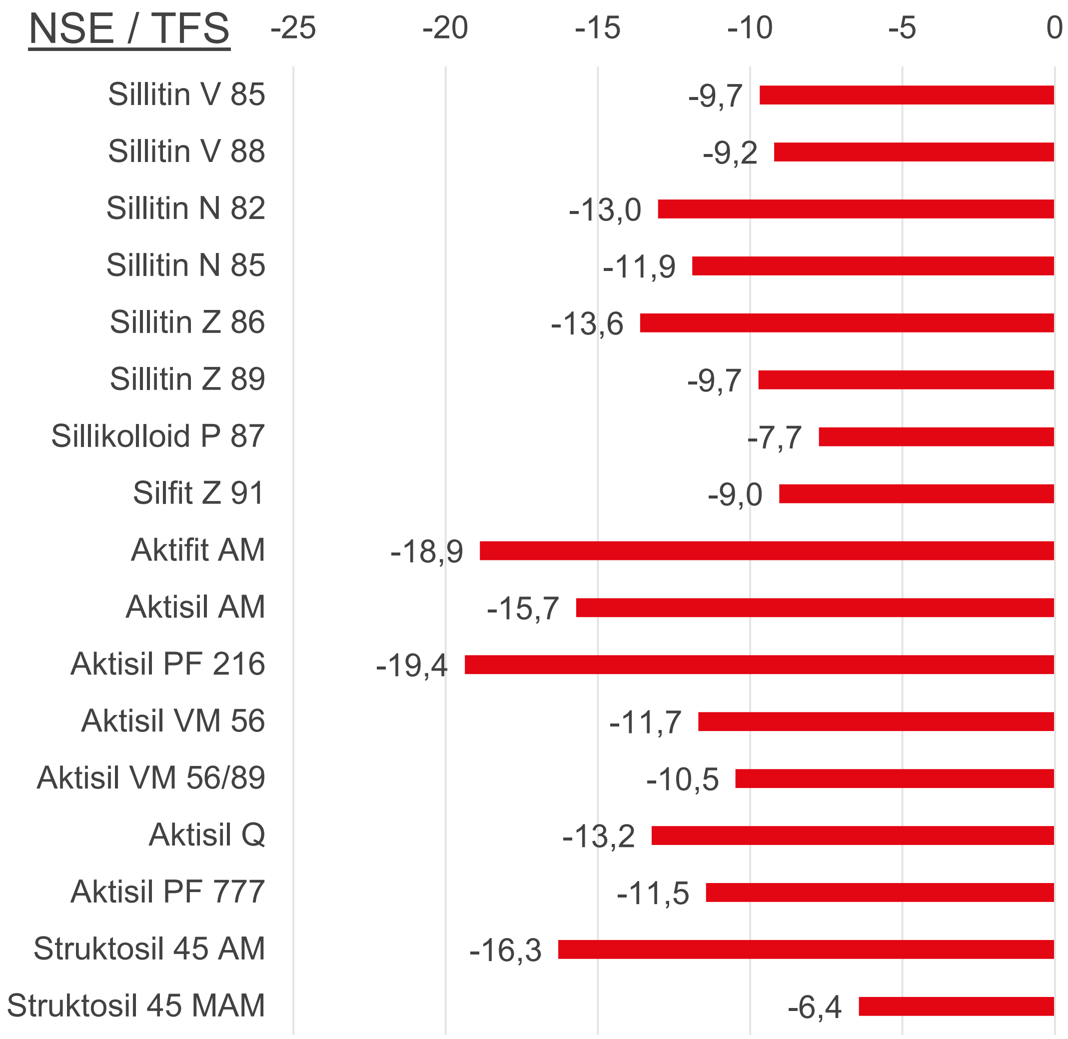
Hot air aging 168 h / 70 °C
Change of tensile strength in %

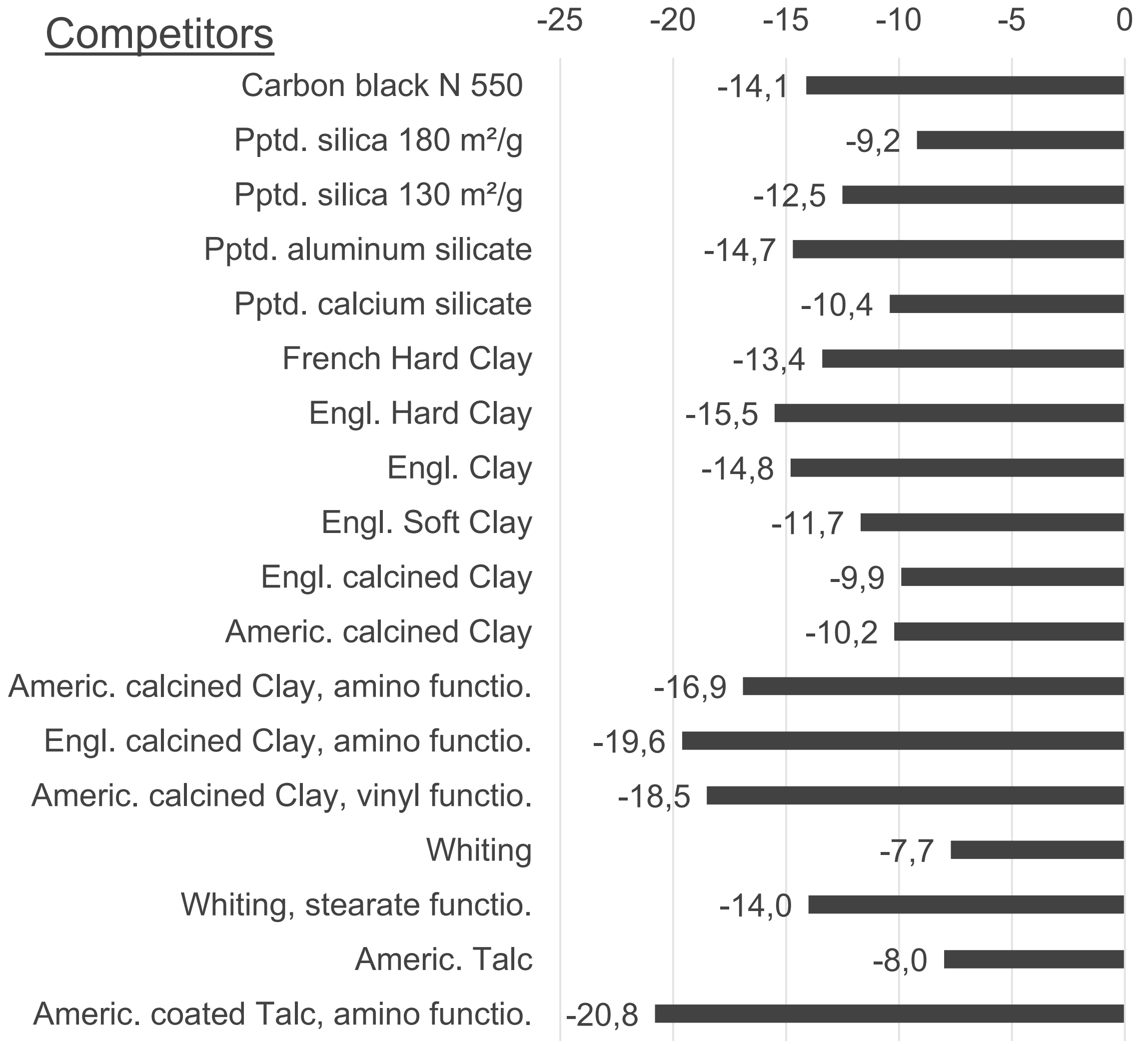




Note: Sillitin N 82 will be replaced by Sillitin N 75

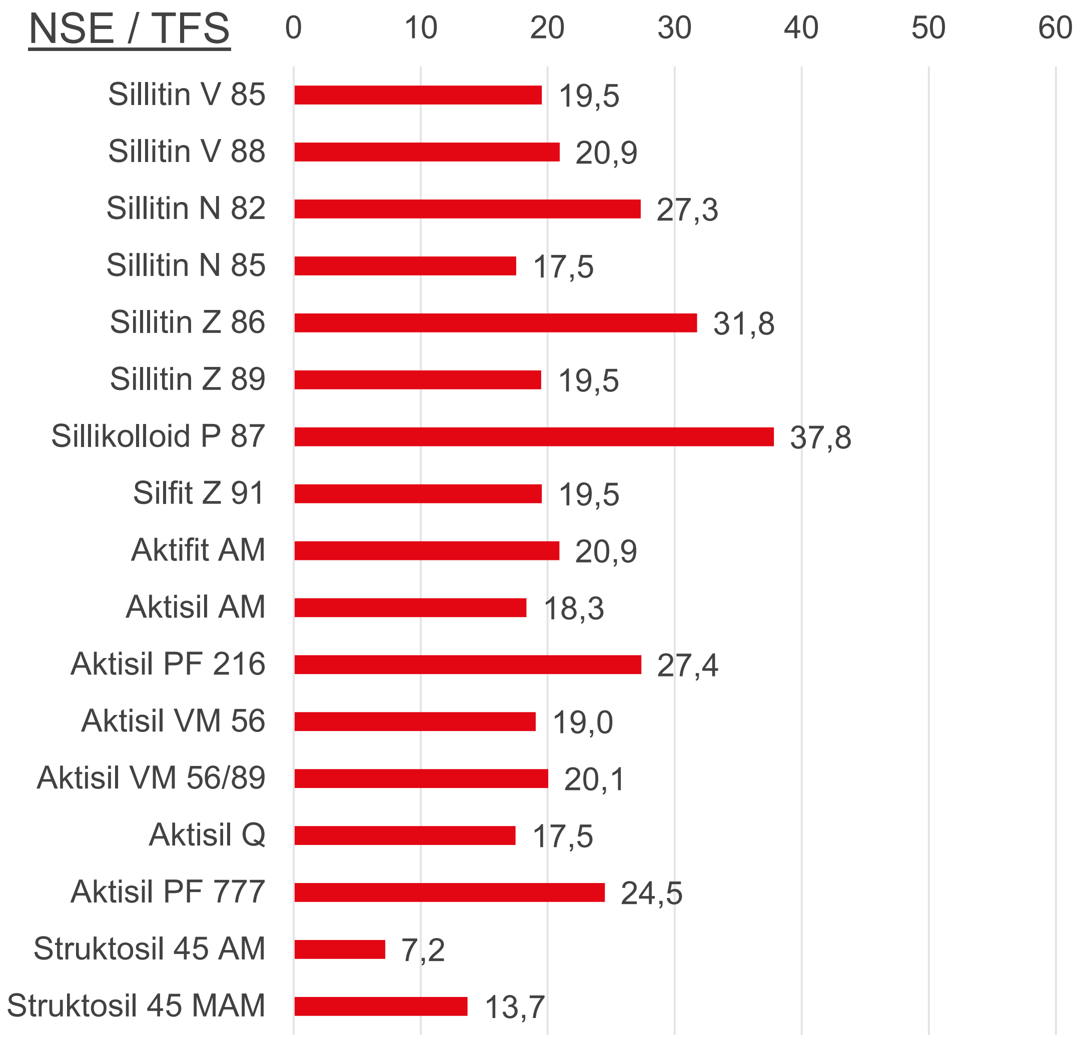
Hot air aging 168 h / 70 °C
Change of elongation at break in rel.%

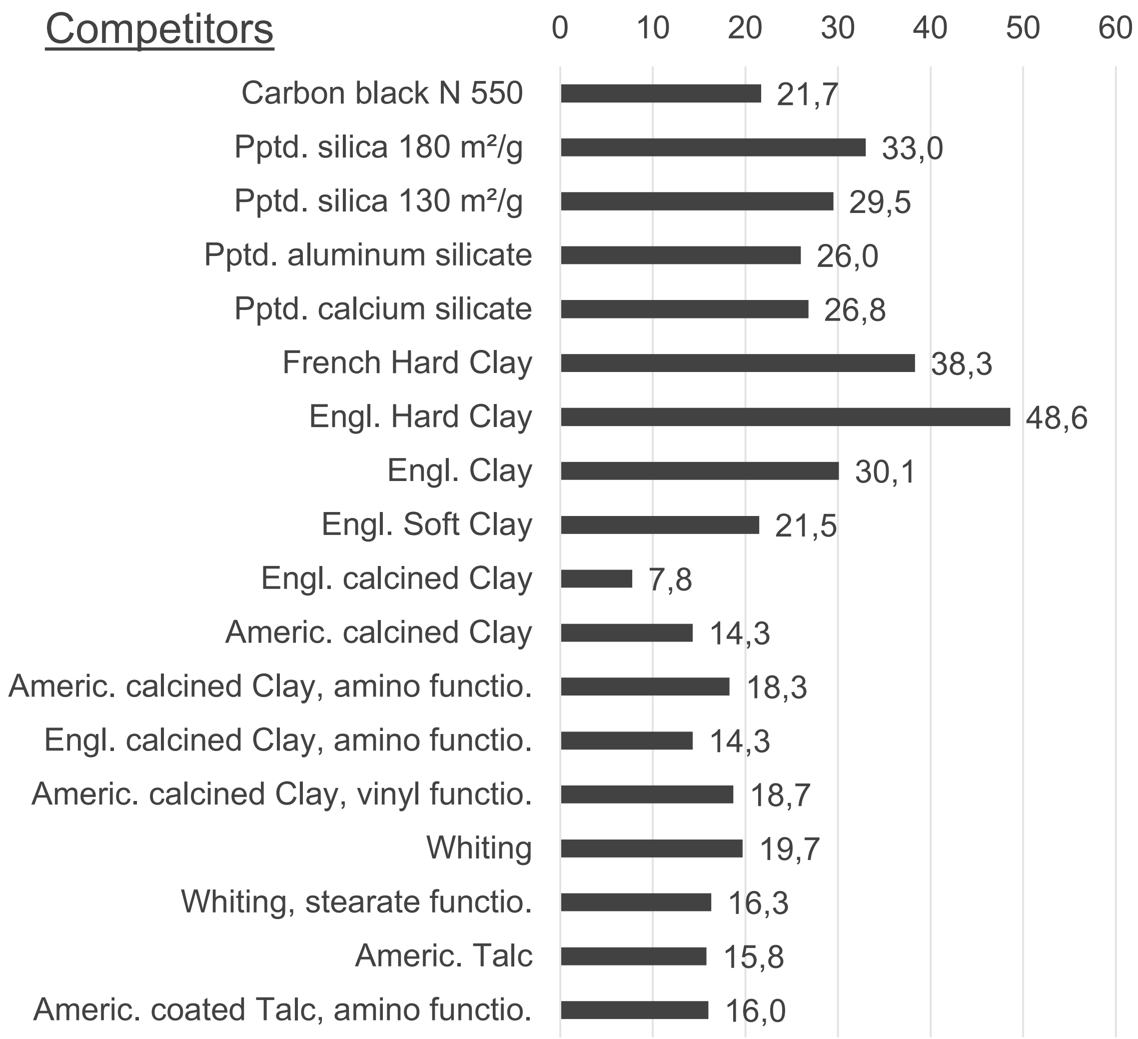




Note: Sillitin N 82 will be replaced by Sillitin N 75

Hot air aging 168 h / 70 °C
Change of modulus 100 % in %





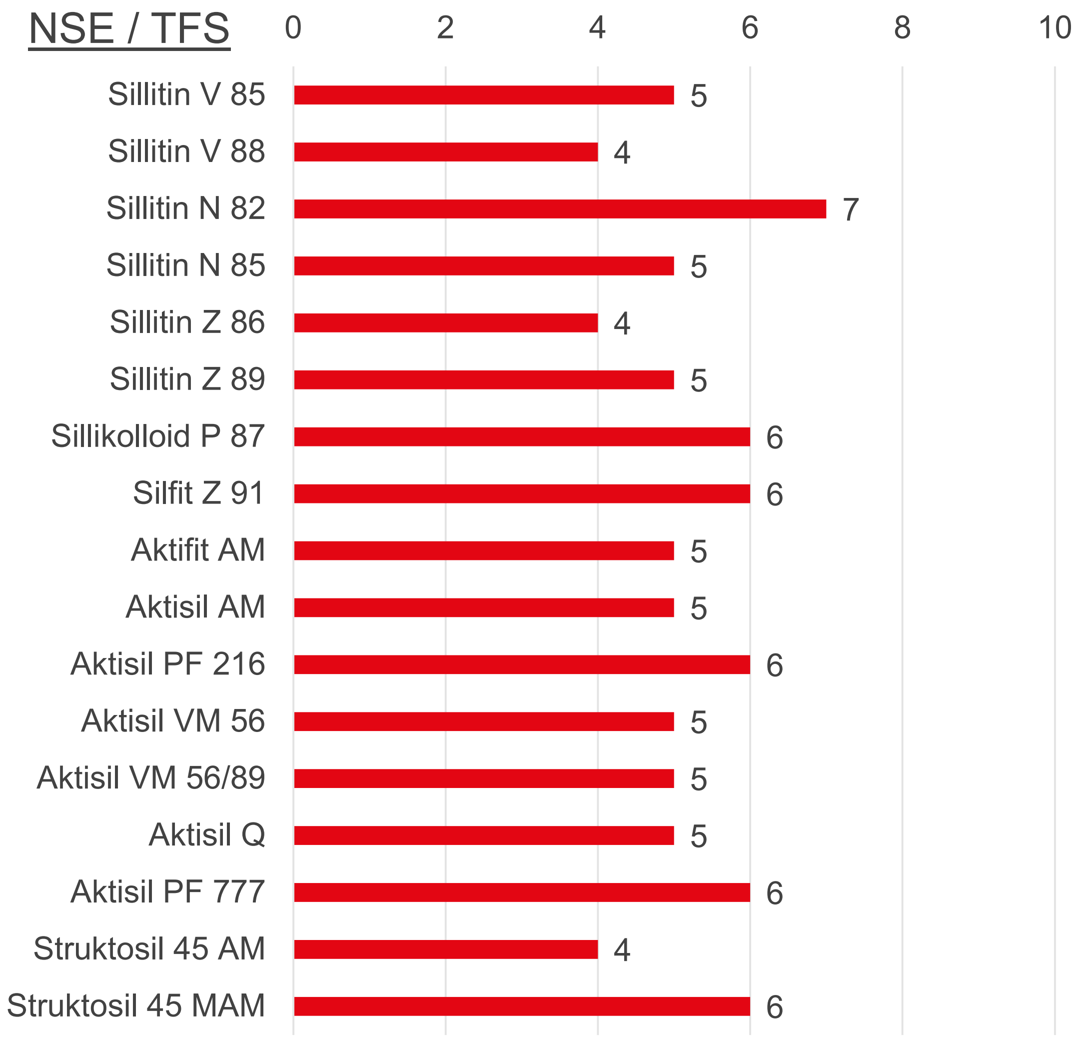
Note: Sillitin N 82 will be replaced by Sillitin N 75

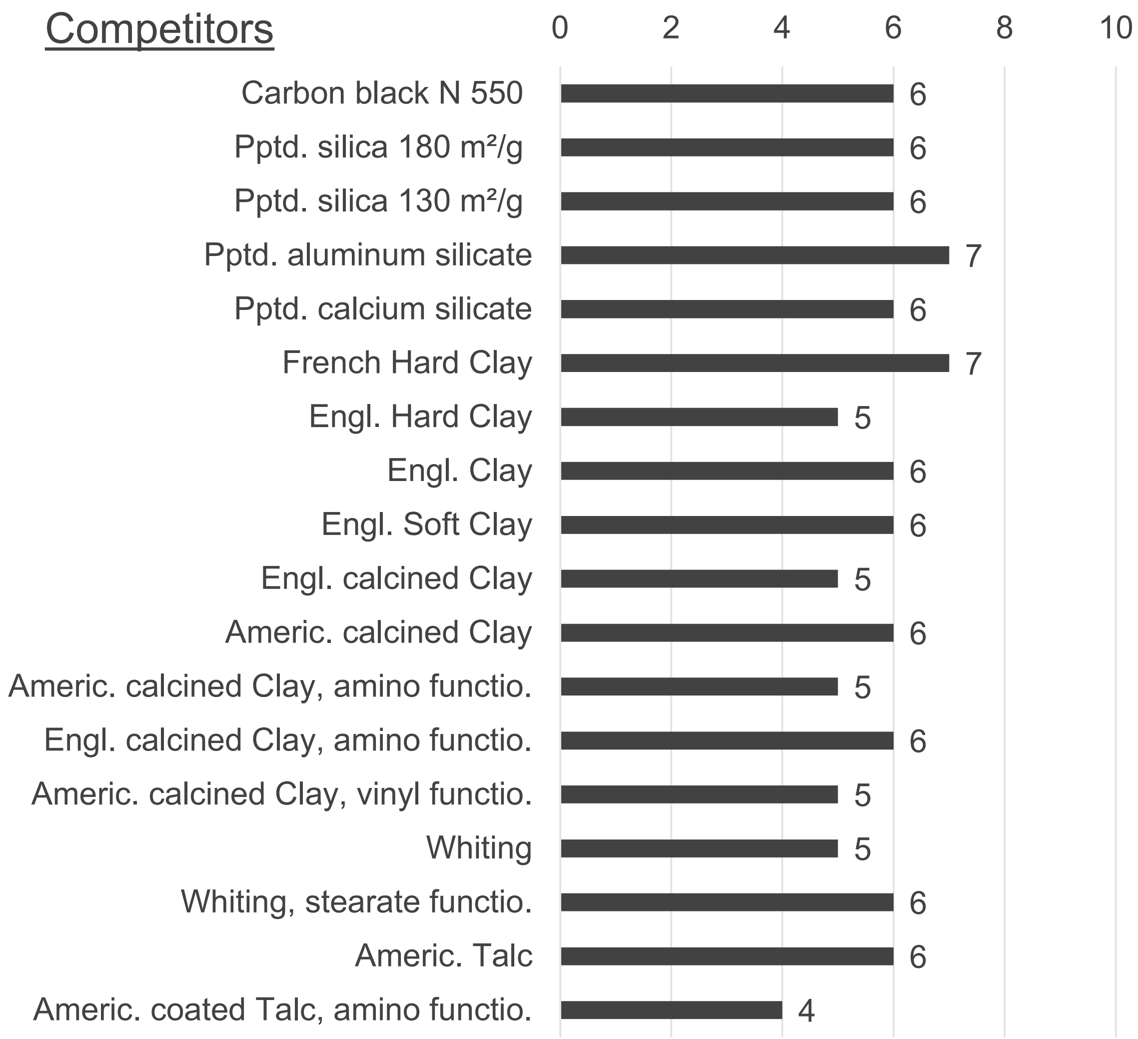
→ back to results

Hot air aging 168 h / 100 °C

ISO 188, D

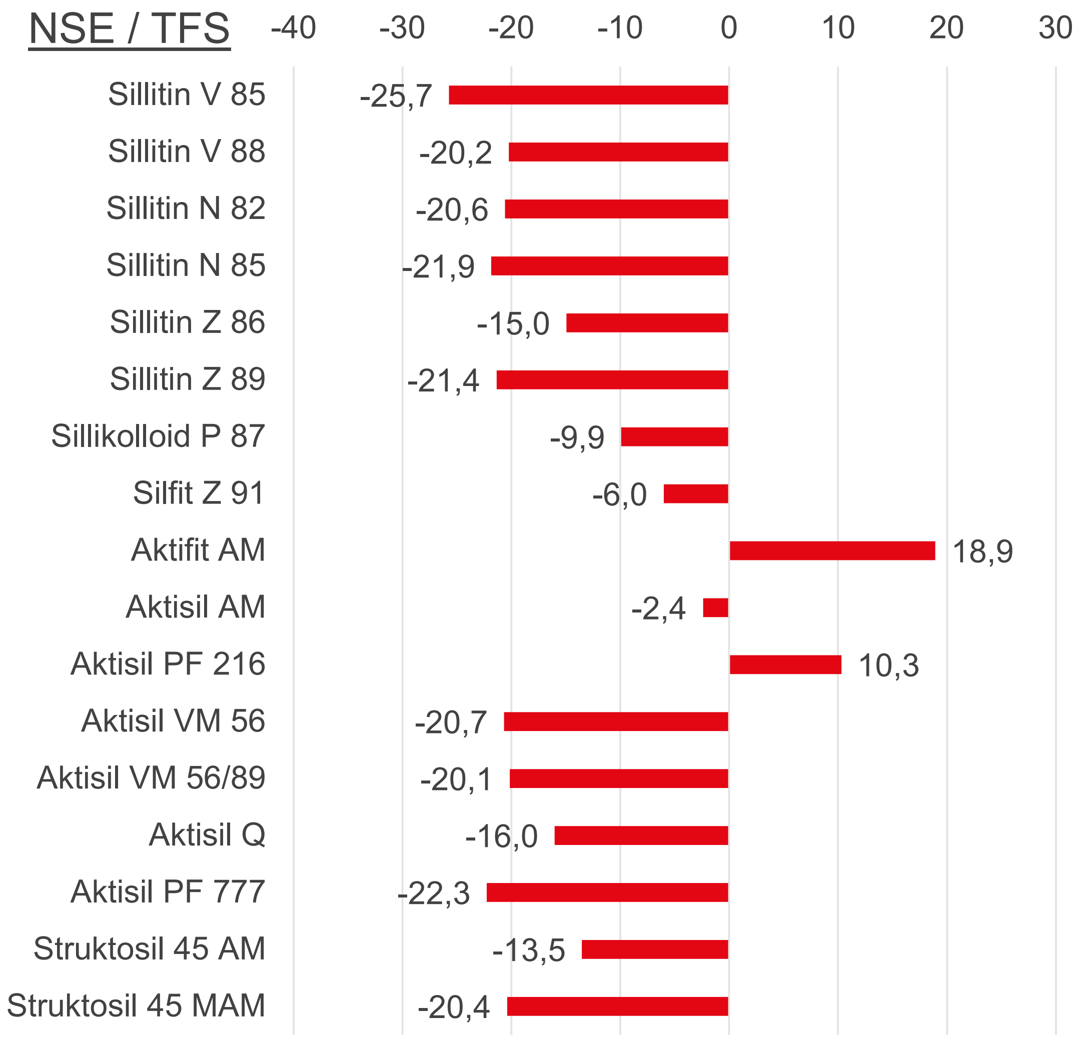
Hot air aging 168 h / 100 °C
Change of hardness in Shore A – piled up S2 dumbbells

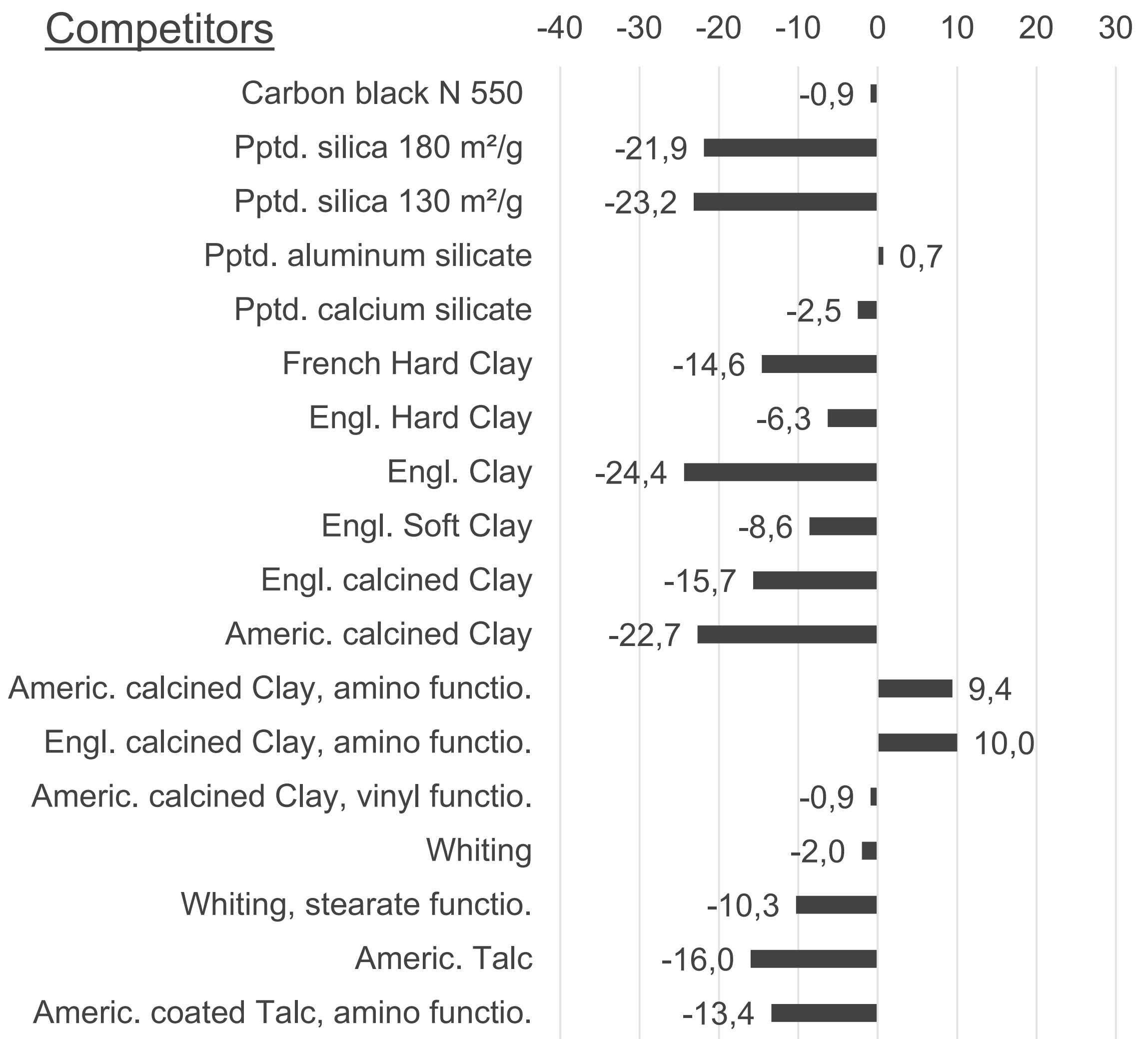




Note: Sillitin N 82 will be replaced by Sillitin N 75

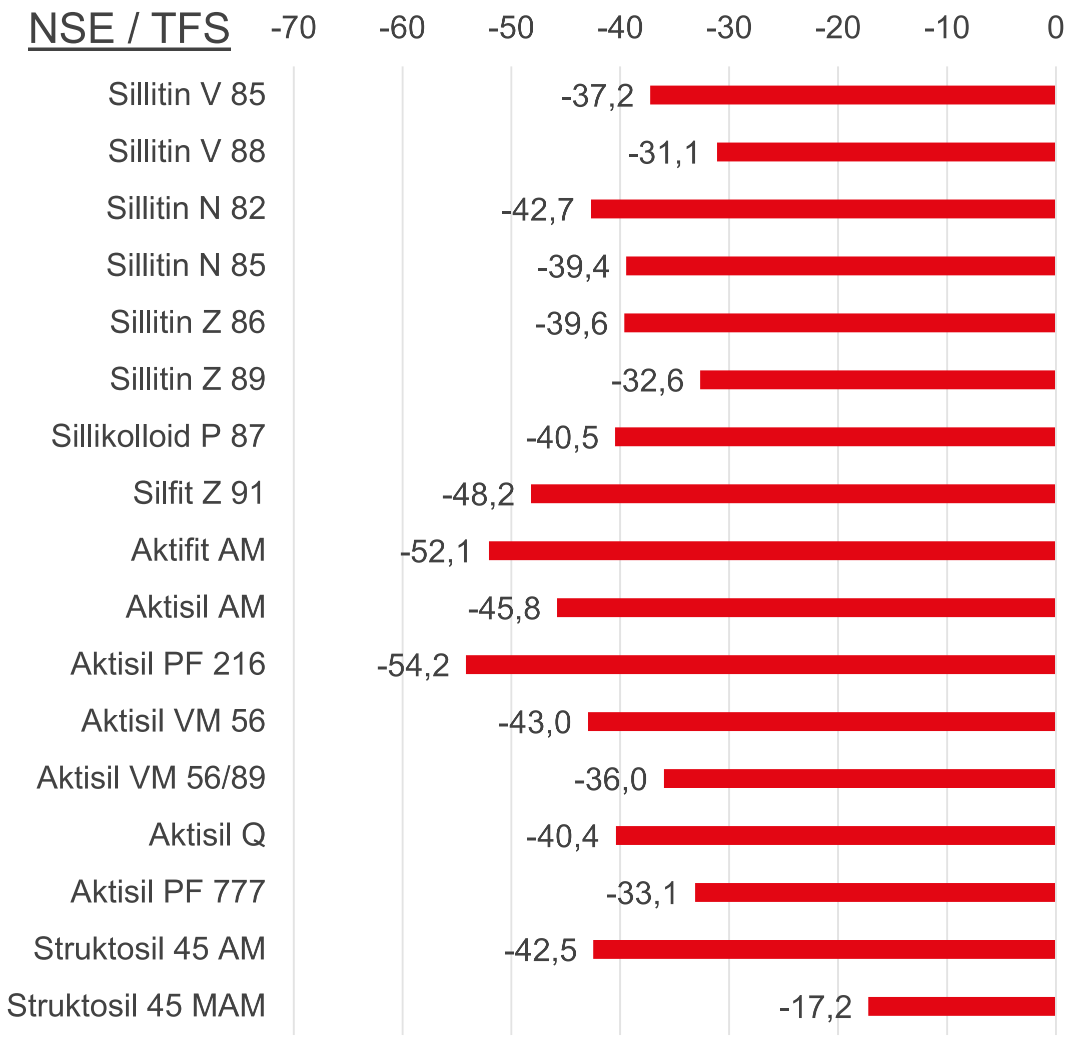
Hot air aging 168 h / 100 °C
Change of tensile strength in %

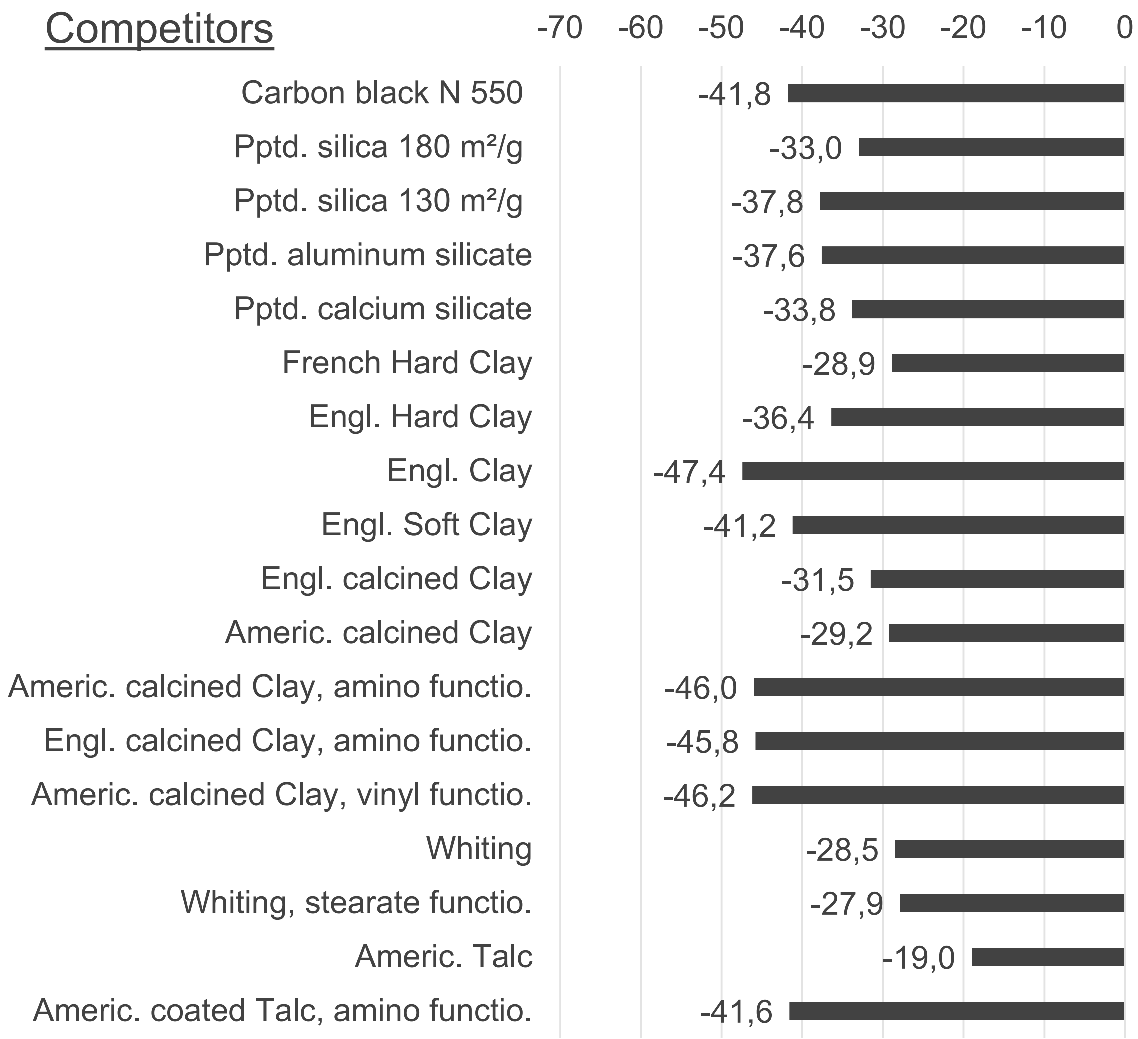




Note: Sillitin N 82 will be replaced by Sillitin N 75

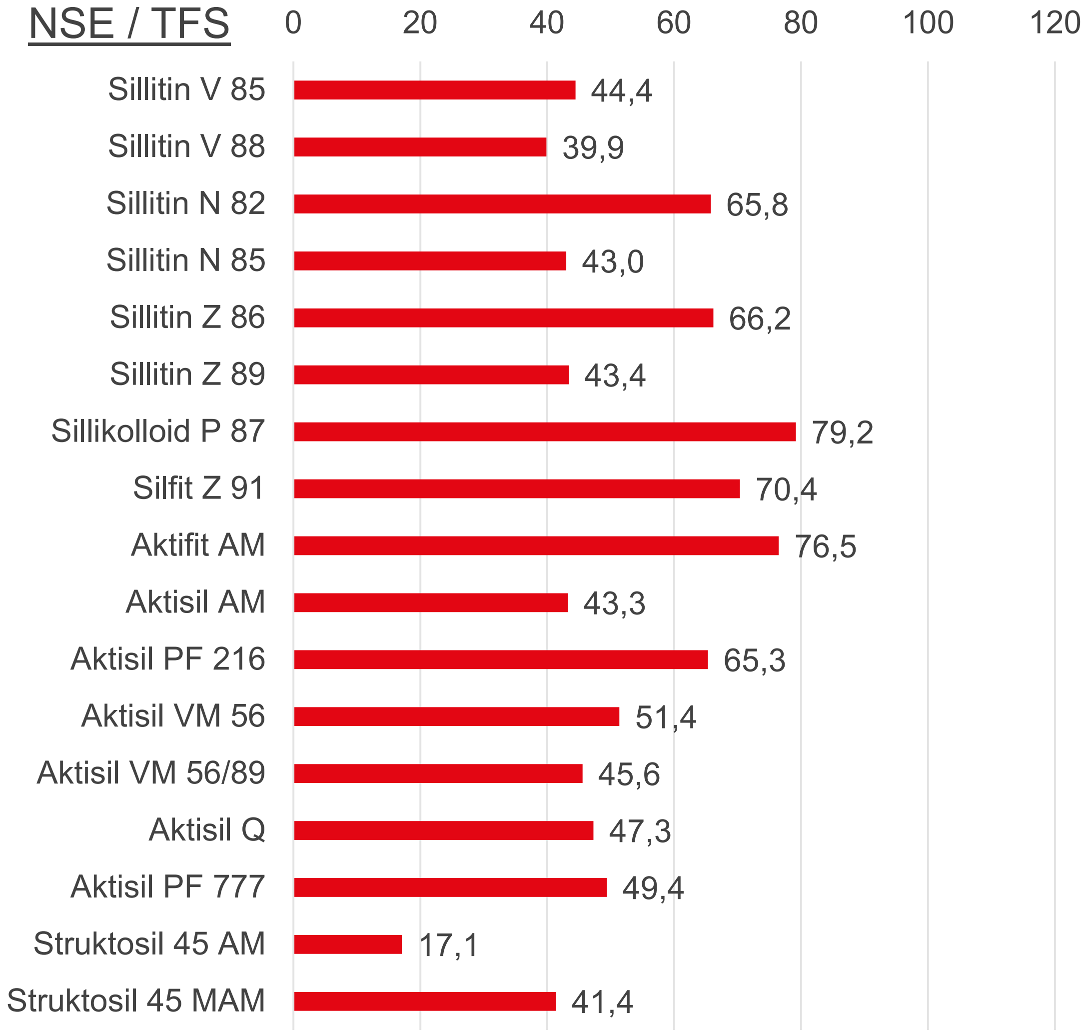
Hot air aging 168 h / 100 °C
Change of elongation at break in rel.%

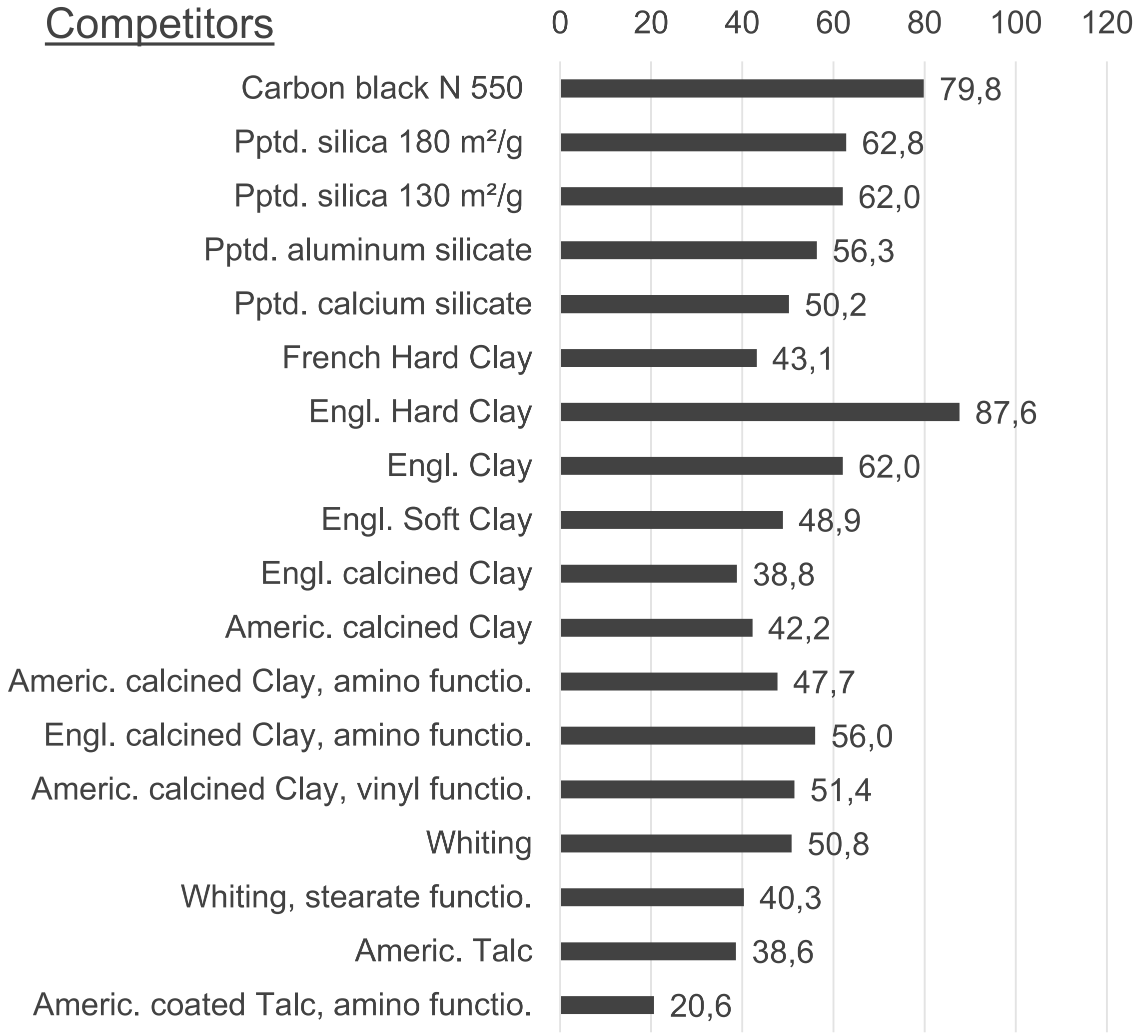




Note: Sillitin N 82 will be replaced by Sillitin N 75

Hot air aging 168 h / 100 °C
Change of modulus 100 % in %





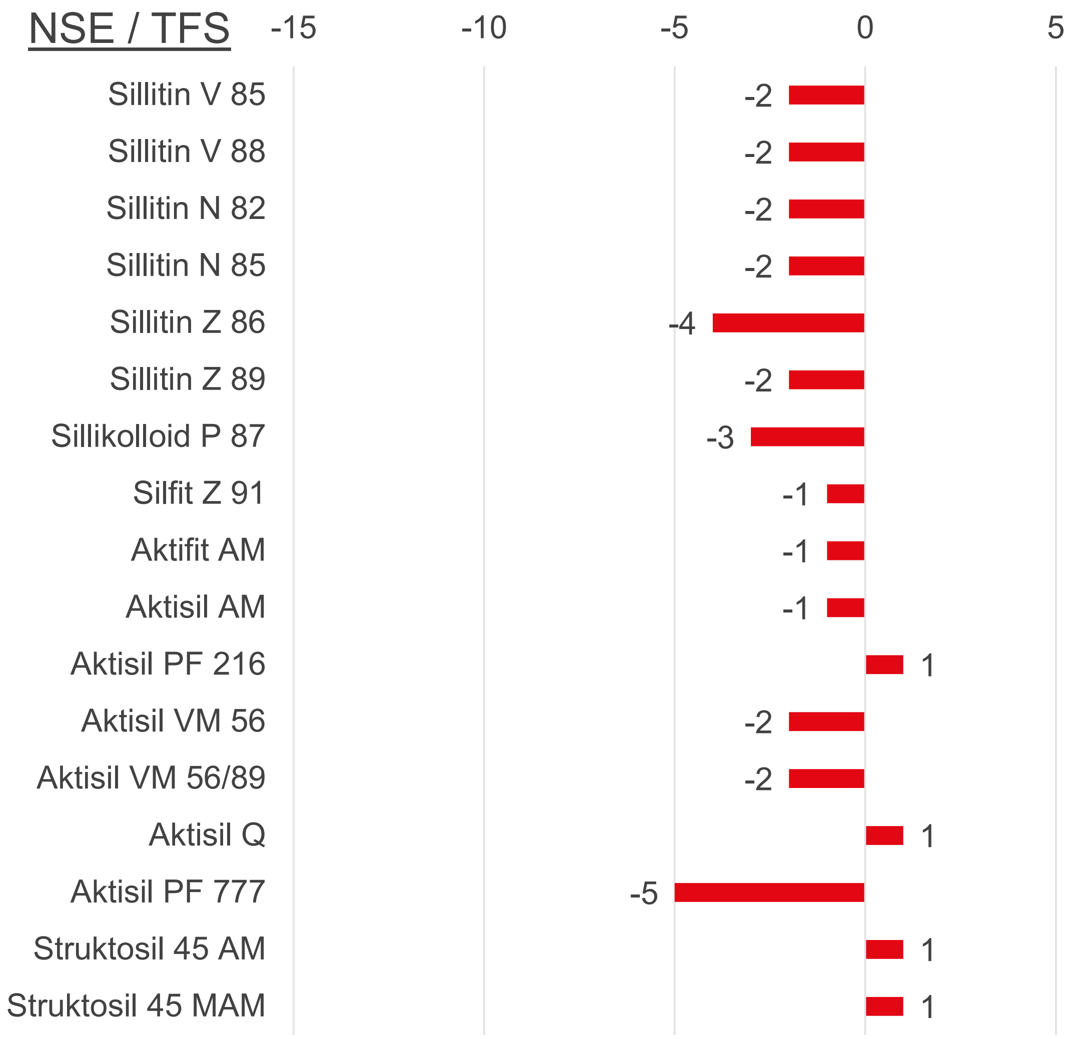
Note: Sillitin N 82 will be replaced by Sillitin N 75

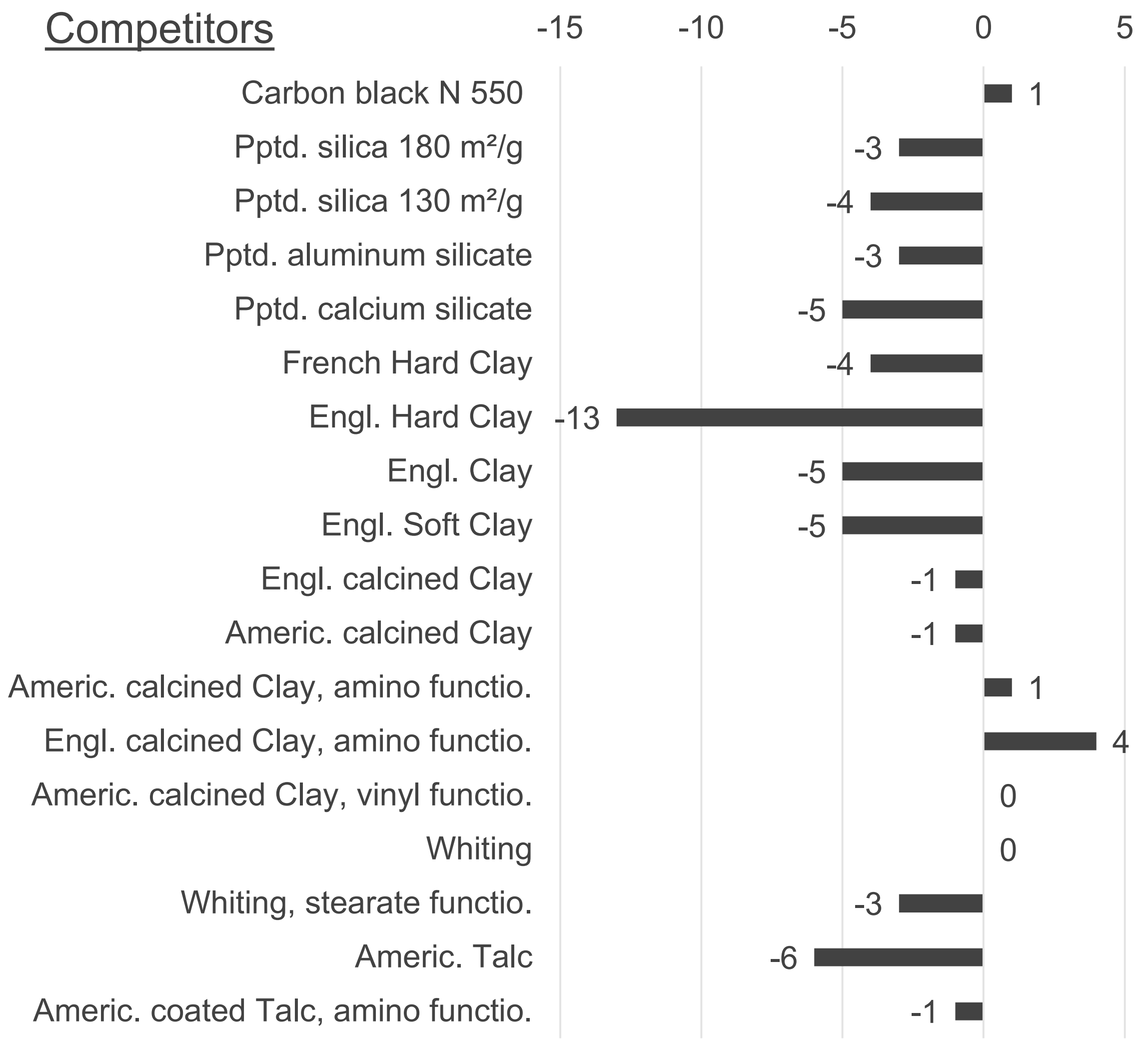
→ back to results

Immersion in deionized water 168 h / 95 °C

DIN ISO 1817

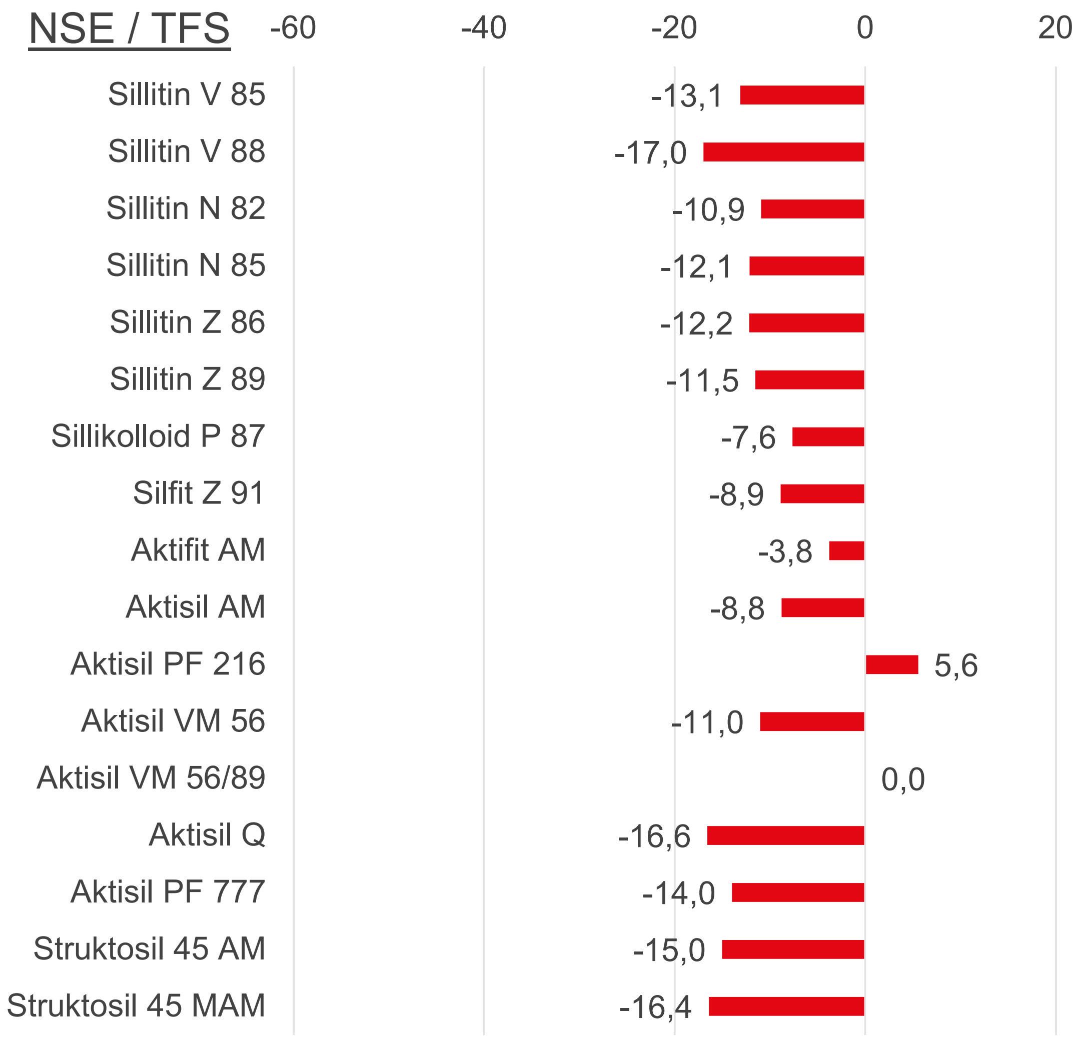
Immersion in deionized water 168 h / 95 °C
Change of hardness in Shore A – piled up S2 dumbbells

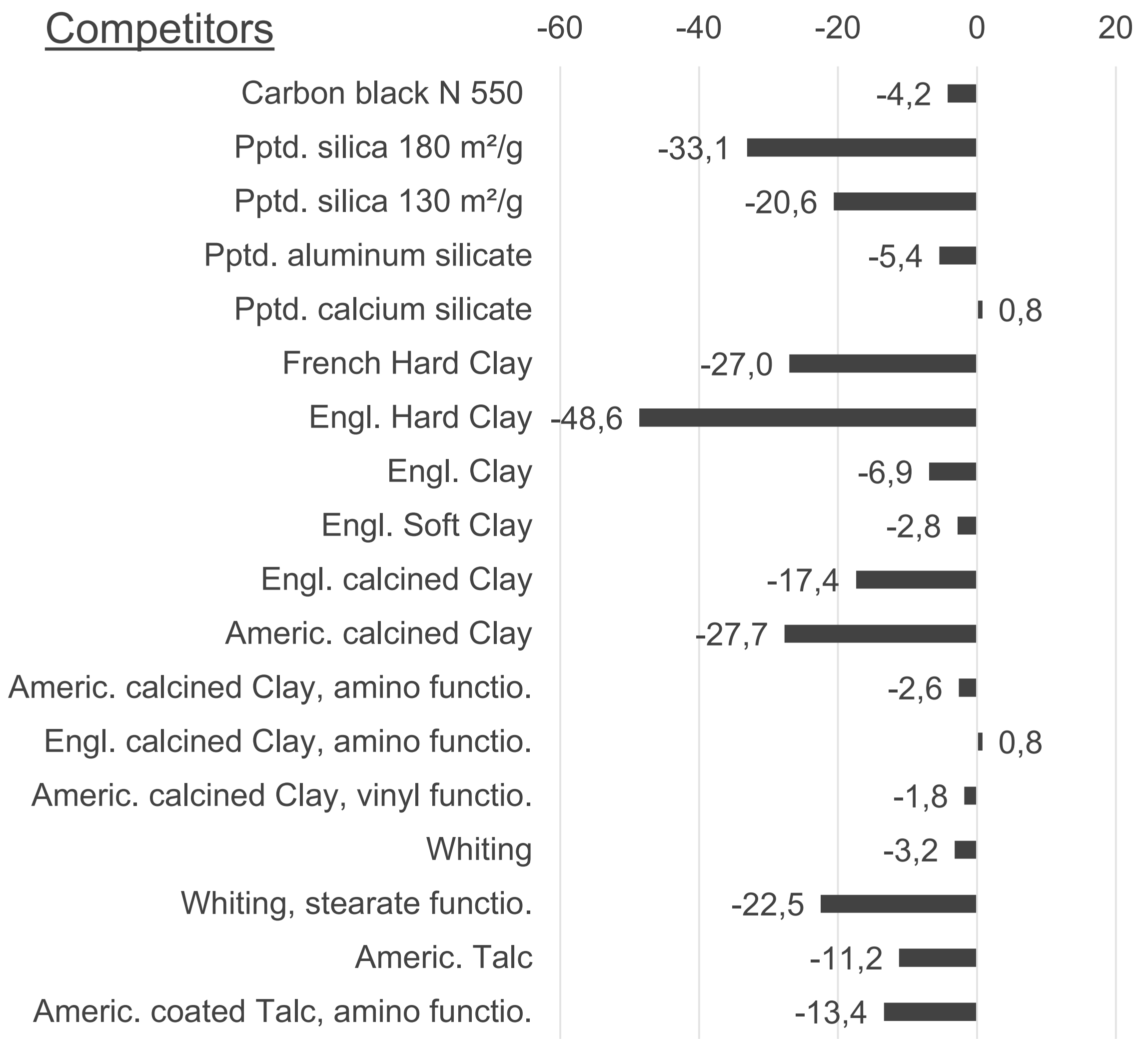




Note: Sillitin N 82 will be replaced by Sillitin N 75

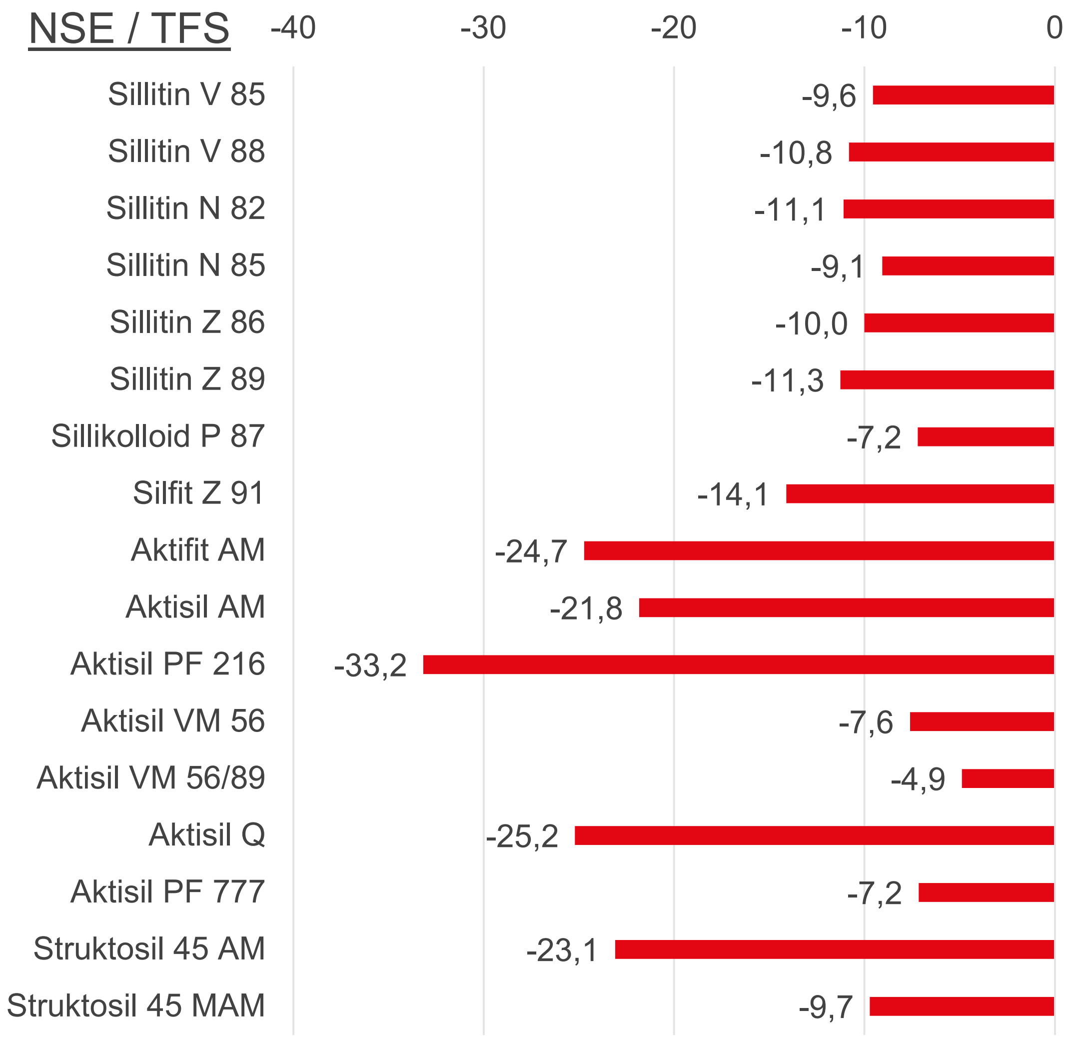
Immersion in deionized water 168 h / 95 °C
Change of tensile strength in %

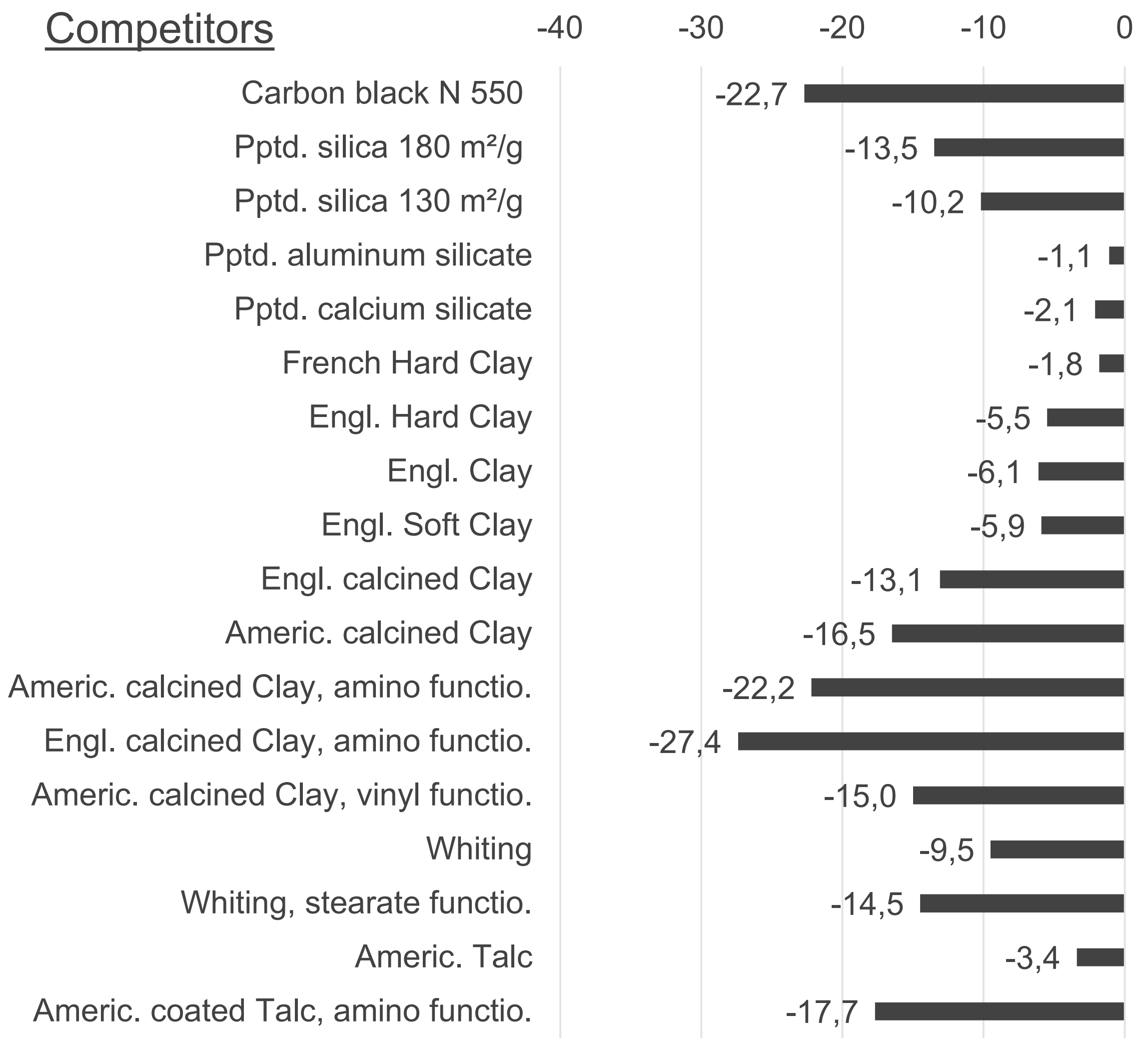




Note: Sillitin N 82 will be replaced by Sillitin N 75

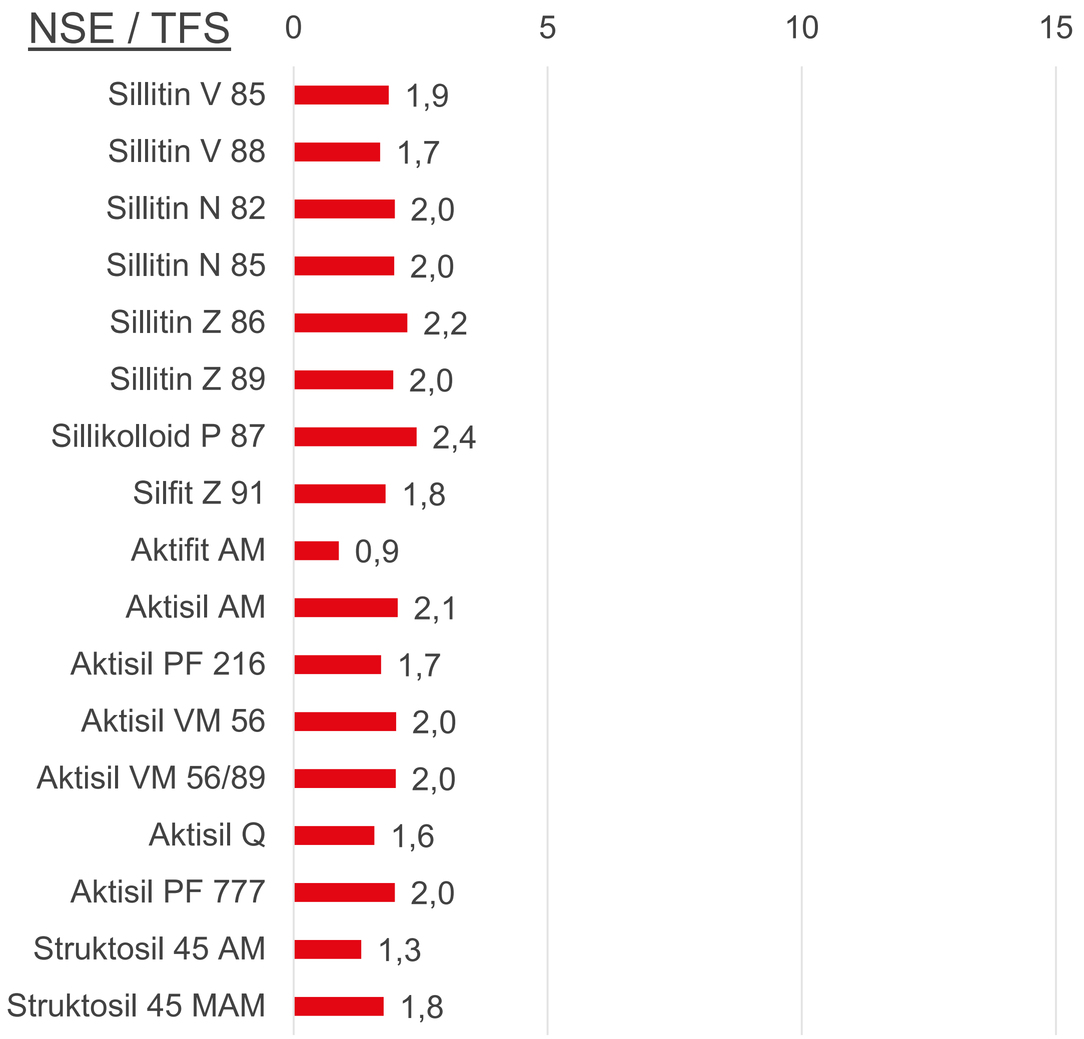
Immersion in deionized water 168 h / 95 °C
Change of elongation at break in rel.%

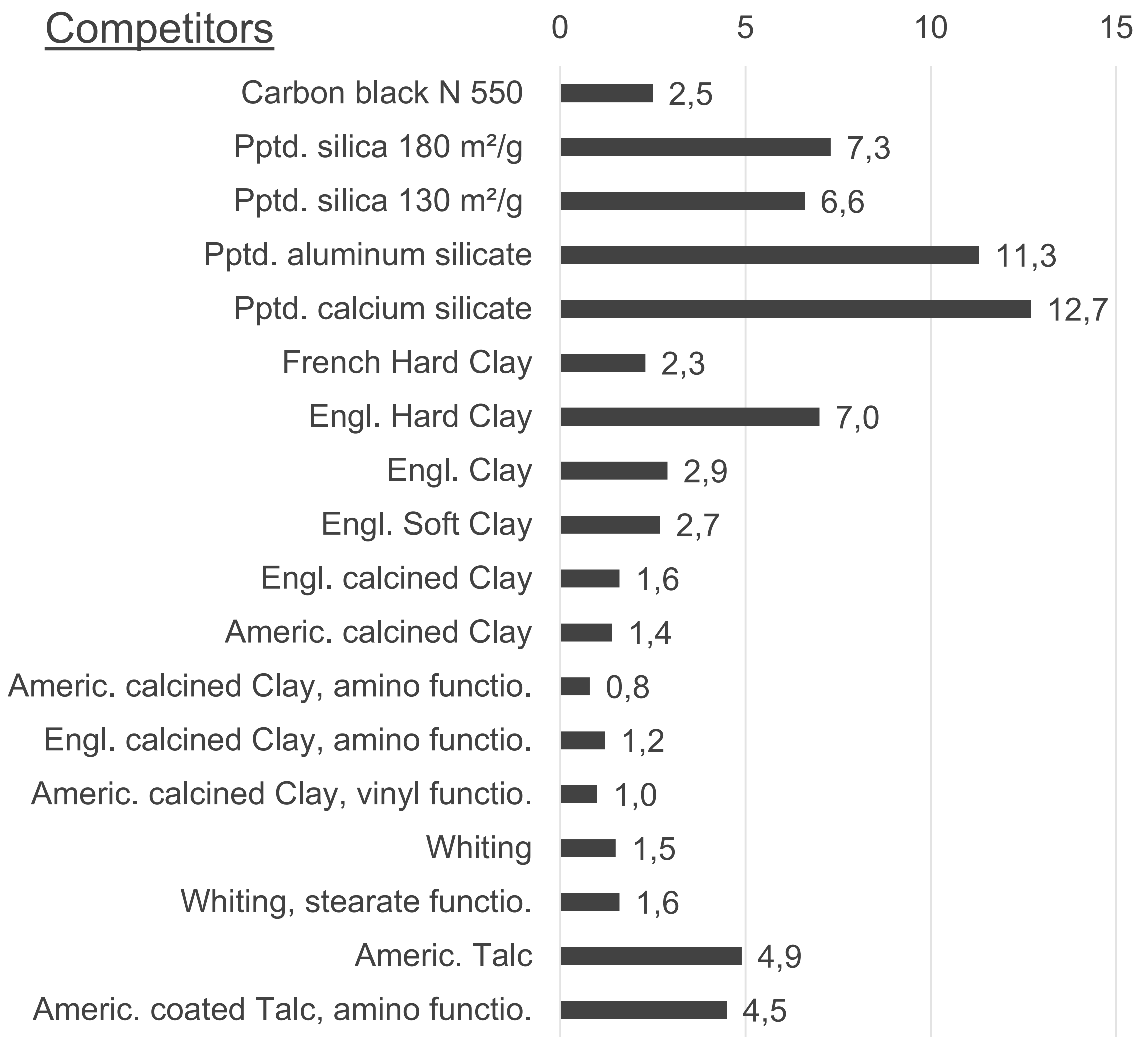




Note: Sillitin N 82 will be replaced by Sillitin N 75

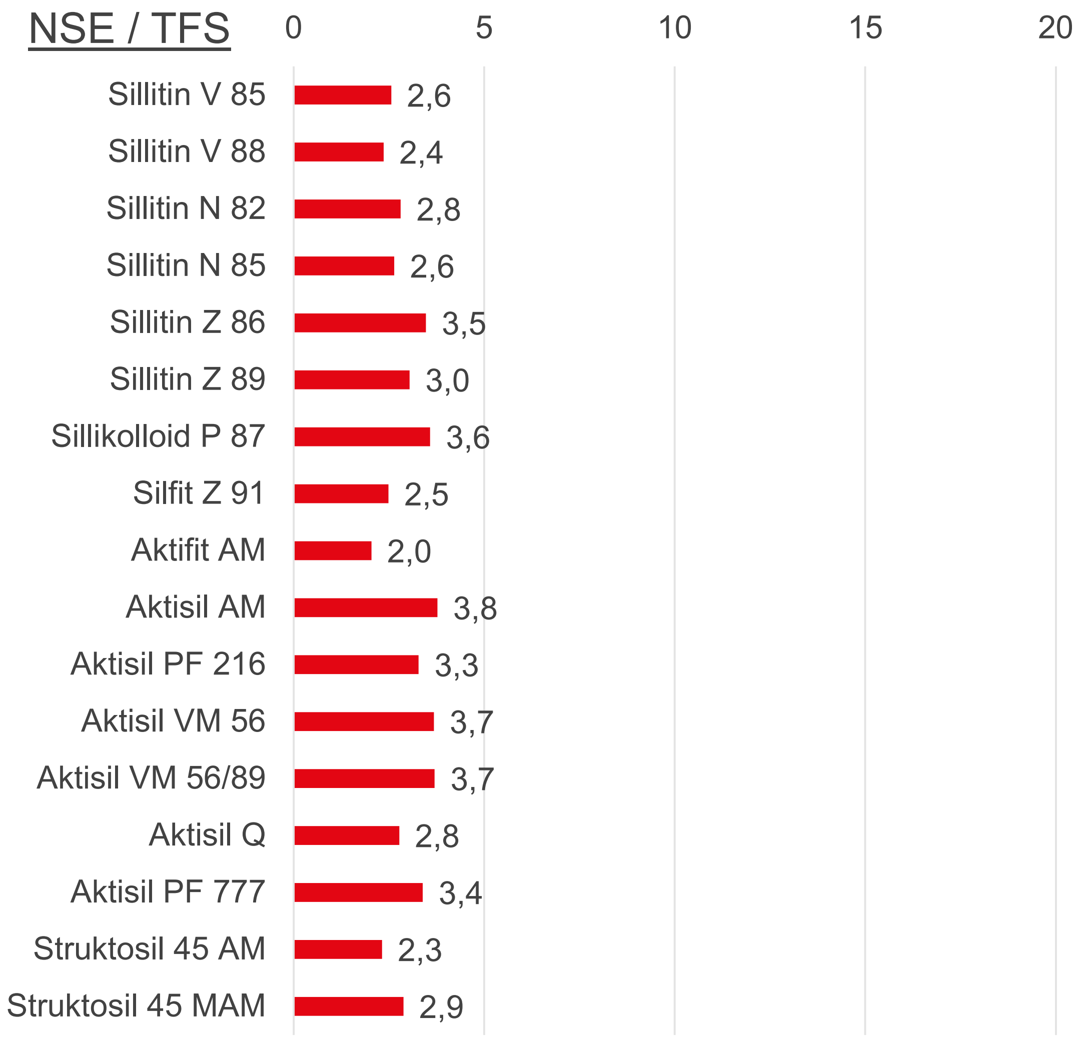
Immersion in deionized water 168 h / 95 °C
Change of weight in %

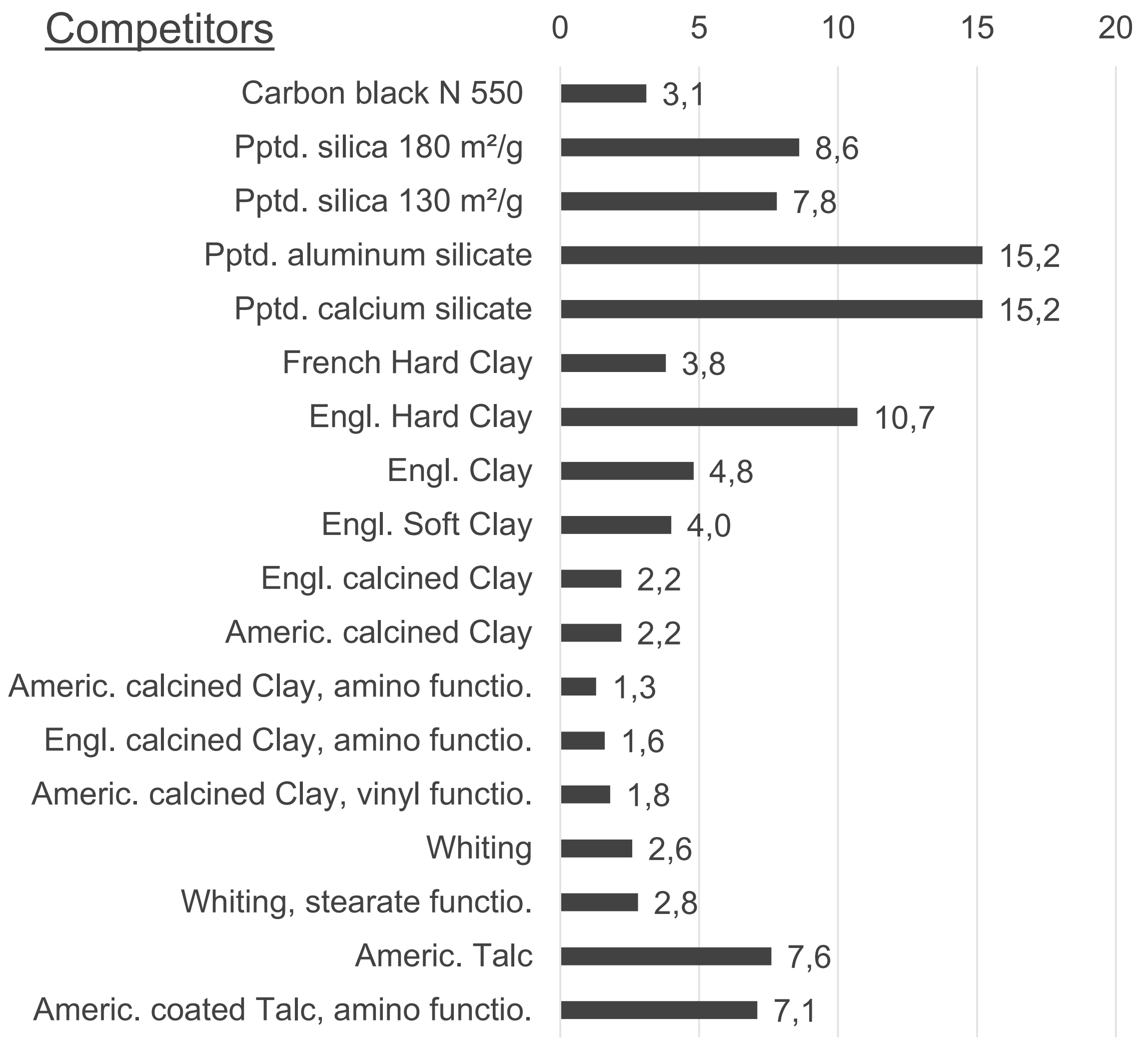




Note: Sillitin N 82 will be replaced by Sillitin N 75

Immersion in deionized water 168 h / 95 °C
Change of volume in %





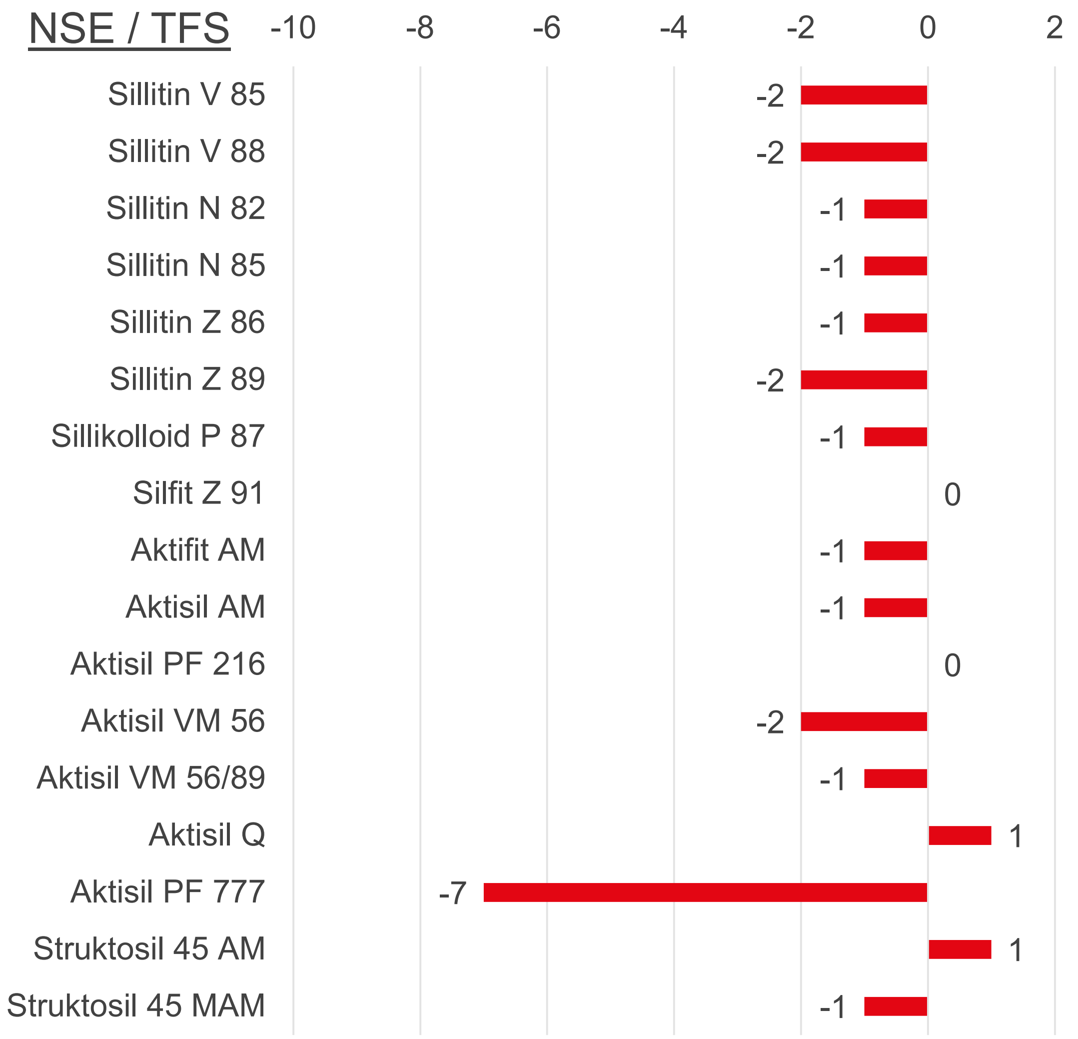
Note: Sillitin N 82 will be replaced by Sillitin N 75

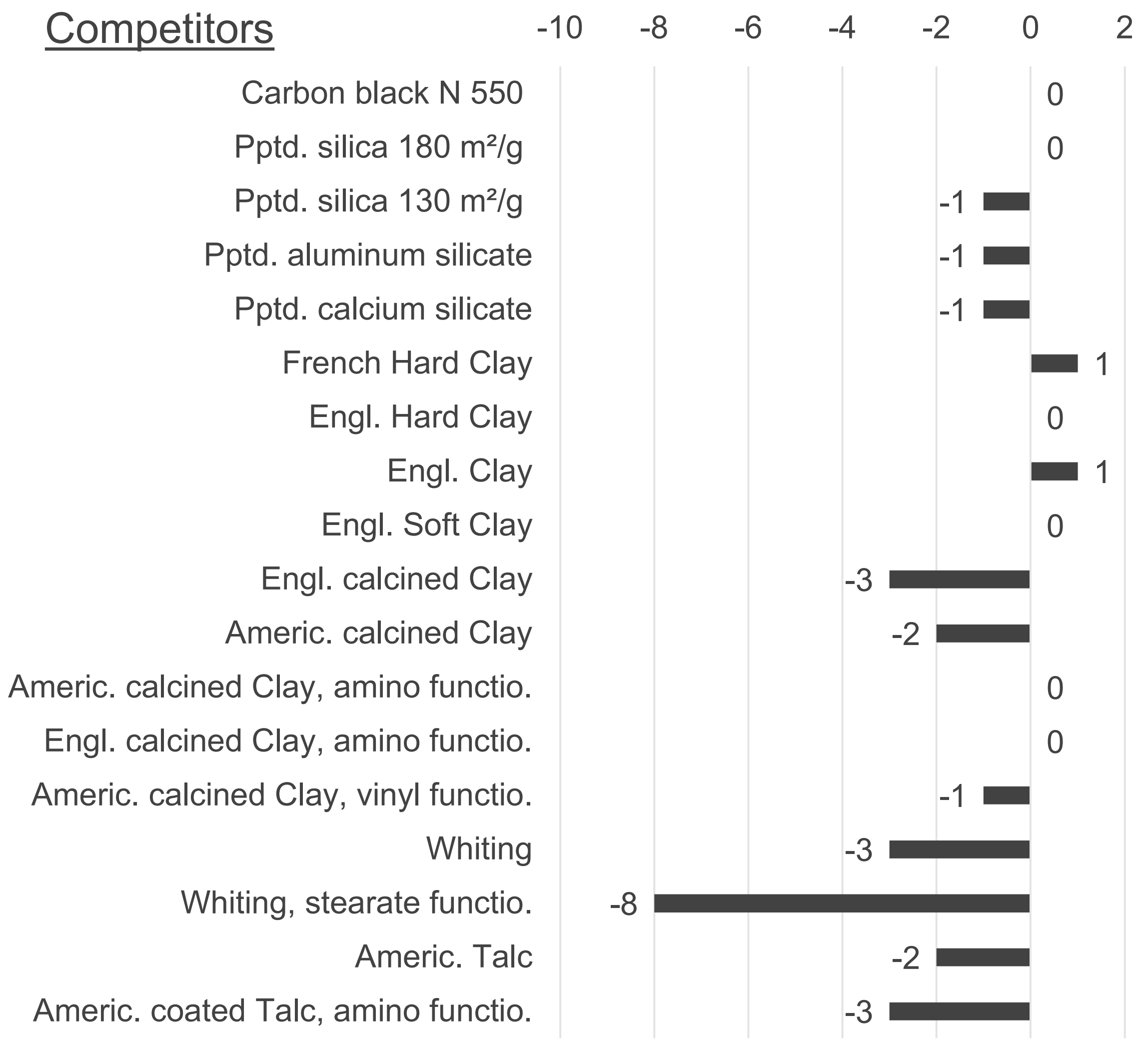
→ back to results

Immersion in reference oil IRM 903 168 h / 100 °C

DIN ISO 1817

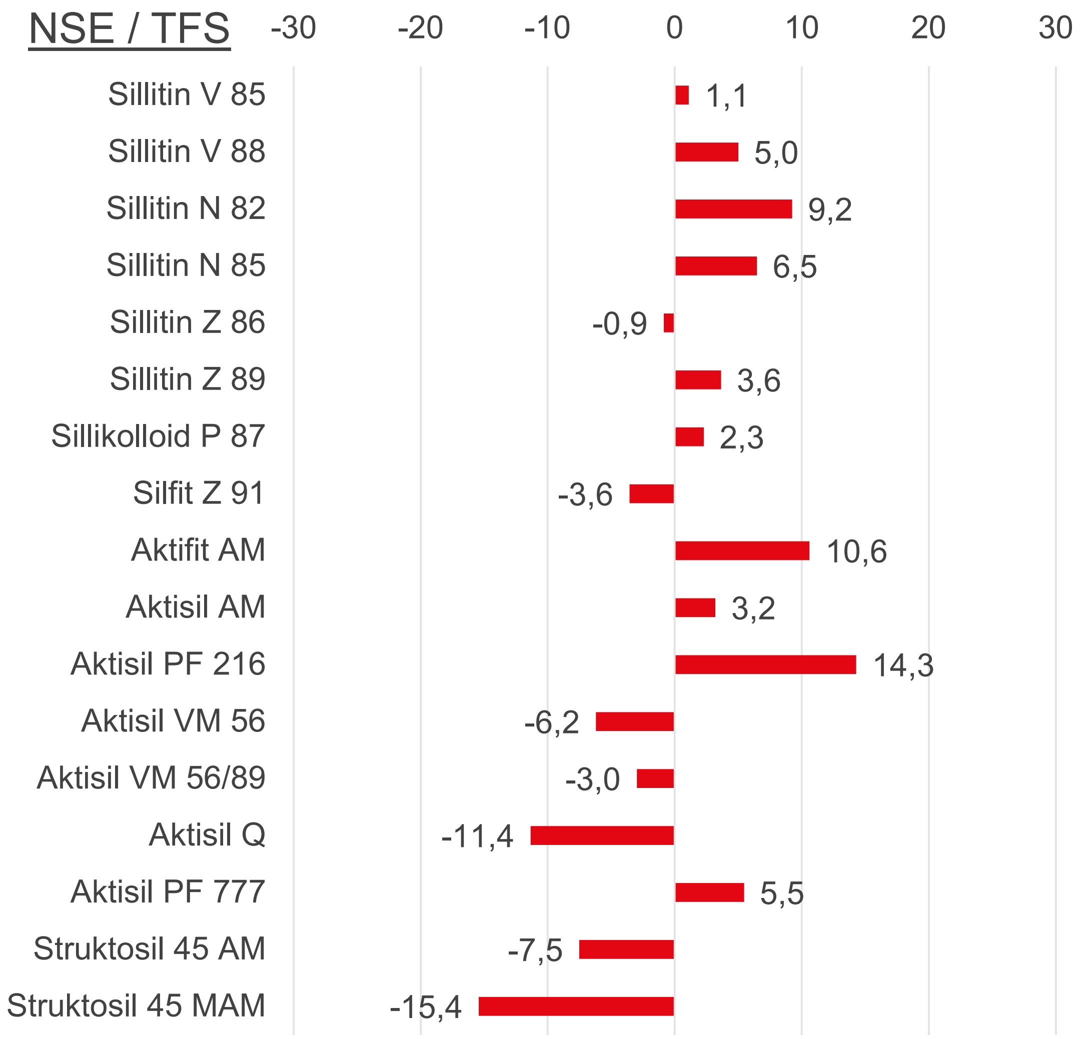
Immersion in reference oil IRM 903 168 h / 100 °C
Change of hardness in Shore A – piled up S2 dumbbells

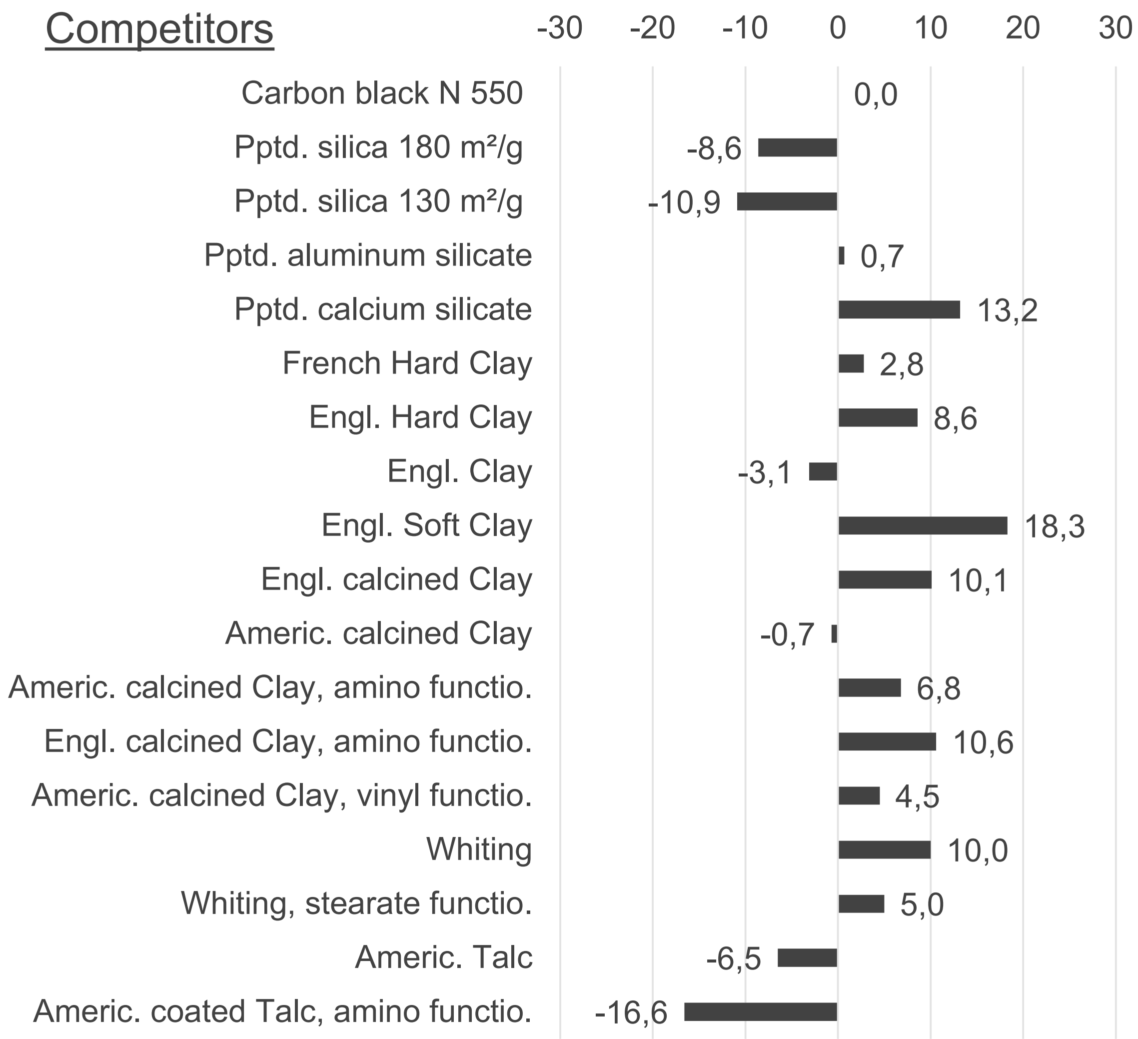




Note: Sillitin N 82 will be replaced by Sillitin N 75

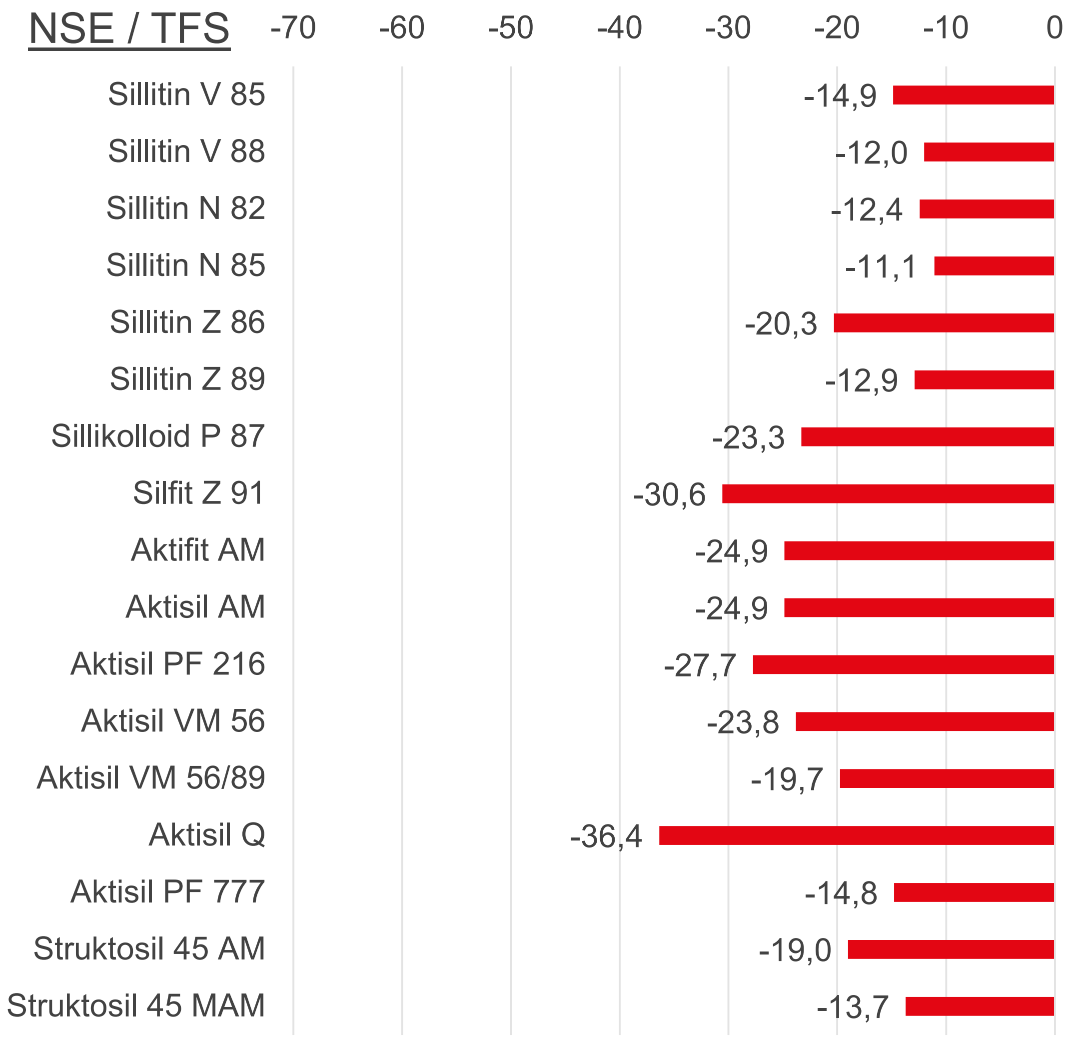
Immersion in reference oil IRM 903 168 h / 100 °C
Change of tensile strength in %

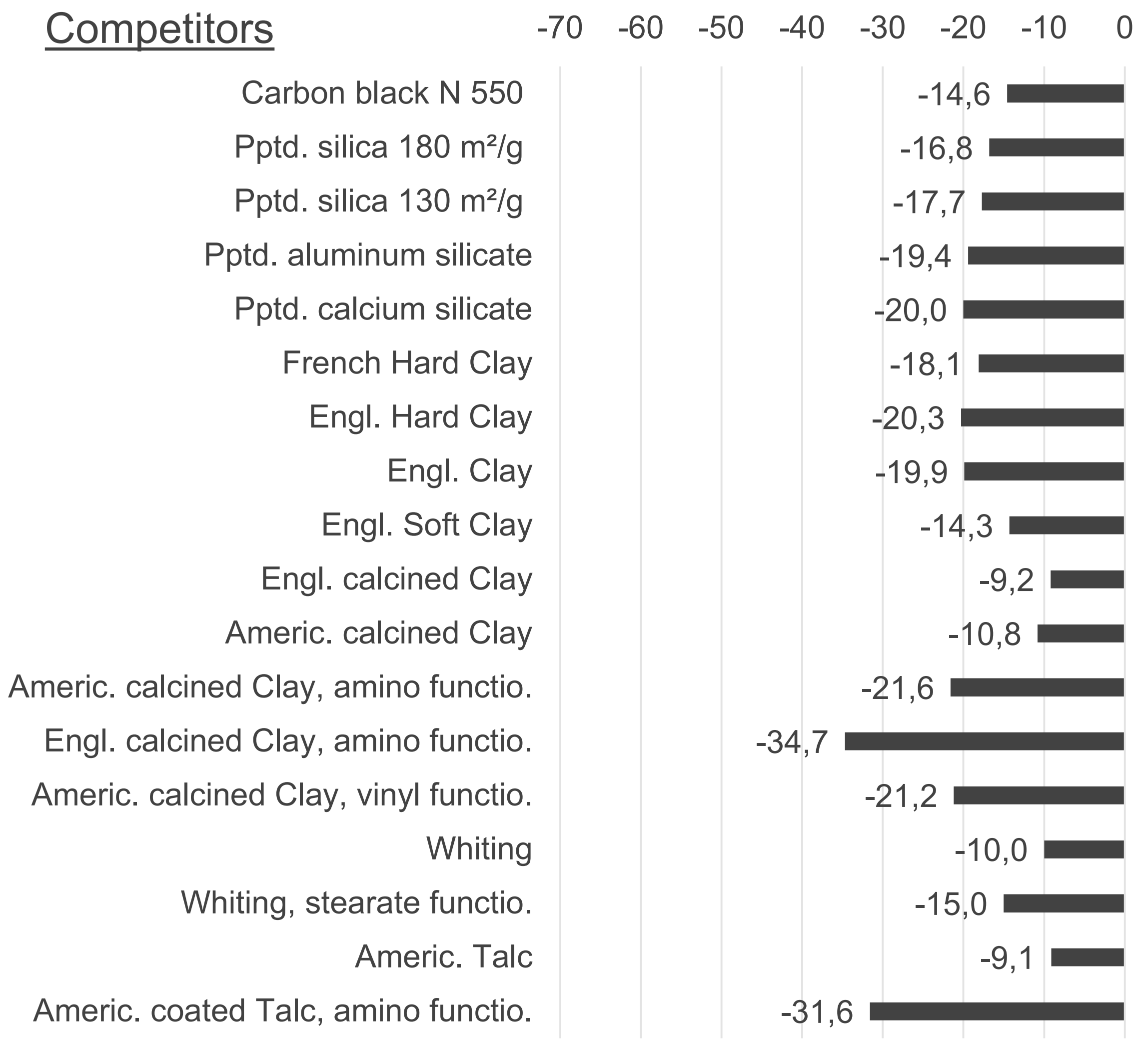




Note: Sillitin N 82 will be replaced by Sillitin N 75

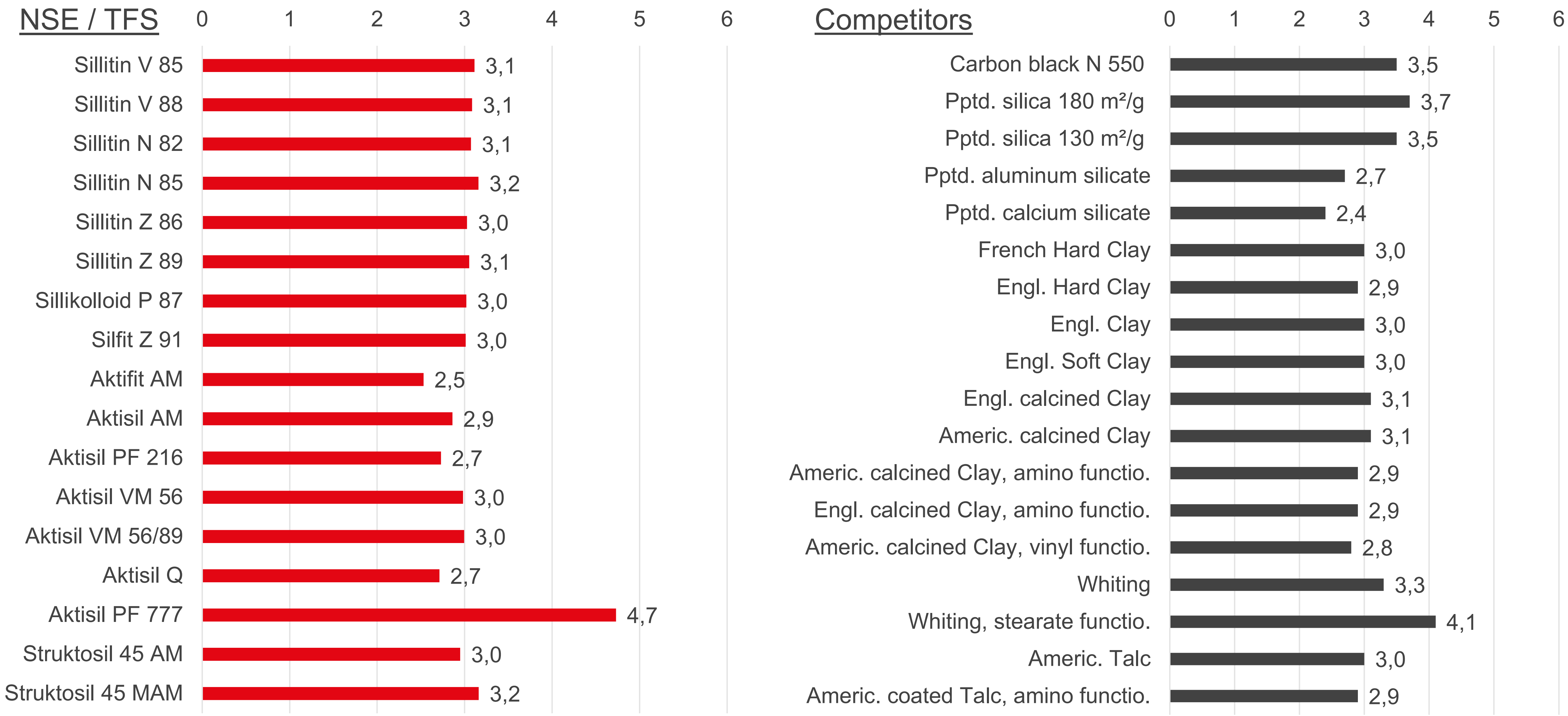
Immersion in reference oil IRM 903 168 h / 100 °C
Change of elongation at break in rel.%





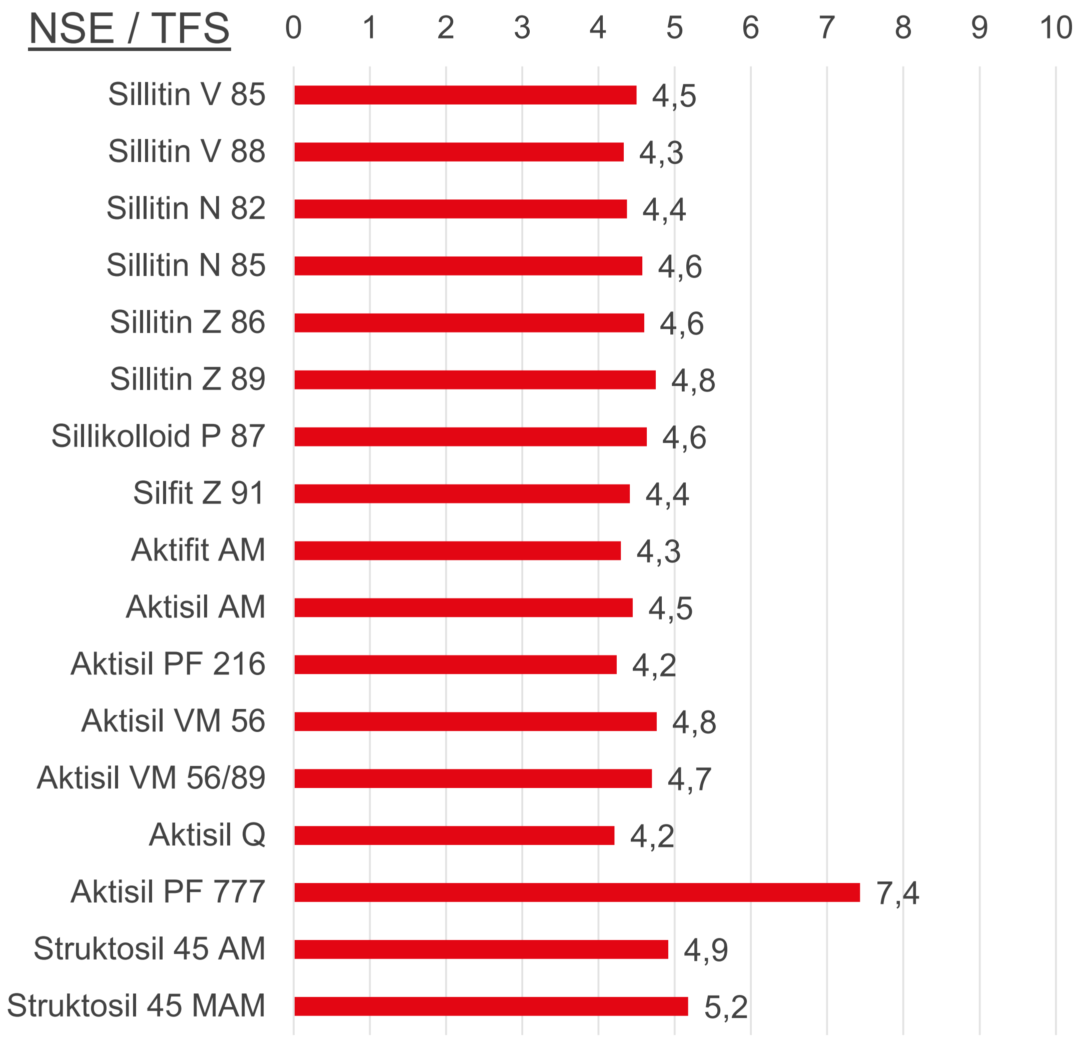
Note: Sillitin N 82 will be replaced by Sillitin N 75

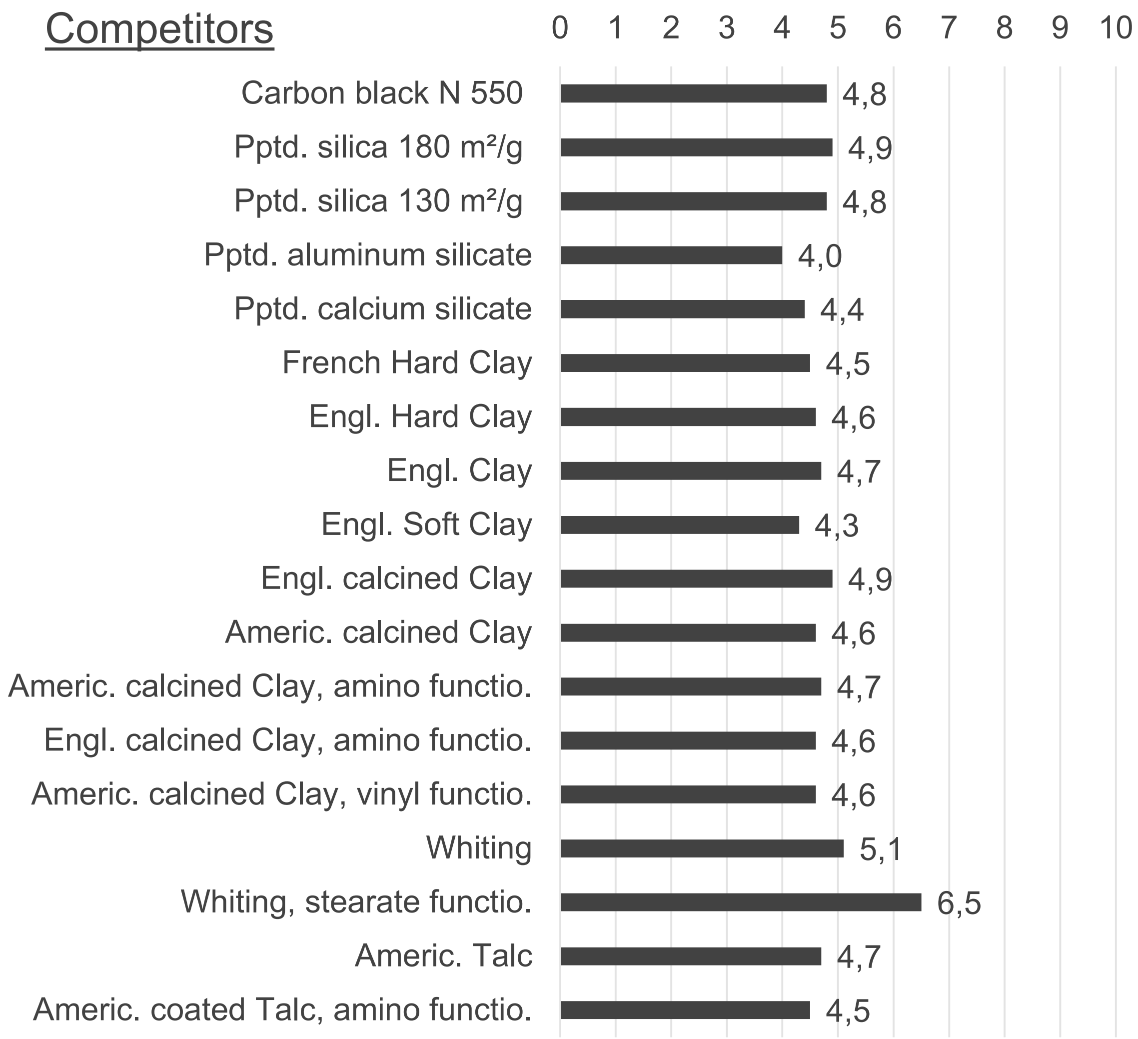
Immersion in reference oil IRM 903 168 h / 100 °C
Change of weight in %



Note: Sillitin N 82 will be replaced by Sillitin N 75

Immersion in reference oil IRM 903 168 h / 100 °C
Change of volume in %





Note: Sillitin N 82 will be replaced by Sillitin N 75

Summary: Special features …

… of the products based on Neuburg Siliceous Earth in sulphur-cured NBR rubber (Sillitin, Aktisil, Silfit, Aktifit)

Typical for NSE:

- good processing properties with medium viscosity
- good ratio of flow time and vulcanization time

Sillitin and Sillikolloid P 87:

- achieve remarkably high tensile strengths

Characteristics of Aktisil and Aktifit AM in NBR rubber:

✓ high modulus 100 % ✓ very good abrasion resistance ✓ low compression set

Immersion in deionized water 168 h / 95 °C:

- almost all NSE products lead to a good water resistance with a very small increase in weight and volume

Immersion in reference oil IRM 903 168 h / 100 °C:

- good oil resistance with almost all NSE products
- lowest weight / volume increase with tetrasulfane, amino functionalized Aktisil and amino functionalized Aktifit

Summary: Special features …

… of Tailored Filler Solutions in sulfur-cured NBR rubber (Struktosil 45 AM, Struktosil 45 MAM)

Immersion in deionised water 168 h / 95 °C:

- less water absorption compared to the american talc and american coated (amino fuctionalized) talc
- filler category: talc

Compression set:

- values of the TFS ≈ Values of the Aktisil and Aktifit
- TFS better than the American coated (amino functionalized) talc

Balance compression set – tear resistance:

- contrasting properties are best combined in Struktosil 45 AM

Filler combination 100 phr Aktisil AM / 20 phr Struktosil 45 AM (additionally tested, but not included in this presentation)**:**

- values of TFS at Aktisil AM level
- improved processing compared to a straight Struktosil 45 AM compound

We supply materials for good ideas!

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→ back to content

Results in tabular form

Properties of raw compound – Mooney Viscosity and Scorch

NSE / TFS	Mooney Viscosity ML 1+4 100 °C [MU]	Mooney Scorch ML+5 120 °C [min.]
Sillitin V 85	60	35
Sillitin V 88	59	34
Sillitin N 82	61	35
Sillitin N 85	62	36
Sillitin Z 86	63	37
Sillitin Z 89	62	35
Sillikolloid P 87	64	36
Silfit Z 91	65	34
Aktifit AM	69	10
Aktisil AM	73	10
Aktisil PF 216	64	35
Aktisil VM 56	61	34
Aktisil VM 56/89	59	32
Aktisil Q	60	29
Aktisil PF 777	59	45
Struktosil 45 AM	53	19
Struktosil 45 MAM	41	35

Competitors	Mooney Viscosity ML 1+4 100 °C [MU]	Mooney Scorch ML +5 120 °C [min.]
Carbon black N 550	64	21
Precipitated silica 180 m^2/g	81	54
Precipitated silica 130 m^2/g	72	50
Precipitated aluminum silicate	71	9,0
Precipitated calcium silicate	68	15
French Hard Clay	61	32
English Hard Clay	54	32
English Clay	57	41
English Soft Clay	52	42
English calcined Clay	66	37
American calcined Clay	67	36
American calcined Clay, amino functionalized	66	22
English calcined Clay, amino functionalized	70	14
American calcined Clay, vinyl functionalized	66	35
Whiting	48	44
Whiting, stearate functionalized	41	32
American Talc	44	36
American coated Talc, amino functionalized	53	24

Properties of raw compound – Neuburg Siliceous Earth / Tailored Filler Solutions

Rotorless curemeter 160 °C	Torque minimum [Nm]	Cross-linking yield [Nm]	Conversion time t_5 [min.]	Conversion time t_{90} [min.]	Max. speed of vulcanization [Nm/min.]	Time until max. speed of vulcanization [min.]	tan δ
Sillitin V 85	0.07	0.65	1.86	3.52	0.58	2.84	0.10
Sillitin V 88	0.07	0.62	1.80	3.32	0.56	2.74	0.09
Sillitin N 82	0.07	0.61	1.80	3.30	0.56	2.69	0.10
Sillitin N 85	0.08	0.63	1.83	3.36	0.56	2.80	0.10
Sillitin Z 86	0.08	0.58	1.79	3.28	0.54	2.80	0.10
Sillitin Z 89	0.07	0.58	1.80	3.29	0.54	2.80	0.09
Sillikolloid P 87	0.08	0.56	1.67	3.19	0.52	2.61	0.11
Silfit Z 91	0.08	0.64	1.84	3.46	0.70	2.61	0.10
Aktifit AM	0.08	0.62	0.79	2.32	0.90	1.25	0.10
Aktisil AM	0.08	0.64	0.73	2.80	0.78	1.19	0.12
Aktisil PF 216	0.07	0.55	1.90	3.18	0.70	2.87	0.10
Aktisil VM 56	0.08	0.58	1.96	3.51	0.56	3.03	0.09
Aktisil VM 56/89	0.07	0.58	1.95	3.52	0.56	3.03	0.09
Aktisil Q	0.06	0.63	1.91	4.42	0.60	3.16	0.09
Aktisil PF 777	0.07	0.53	2.08	3.73	0.47	3.07	0.10
Struktosil 45 AM	0.05	0.47	0.95	3.48	0.52	1.51	0.08
Struktosil 45 MAM	0.04	0.42	1.87	5.70	0.43	2.56	0.11

Properties of raw compound – Competitors

Rotorless curemeter 160 °C	Torque minimum [Nm]	Cross-linking yield [Nm]	Conversion time t_5 [min.]	Conversion time t_{90} [min.]	Max. speed of vulcanization [Nm/min.]	Time until max. speed of vulcanization [min.]	tan δ
Carbon black N 550	0.06	0.50	1.10	2.27	0.80	1.83	0.11
Precipitated silica 180 m^2/g	0.09	0.62	1.05	4.24	0.53	3.80	0.11
Precipitated silica 130 m^2/g	0.09	0.64	0.81	4.02	0.57	3.64	0.10
Precipitated aluminum silicate	0.08	0.73	0.64	2.67	1.14	0.81	0.14
Precipitated calcium silicate	0.06	0.69	1.01	1.81	1.27	1.39	0.12
French Hard Clay	0.06	0.40	1.21	3.08	0.38	2.43	0.14
English Hard Clay	0.05	0.44	1.66	3.29	0.45	2.63	0.12
English Clay	0.06	0.45	1.82	3.53	0.43	2.85	0.12
English Soft Clay	0.05	0.51	1.92	3.53	0.53	2.77	0.09
English calcined Clay	0.07	0.59	1.91	3.57	0.64	2.84	0.09
American calcined Clay	0.06	0.58	1.99	3.62	0.65	2.80	0.09
American calcined Clay, amino functionalized	0.06	0.54	1.22	2.58	0.66	1.96	0.10
English calcined Clay, amino functionalized	0.08	0.60	0.63	2.60	0.86	1.01	0.11
American calcined Clay, vinyl functionalized	0.06	0.61	1.90	3.68	0.76	2.78	0.08
Whiting	0.05	0.53	1.83	3.55	0.43	3.05	0.10
Whiting, stearate functionalized	0.04	0.52	1.57	5.97	0.51	2.19	0.10
American Talc	0.05	0.47	1.79	5.53	0.46	2.97	0.11
American coated Talc, amino functionalized	0.06	0.51	1.34	4.42	0.47	2.19	0.10

Properties of vulcanizate – Neuburg Siliceous Earth / Tailored Filler Solutions

	Hardness S2 specimen [Shore A]	Tensile strength [MPa]	Elongation at break [%]	Modulus 100 % [MPa]	Tear resistance Trousers specimen [N/mm]	Tear resistance Graves specimen [N/mm]	Rebound elasticity [%]	Abrasion loss 10 N [mm³]	Compression set [24 h / 70 °C / 25 % Def.] [%]
Sillitin V 85	69	9.5	643	3.0	8.4	16.3	38	221	21
Sillitin V 88	68	10.4	642	3.1	8.4	17.5	39	205	21
Sillitin N 82	69	12.2	632	3.6	10.2	19.9	39	169	23
Sillitin N 85	70	12.4	648	3.7	10.3	20.0	39	180	23
Sillitin Z 86	70	13.7	635	4.0	11.4	21.2	39	151	24
Sillitin Z 89	69	11.8	629	3.4	9.6	18.4	39	167	22
Sillikolloid P 87	70	14.6	609	4.1	12.2	24.6	38	147	25
Silfit Z 91	69	10.0	633	3.3	9.7	19.3	36	177	19
Aktifit AM	70	13.7	391	4.6	8.8	22.1	37	102	15
Aktisil AM	70	13.8	460	4.7	9.7	23.1	36	131	16
Aktisil PF 216	69	14.0	518	4.7	9.7	22.3	38	119	17
Aktisil VM 56	70	12.9	601	3.9	12.1	24.1	38	145	21
Aktisil VM 56/89	69	12.2	600	3.8	11.0	22.2	38	148	21
Aktisil Q	68	11.0	593	3.2	8.0	17.7	37	187	17
Aktisil PF 777	67	9.9	635	2.7	9.7	17.6	36	204	23
Struktosil 45 AM	72	12.1	465	7.9	19.0	37.2	32	117	16
Struktosil 45 MAM	68	13.2	568	4.2	17.8	30.6	30	126	21

Properties of vulcanizate – Competitors

	Hardness S2 specimen [Shore A]	Tensile strength [MPa]	Elongation at break [%]	Modulus 100 % [MPa]	Tear resistance Trousers specimen [N/mm]	Tear resistance Graves specimen [N/mm]	Rebound elasticity [%]	Abrasion loss 10 N [mm³]	Compression set [24 h / 70 °C / 25 % Def.] [%]
Carbon black N 550	68	20.4	396	3.8	9.7	23.6	38	57	14
Precipitated silica 180 m²/g	65	26.8	714	2.0	16.8	28.2	42	107	29
Precipitated silica 130 m²/g	65	28.8	701	2.0	16.1	30.7	42	95	25
Precipitated aluminum silicate	66	14.7	503	2.7	9.5	20.6	42	112	17
Precipitated calcium silicate	66	13.0	607	2.8	9.4	19.4	39	147	19
French Hard Clay	67	16.5	641	4.7	16.6	28.8	40	155	36
English Hard Clay	69	15.9	618	4.4	13.1	24.9	38	156	28
English Clay	69	15.1	654	5.1	13.3	28.1	39	162	30
English Soft Clay	68	10.5	648	4.1	10.7	20.9	37	225	26
English calcined Clay	66	8.7	634	3.0	6.7	15.0	39	155	19
American calcined Clay	66	9.4	663	2.9	7.2	15.5	40	178	18
American calcined Clay, amino functionalized	68	12.0	403	4.4	8.7	18.4	41	114	14
English calcined Clay, amino functionalized	68	12.3	384	5.0	8.9	23.5	39	126	15
American calcined Clay, vinyl functionalized	70	10.6	560	4.3	12.0	19.2	39	139	15
Whiting	60	5.9	640	1.7	4.5	10.7	41	175	26
Whiting, stearate functionalized	56	3.4	552	1.3	3.2	7.9	37	207	21
American Talc	69	16.8	648	4.3	13.5	28.9	32	106	27
American coated Talc, amino functionalized	70	16.9	530	7.4	12.5	32.8	34	107	20

Hot air aging 168 h / 70 °C –
Neuburg Siliceous Earth / Tailored Filler Solutions

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]
Sillitin V 85	3	0.1	-9.7	19.5
Sillitin V 88	3	3.8	-9.2	20.9
Sillitin N 82	3	2.5	-13.0	27.3
Sillitin N 85	3	1.9	-11.9	17.5
Sillitin Z 86	3	2.6	-13.6	31.8
Sillitin Z 89	4	0.9	-9.7	19.5
Sillikolloid P 87	3	15.3	-7.7	37.8
Silfit Z 91	3	0.4	-9.0	19.5
Aktifit AM	2	3.0	-18.9	20.9
Aktisil AM	2	3.2	-15.7	18.3
Aktisil PF 216	3	7.9	-19.4	27.4
Aktisil VM 56	3	-6.2	-11.7	19.0
Aktisil VM 56/89	2	-3.0	-10.5	20.1
Aktisil Q	2	-3.6	-13.2	17.5
Aktisil PF 777	3	-1.8	-11.5	24.5
Struktosil 45 AM	1	4.1	-16.3	7.2
Struktosil 45 MAM	3	12.9	-6.4	13.7

Hot air aging 168 h / 70 °C – Competitors

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]
Carbon black N 550	3	1.9	-14.1	21.7
Precipitated silica 180 m^2/g	4	10.0	-9.2	33.0
Precipitated silica 130 m^2/g	5	-0.4	-12.5	29.5
Precipitated aluminum silicate	4	7.4	-14.7	26.0
Precipitated calcium silicate	2	7.4	-10.4	26.8
French Hard Clay	4	3.9	-13.4	38.3
English Hard Clay	3	10.3	-15.5	48.6
English Clay	3	-6.3	-14.8	30.1
English Soft Clay	2	4.6	-11.7	21.5
English calcined Clay	2	-4.9	-9.9	7.8
American calcined Clay	2	-5.9	-10.2	14.3
American calcined Clay, amino functionalized	2	4.3	-16.9	18.3
English calcined Clay, amino functionalized	2	6.5	-19.6	14.3
American calcined Clay, vinyl functionalized	2	-3.6	-18.5	18.7
Whiting	3	11.0	-7.7	19.7
Whiting, stearate functionalized	2	-2.8	-14.0	16.3
American Talc	2	-13.0	-8.0	15.8
American coated Talc, amino functionalized	3	-10.8	-20.8	16.0

Hot air aging 168 h / 100 °C –
Neuburg Siliceous Earth / Tailored Filler Solutions

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]
Sillitin V 85	5	-25.7	-37.2	44.4
Sillitin V 88	4	-20.2	-31.1	39.9
Sillitin N 82	7	-20.6	-42.7	65.8
Sillitin N 85	5	-21.9	-39.4	43.0
Sillitin Z 86	4	-15.0	-39.6	66.2
Sillitin Z 89	5	-21.4	-32.6	43.4
Sillikolloid P 87	6	-9.9	-40.5	79.2
Silfit Z 91	6	-6.0	-48.2	70.4
Aktifit AM	5	18.9	-52.1	76.5
Aktisil AM	5	-2.4	-45.8	43.3
Aktisil PF 216	6	10.3	-54.2	65.3
Aktisil VM 56	5	-20.7	-43.0	51.4
Aktisil VM 56/89	5	-20.1	-36.0	45.6
Aktisil Q	5	-16.0	-40.4	47.3
Aktisil PF 777	6	-22.3	-33.1	49.4
Struktosil 45 AM	4	-13.5	-42.5	17.1
Struktosil 45 MAM	6	-20.4	-17.2	41.4

Hot air aging 168 h / 100 °C – Competitors

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]
Carbon black N 550	6	-0.9	-41.8	79.8
Precipitated silica 180 m^2/g	6	-21.9	-33.0	62.8
Precipitated silica 130 m^2/g	6	-23.2	-37.8	62.0
Precipitated aluminum silicate	7	0.7	-37.6	56.3
Precipitated calcium silicate	6	-2.5	-33.8	50.2
French Hard Clay	7	-14.6	-28.9	43.1
English Hard Clay	5	-6.3	-36.4	87.6
English Clay	6	-24.4	-47.4	62.0
English Soft Clay	6	-8.6	-41.2	48.9
English calcined Clay	5	-15.7	-31.5	38.8
American calcined Clay	6	-22.7	-29.2	42.2
American calcined Clay, amino functionalized	5	9.4	-46.0	47.7
English calcined Clay, amino functionalized	6	10.0	-45.8	56.0
American calcined Clay, vinyl functionalized	5	-0.9	-46.2	51.4
Whiting	5	-2.0	-28.5	50.8
Whiting, stearate functionalized	6	-10.3	-27.9	40.3
American Talc	6	-16.0	-19.0	38.6
American coated Talc, amino functionalized	4	-13.4	-41.6	20.6

Immersion in deionized water 168 h / 95 °C – Neuburg Siliceous Earth / Tailored Filler Solutions

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of weight [%]	Change of volume [%]
Sillitin V 85	-2	-13.1	-9.6	1.9	2.6
Sillitin V 88	-2	-17.0	-10.8	1.7	2.4
Sillitin N 82	-2	-10.9	-11.1	2.0	2.8
Sillitin N 85	-2	-12.1	-9.1	2.0	2.6
Sillitin Z 86	-4	-12.2	-10.0	2.2	3.5
Sillitin Z 89	-2	-11.5	-11.3	2.0	3.0
Sillikolloid P 87	-3	-7.6	-7.2	2.4	3.6
Silfit Z 91	-1	-8.9	-14.1	1.8	2.5
Aktifit AM	-1	-3.8	-24.7	0.9	2.0
Aktisil AM	-1	-8.8	-21.8	2.1	3.8
Aktisil PF 216	1	5.6	-33.2	1.7	3.3
Aktisil VM 56	-2	-11.0	-7.6	2.0	3.7
Aktisil VM 56/89	-2	0.0	-4.9	2.0	3.7
Aktisil Q	1	-16.6	-25.2	1.6	2.8
Aktisil PF 777	-5	-14.0	-7.2	2.0	3.4
Struktosil 45 AM	1	-15.0	-23.1	1.3	2.3
Struktosil 45 MAM	1	-16.4	-9.7	1.8	2.9

Immersion in deionized water 168 h / 95 °C – Competitors

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of weight [%]	Change of volume [%]
Carbon black N 550	1	-4.2	-22.7	2.5	3.1
Precipitated silica 180 m^2/g	-3	-33.1	-13.5	7.3	8.6
Precipitated silica 130 m^2/g	-4	-20.6	-10.2	6.6	7.8
Precipitated aluminum silicate	-3	-5.4	-1.1	11.3	15.2
Precipitated calcium silicate	-5	0.8	-2.1	12.7	15.2
French Hard Clay	-4	-27.0	-1.8	2.3	3.8
English Hard Clay	-13	-48.6	-5.5	7.0	10.7
English Clay	-5	-6.9	-6.1	2.9	4.8
English Soft Clay	-5	-2.8	-5.9	2.7	4.0
English calcined Clay	-1	-17.4	-13.1	1.6	2.2
American calcined Clay	-1	-27.7	-16.5	1.4	2.2
American calcined Clay, amino functionalized	1	-2.6	-22.2	0.8	1.3
English calcined Clay, amino functionalized	4	0.8	-27.4	1.2	1.6
American calcined Clay, vinyl functionalized	0	-1.8	-15.0	1.0	1.8
Whiting	0	-3.2	-9.5	1.5	2.6
Whiting, stearate functionalized	-3	-22.5	-14.5	1.6	2.8
American Talc	-6	-11.2	-3.4	4.9	7.6
American coated Talc, amino functionalized	-1	-13.4	-17.7	4.5	7.1

Immersion in reference oil IRM 903 168 h / 100 °C – Neuburg Siliceous Earth / Tailored Filler Solutions

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of weight [%]	Change of volume [%]
Sillitin V 85	-2	1.1	-14.9	3.1	4.5
Sillitin V 88	-2	5.0	-12.0	3.1	4.3
Sillitin N 82	-1	9.2	-12.4	3.1	4.4
Sillitin N 85	-1	6.5	-11.1	3.2	4.6
Sillitin Z 86	-1	-0.9	-20.3	3.0	4.6
Sillitin Z 89	-2	3.6	-12.9	3.1	4.8
Sillikolloid P 87	-1	2.3	-23.3	3.0	4.6
Silfit Z 91	0	-3.6	-30.6	3.0	4.4
Aktifit AM	-1	10.6	-24.9	2.5	4.3
Aktisil AM	-1	3.2	-24.9	2.9	4.5
Aktisil PF 216	0	14.3	-27.7	2.7	4.2
Aktisil VM 56	-2	-6.2	-23.8	3.0	4.8
Aktisil VM 56/89	-1	-3.0	-19.7	3.0	4.7
Aktisil Q	1	-11.4	-36.4	2.7	4.2
Aktisil PF 777	-7	5.5	-14.8	4.7	7.4
Struktosil 45 AM	1	-7.5	-19.0	3.0	4.9
Struktosil 45 MAM	-1	-15.4	-13.7	3.2	5.2

Immersion in reference oil IRM 903 168 h / 100 °C – Competitors

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of weight [%]	Change of volume [%]
Carbon black N 550	0	0.0	-14.6	3.5	4.8
Precipitated silica 180 m^2/g	0	-8.6	-16.8	3.7	4.9
Precipitated silica 130 m^2/g	-1	-10.9	-17.7	3.5	4.8
Precipitated aluminum silicate	-1	0.7	-19.4	2.7	4.0
Precipitated calcium silicate	-1	13.2	-20.0	2.4	4.4
French Hard Clay	1	2.8	-18.1	3.0	4.5
English Hard Clay	0	8.6	-20.3	2.9	4.6
English Clay	1	-3.1	-19.9	3.0	4.7
English Soft Clay	0	18.3	-14.3	3.0	4.3
English calcined Clay	-3	10.1	-9.2	3.1	4.9
American calcined Clay	-2	-0.7	-10.8	3.1	4.6
American calcined Clay, amino functionalized	0	6.8	-21.6	2.9	4.7
English calcined Clay, amino functionalized	0	10.6	-34.7	2.9	4.6
American calcined Clay, vinyl functionalized	-1	4.5	-21.2	2.8	4.6
Whiting	-3	10.0	-10.0	3.3	5.1
Whiting, stearate functionalized	-8	5.0	-15.0	4.1	6.5
American Talc	-2	-6.5	-9.1	3.0	4.7
American coated Talc, amino functionalized	-3	-16.6	-31.6	2.9	4.5