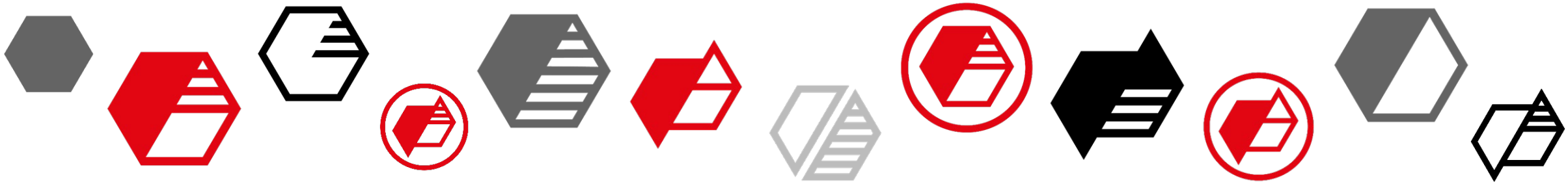


Filler comparison

Non black fillers in peroxide cross-linked HNBR rubber

Author: Meier Julia

HOFFMANN MINERAL®
We supply materials for good ideas

Contents

Status Quo

A hardness of approx. 70 Shore A was targeted.

The formula has been adapted to the latest conditions. The formulation was created using up-to-date raw materials without critical ingredients.

The adjustments were also aimed at improving the high-temperature resistance of the formulation.

Experimental

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

Formulation

Ingredients	Description	phr
Therban 3407	Hydrogenated acrylonitrile-butadiene rubber Acrylonitrile content: approx. 34 % ML 1+4 (100 °C): 70 ME	100
Zinkoxyd aktiv	Zinc oxide active	3
Maglite DE	Magnesium oxide	3
Filler	*Please see slides „Fillers“*	variable 100 / 70 / 60 / 50 / 40 / 35
Alcanplast TOTM	Trioctyl trimellitate, plasticizer	10
Luvomaxx CDPA	4,4’-Bis-(1,1-dimethylbenzyl)-diphenylamine, antioxidant	1.6
Rhenofit TRIM/S	Trimethylolpropane trimethacrylate (70 %), activator	2.5
Perkadox 14/40 B pd s	Di(tert-butylperoxyisopropyl)benzene (40 %), peroxide	8
Silquest RC1	Liquid organosilane	0 / 1 *(please see slides „Fillers“)*
Total:		**max. 229.1 / min. 164.1**

Fillers – Neuburg Siliceous Earth (NSE)

	phr	Silane addition (1 phr)
Sillitin V 85	100	✓
Sillitin V 88	100	✓
Sillitin N 75 *	100	✓
Sillitin N 85	100	✓
Sillitin Z 86	100	✓
Sillitin Z 89	100	✓
Sillikolloid P 87	100	✓

***Sillitin N 82 was replaced by Sillitin N 75**

	Basic material	Calcination	Functionalization	phr	Silane addition (1 phr)
Aktisil AM	Sillitin Z 86	-	Amino	100	-
Aktisil VM 56	Sillitin Z 86	-	Vinyl	100	-
Aktisil VM 56/89	Sillitin Z 89	-	Vinyl	100	-
Aktisil MAM-R	Sillitin V 85	-	Methacryl	100	-
Aktisil Q	Sillitin V 90 *interne Produktqualität	-	Methacryl	100	-
Aktisil PF 777	Sillitin Z 86	-	Alkyl	100	-

Fillers – Competitors

	Calcination	Functionalization	phr	Silane addition (1 phr)
Carbon Black N 550/30 (50 phr)	-	-	50	-
Carbon Black N 990 (100 phr)	-	-	100	-
pptd. silica 180 m²/g (35 phr)*	-	-	35	✓
pptd. silica 130 m²/g (40 phr)*	-	-	40	✓
pptd. aluminum silicate (60 phr)*	-	-	60	✓
pptd calcium silicate (70 phr)*	-	-	70	✓
pptd. sodium aluminum silicate (60 phr)*	-	-	60	✓
engl. Clay*	-	-	100	✓
engl. calcined Clay*	✓	-	100	✓
americ. calcined Clay*	✓	-	100	✓
americ. calcined Clay, amino functionalized	✓	Amino	100	-
americ. calcined Clay, vinyl functionalized (T)	✓	Vinyl	100	-
engl. calcined Clay, vinyl functionalized	✓	Vinyl	100	-
americ. calcined Clay, vinyl functionalized (B)	✓	Vinyl	100	-
americ. Talc*	-	-	100	✓
americ. coated Talc, amino functionalized	-	Amino	100	-

Compounding and vulcanization

Compounding	
Open mill	Ø 150 x 300 mm
Batch size	approx. 650 ml (730 – 900 g)
Mill temperature	40 °C
Mixing time	approx. 15 - 35 min.

Vulcanization	
The curing was carried out in a press at 180 °C	
Curing time	5 min. or t_{90}+10 %
Test specimen post cured 4 h at 150 °C after vulcanization	

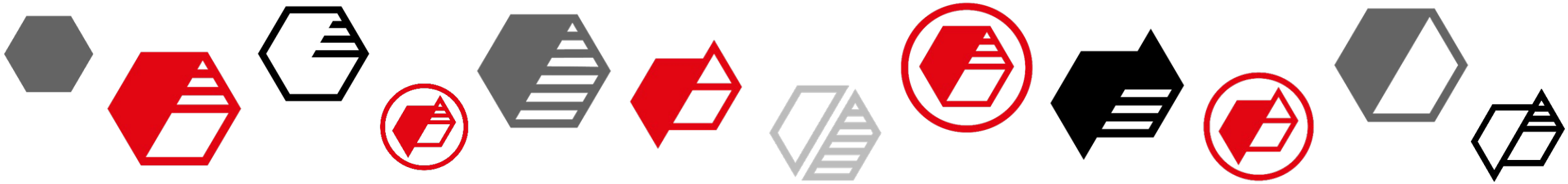
Test standards – overview

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, Type 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 „Contents”

- Properties of raw compound
- Properties of vulcanizate (test specimen non post cured)
- Properties of vulcanizate (test specimen post cured: 4 h / 150 °C)
- Hot air aging 168 h / 150 °C
- Hot air aging 504 h / 150 °C
- Immersion in reference oil IRM 903 168 h / 150 °C



→ back to „Results“

Properties of raw compound

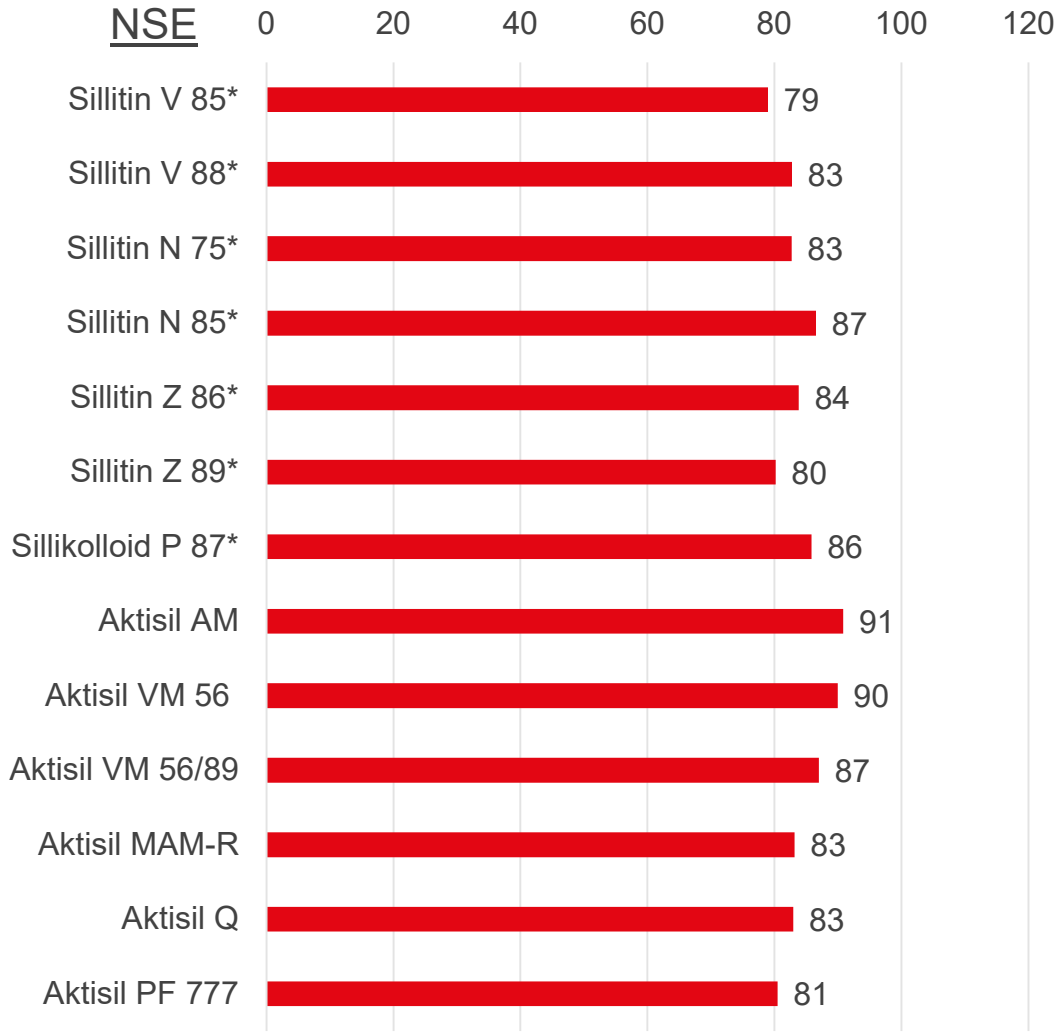
DIN ISO 289-1
DIN ISO 289-2
DIN 53 529, part 1 – 4

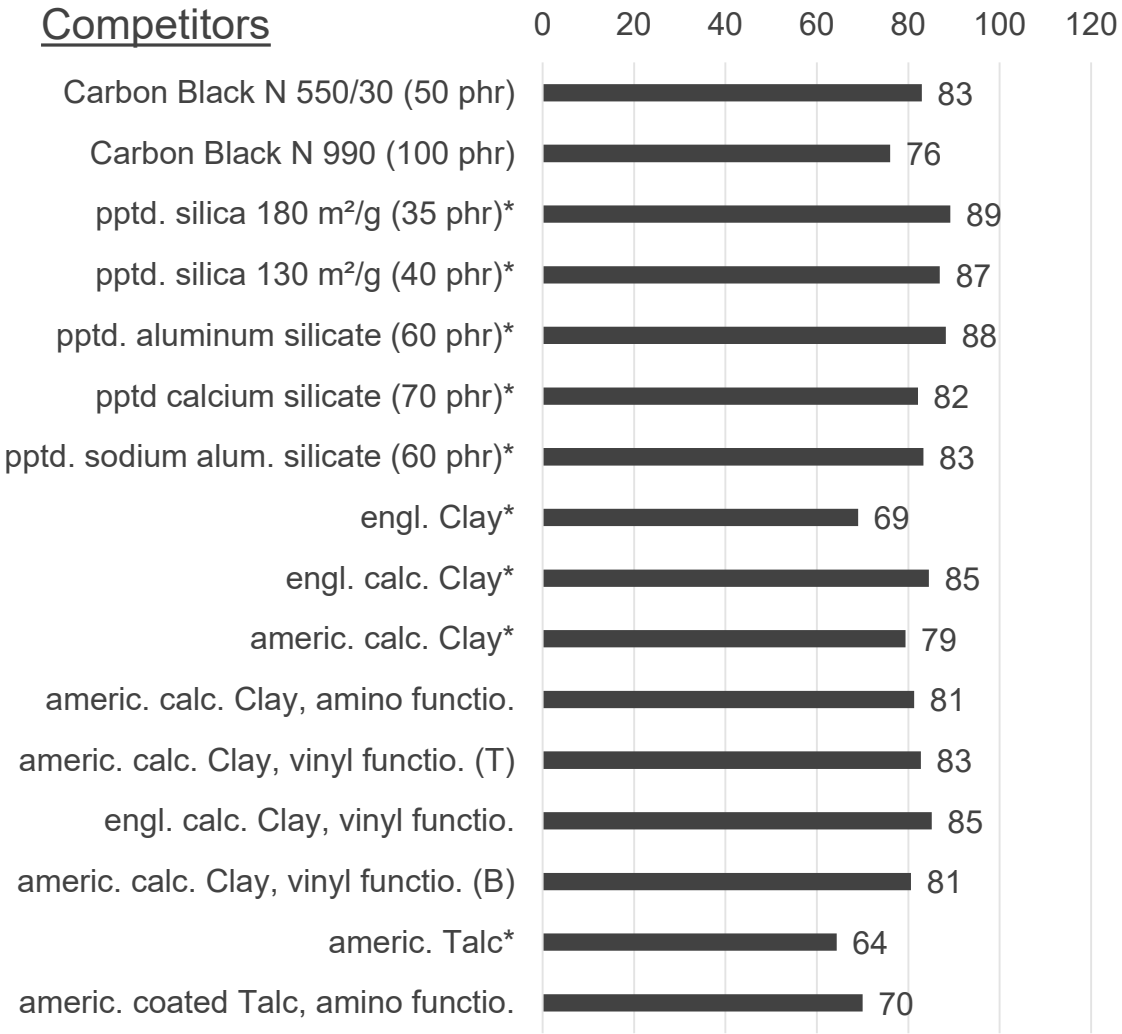
HOFFMANN MINERAL®
We supply materials for good ideas

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

DIN ISO 289-1

* with silane addition

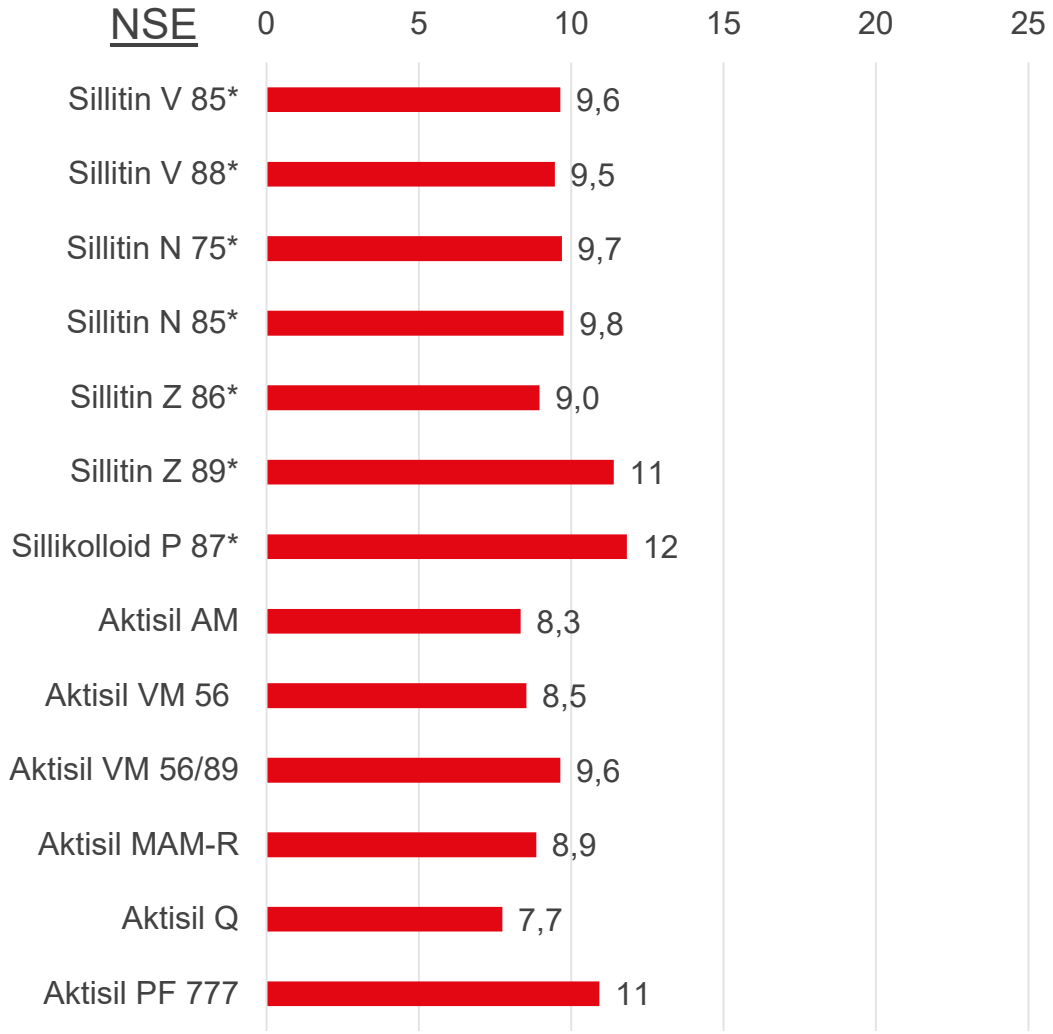


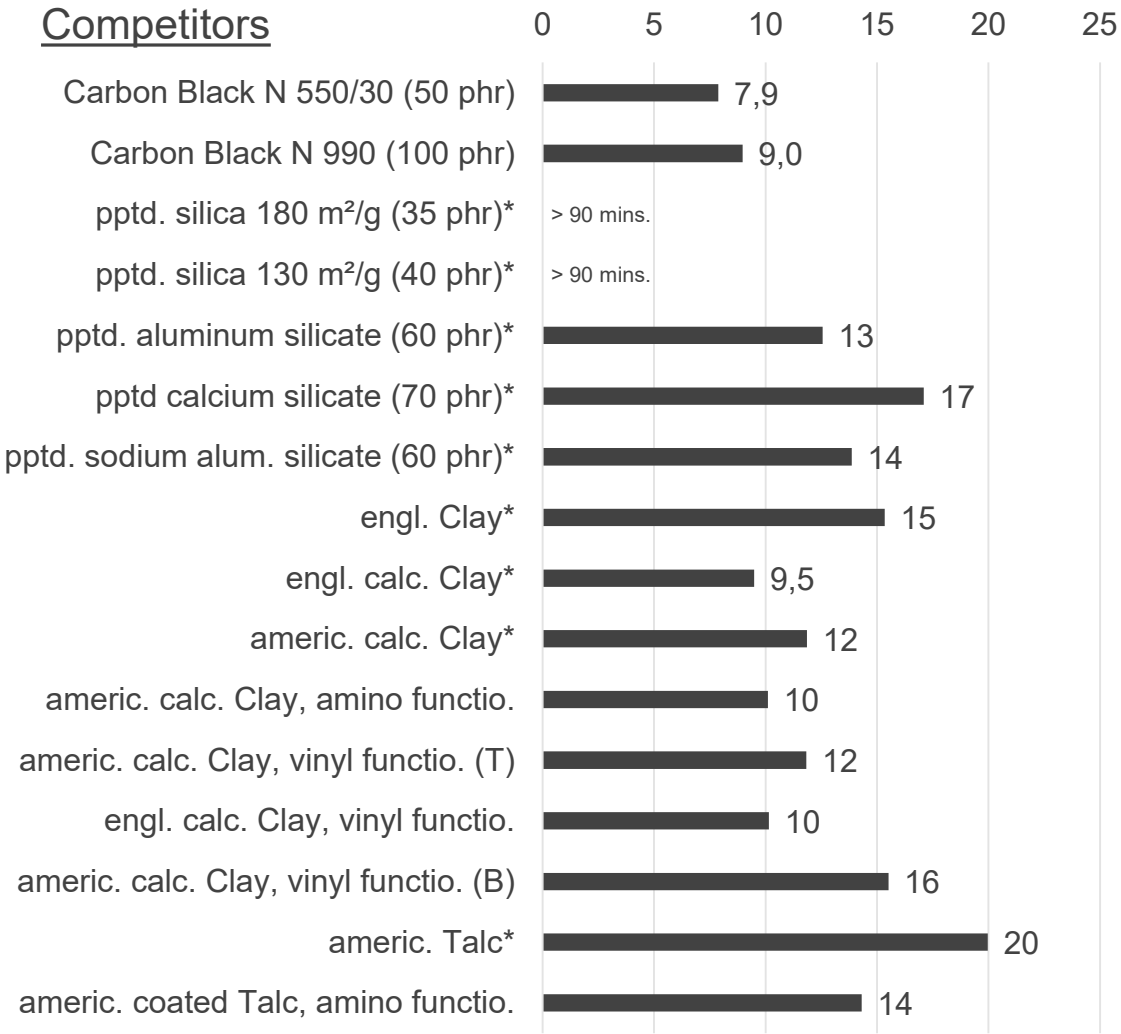


Mooney Scorch ML +5 (120 °C) in mins.

DIN ISO 289-2

* with silane addition

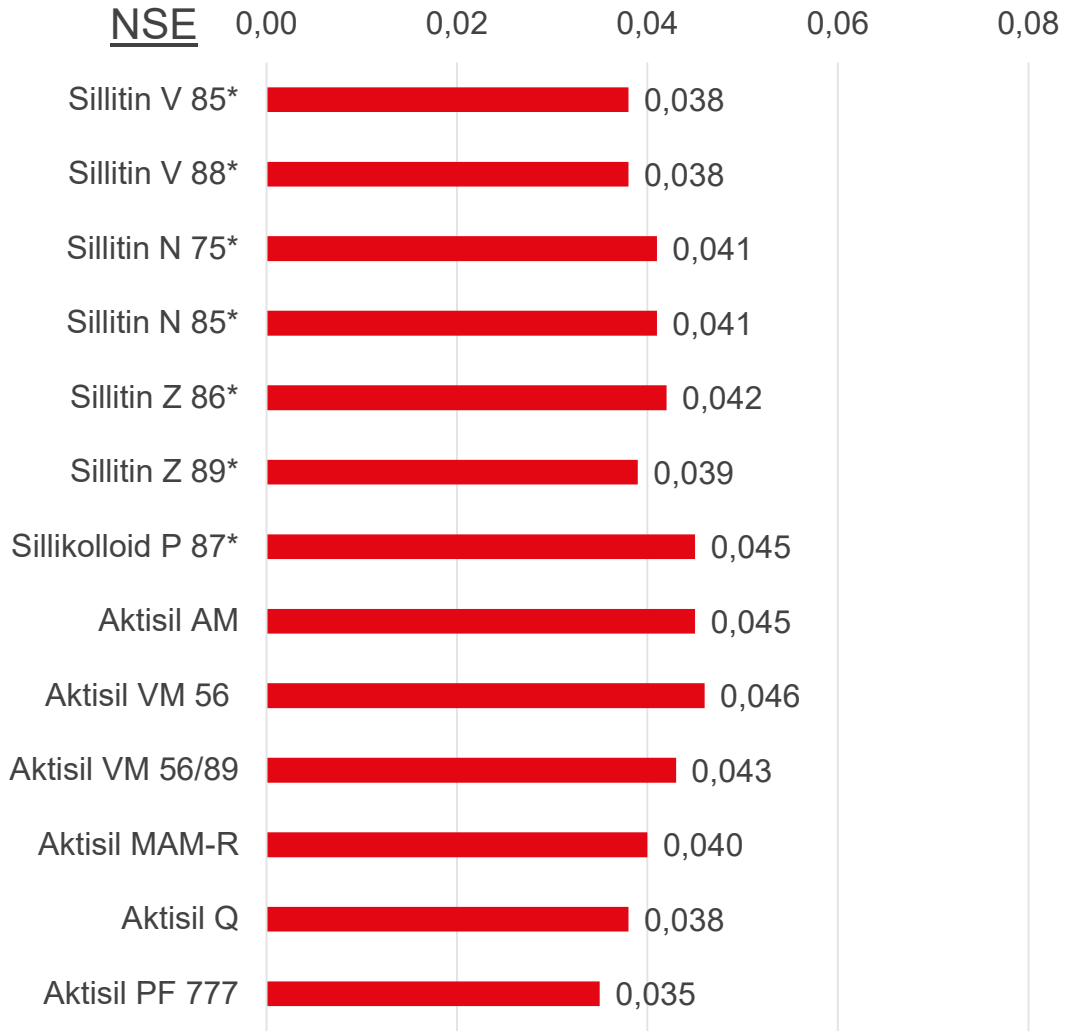


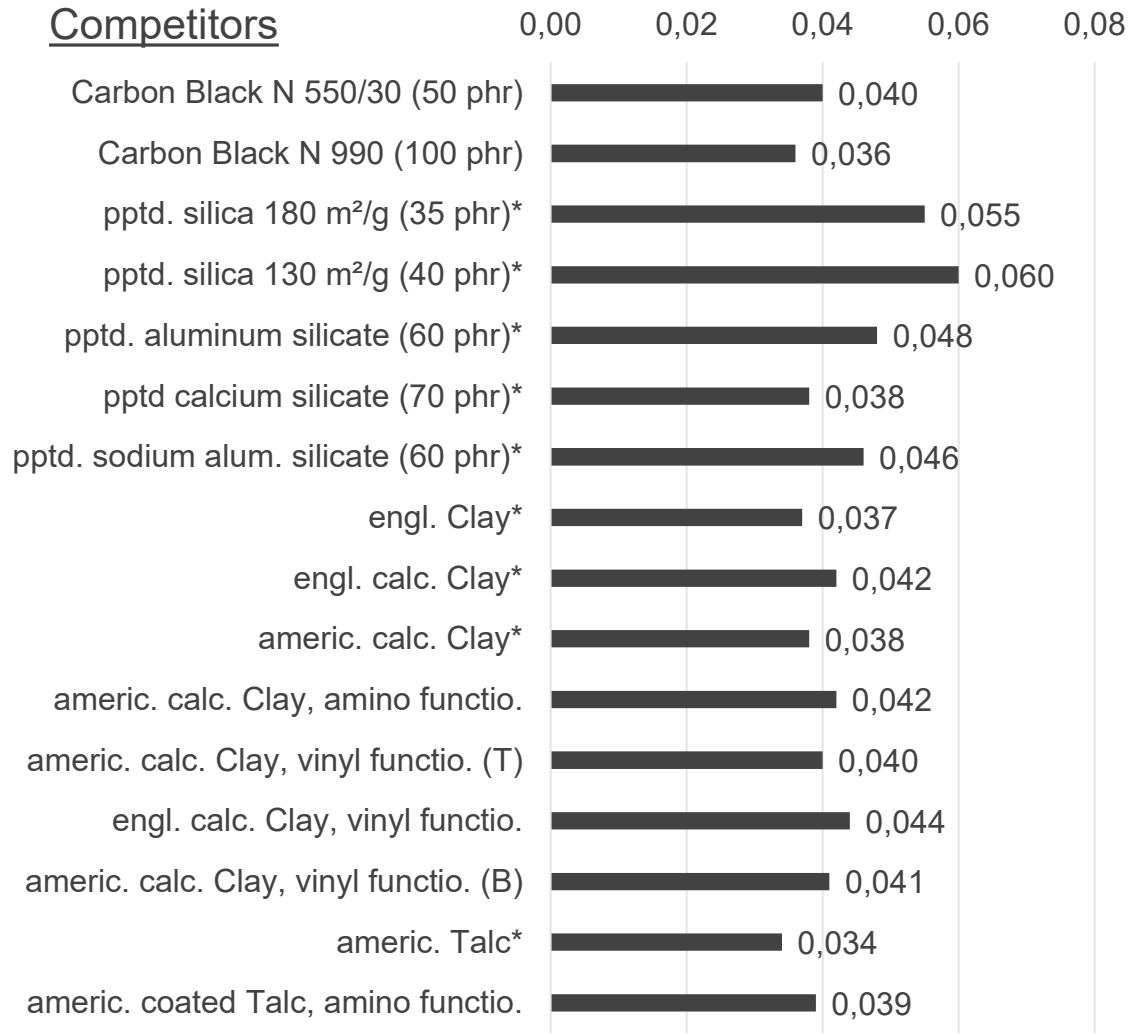


Remark: rapid and slight increase in viscosity at the beginning, up to 15 MU between minute 5 and minute 25 of the measuring time. The curve then flattens out sharply and remains largely constant until the end of the 90-minutes measurement period. Mooney Scorch ML +35 is not achieved with any compound.

Rotorless curemeter, 180 °C
Torque minimum in Nm

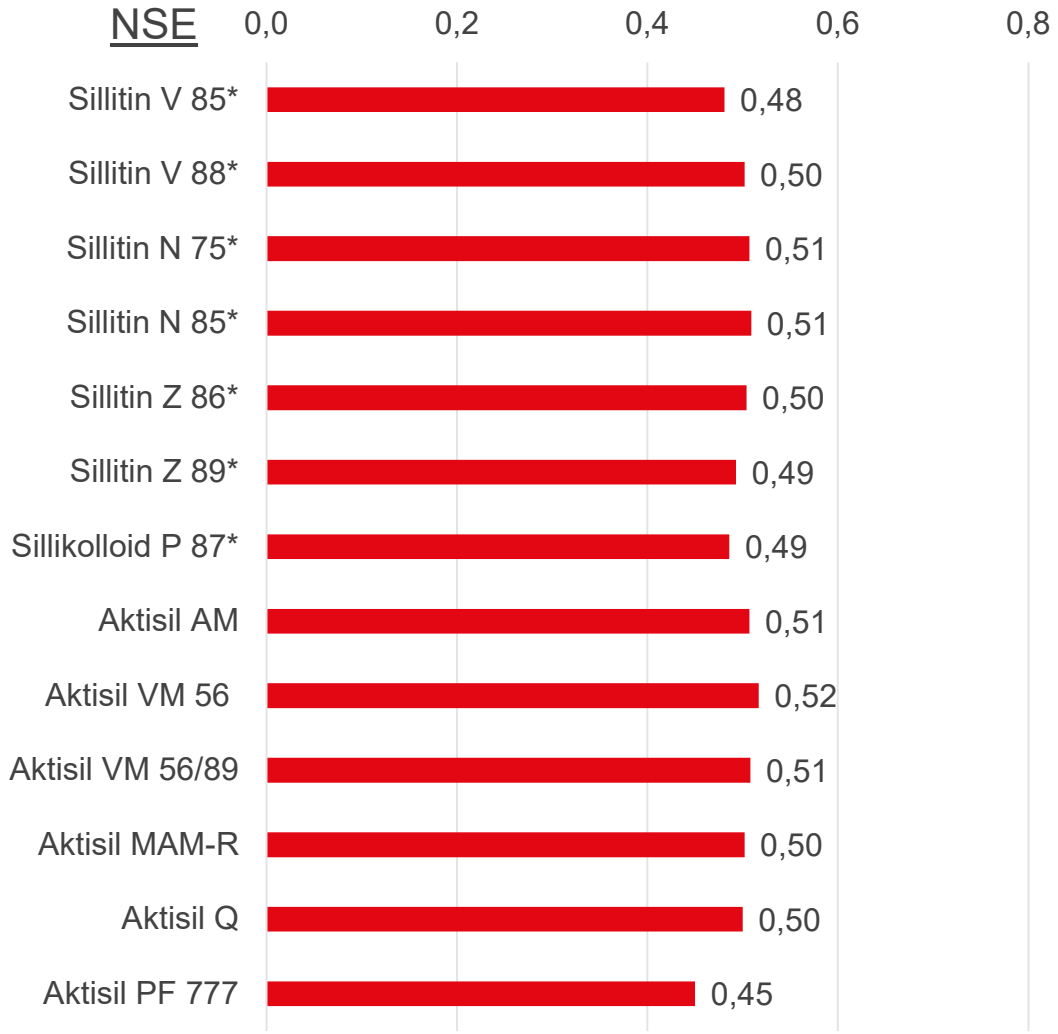
* with silane addition

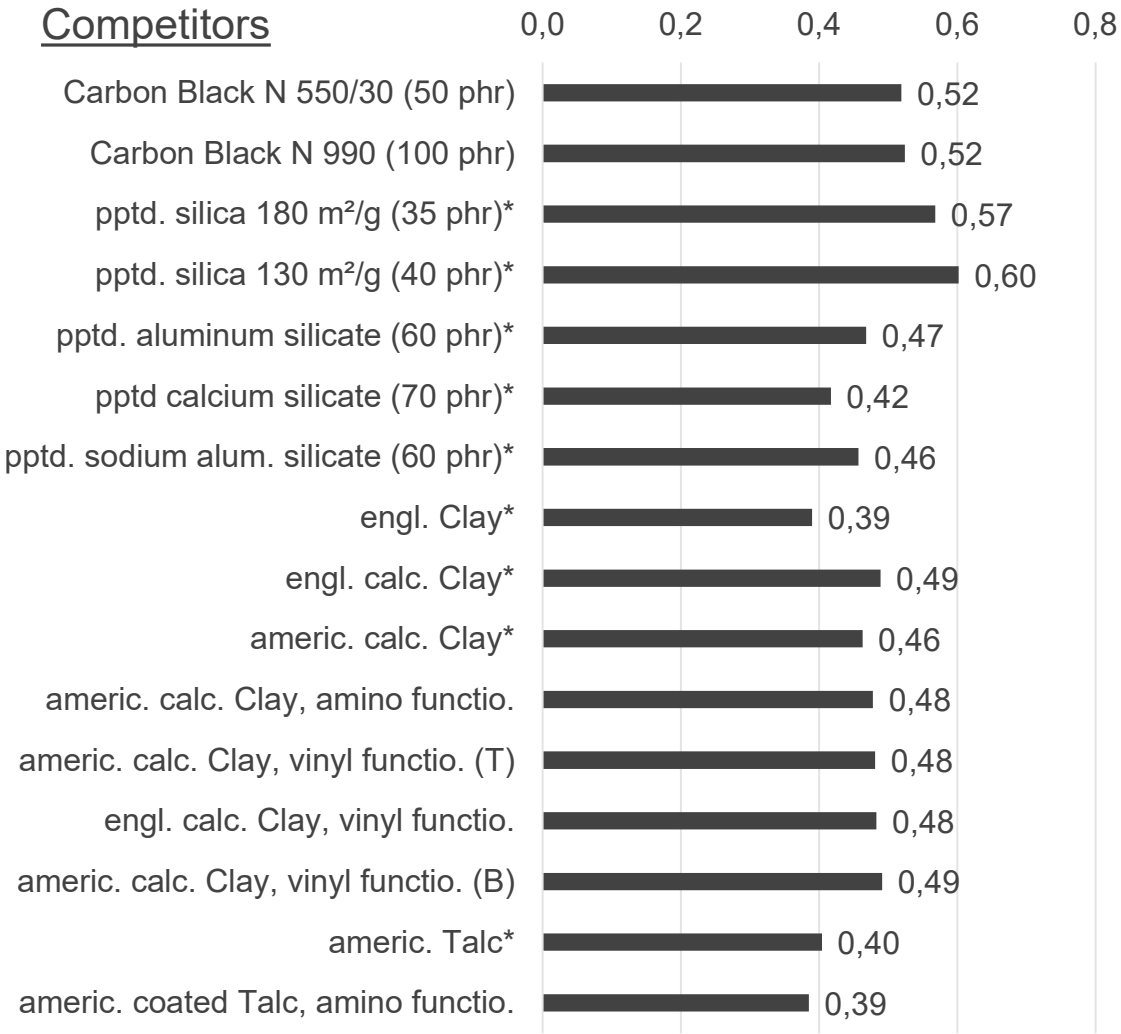




Rotorless curemeter, 180 °C
Cure yield in Nm

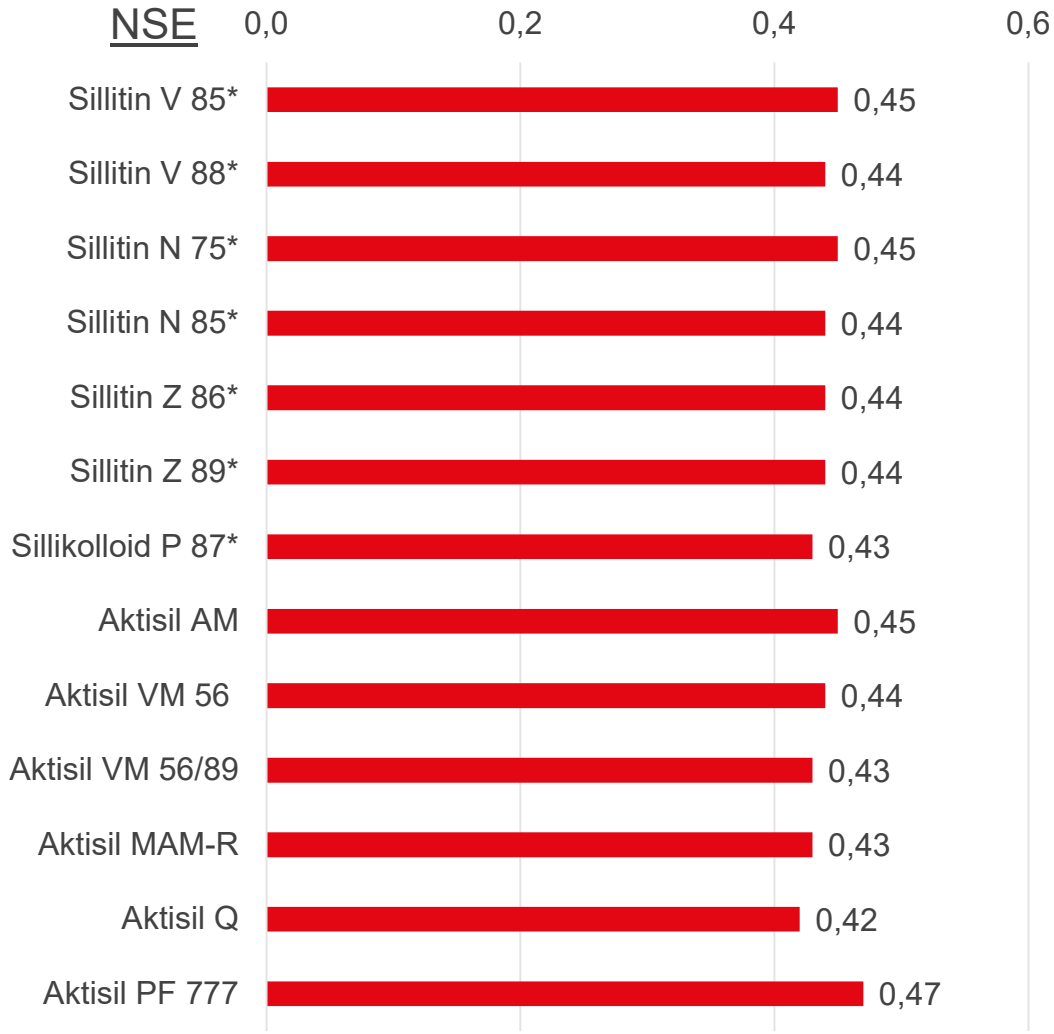
* with silane addition

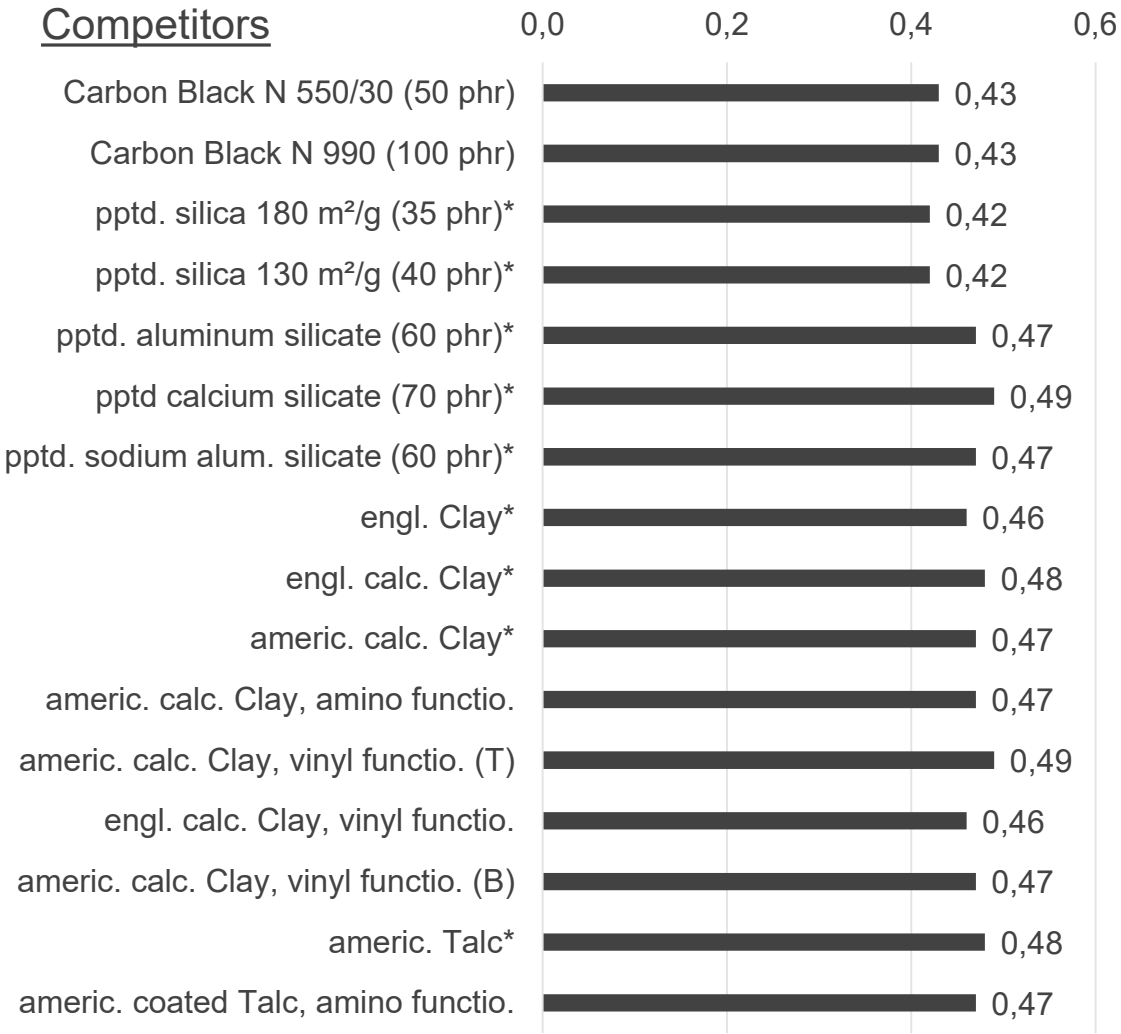




Rotorless curemeter, 180 °C
Conversion time t_5 in min.

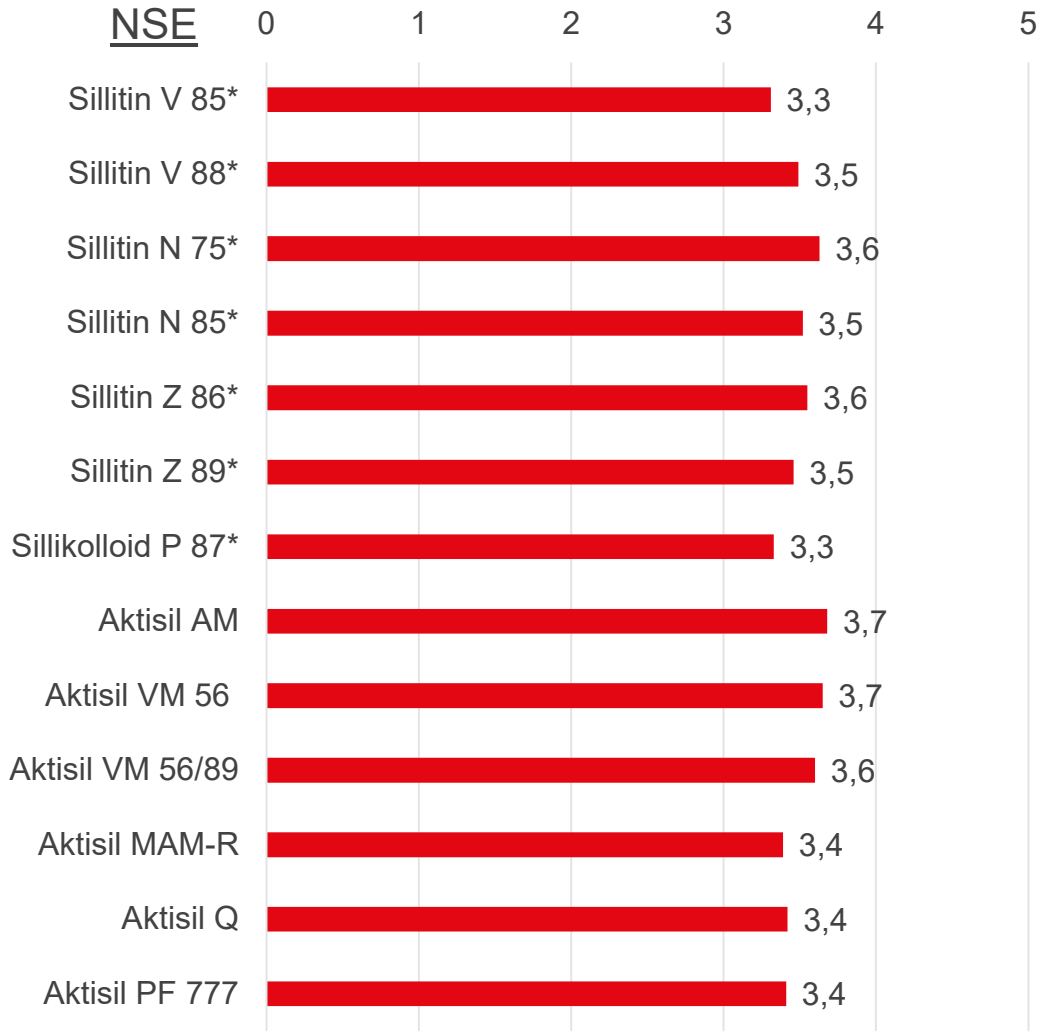
* with silane addition

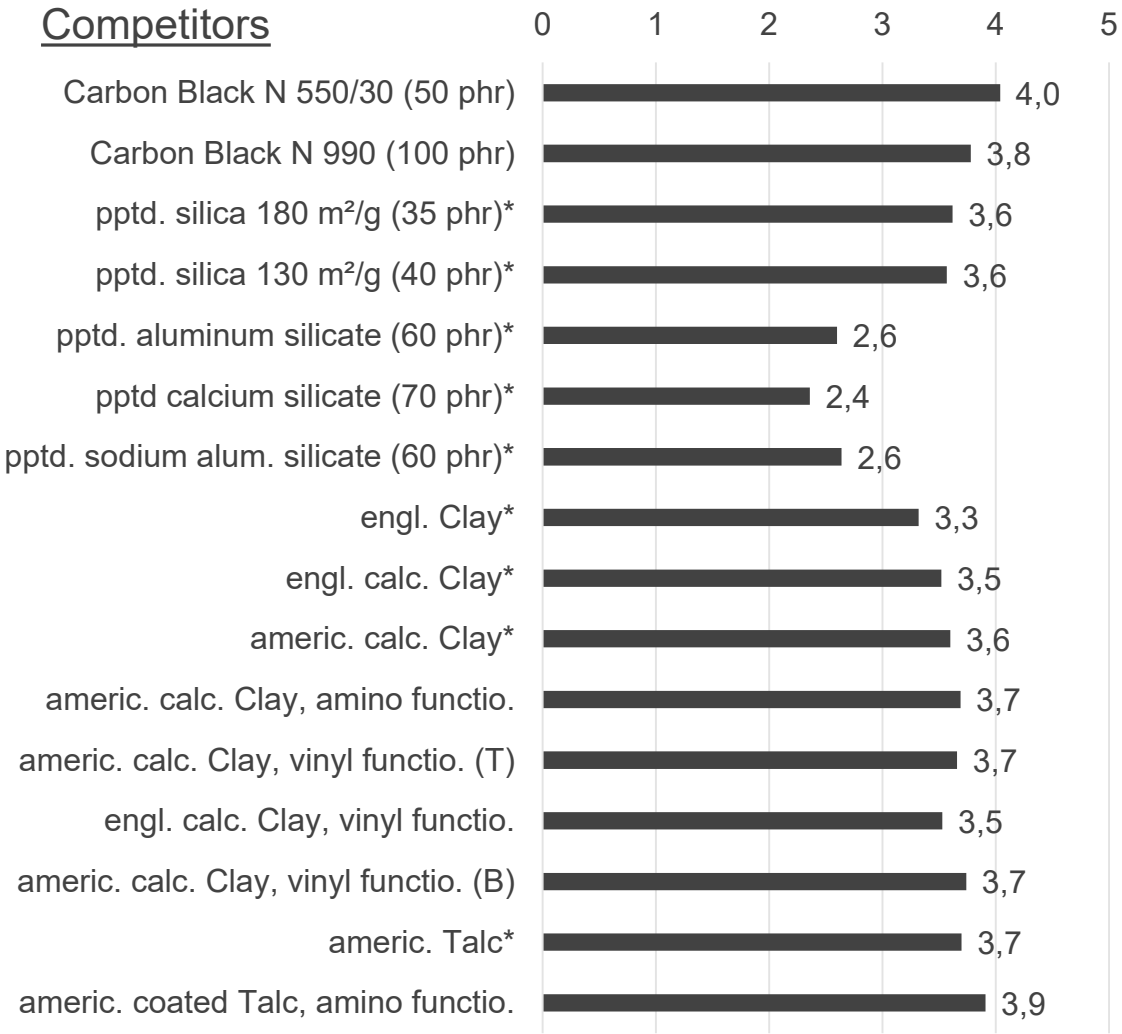




Rotorless curemeter, 180 °C
Conversion time t_{90} in min.

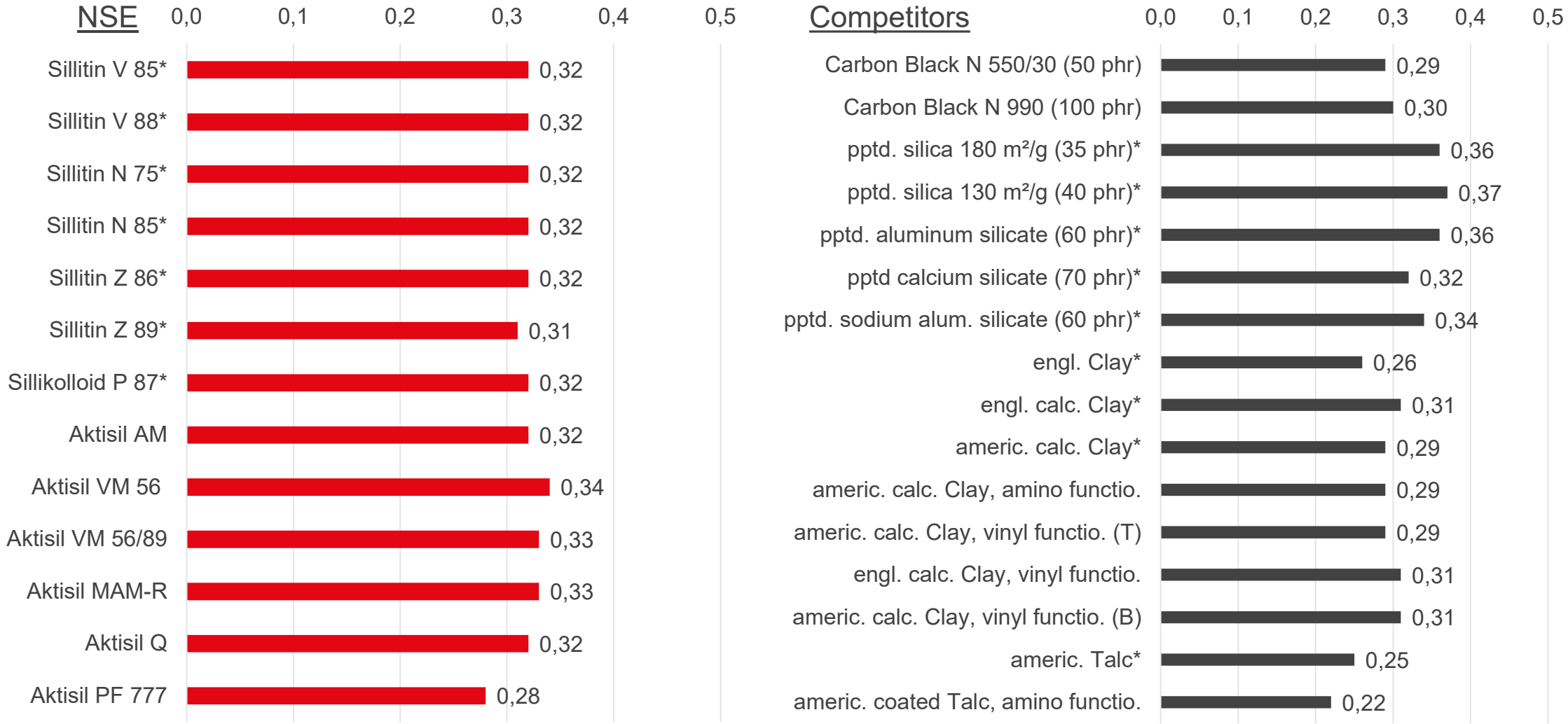
* with silane addition





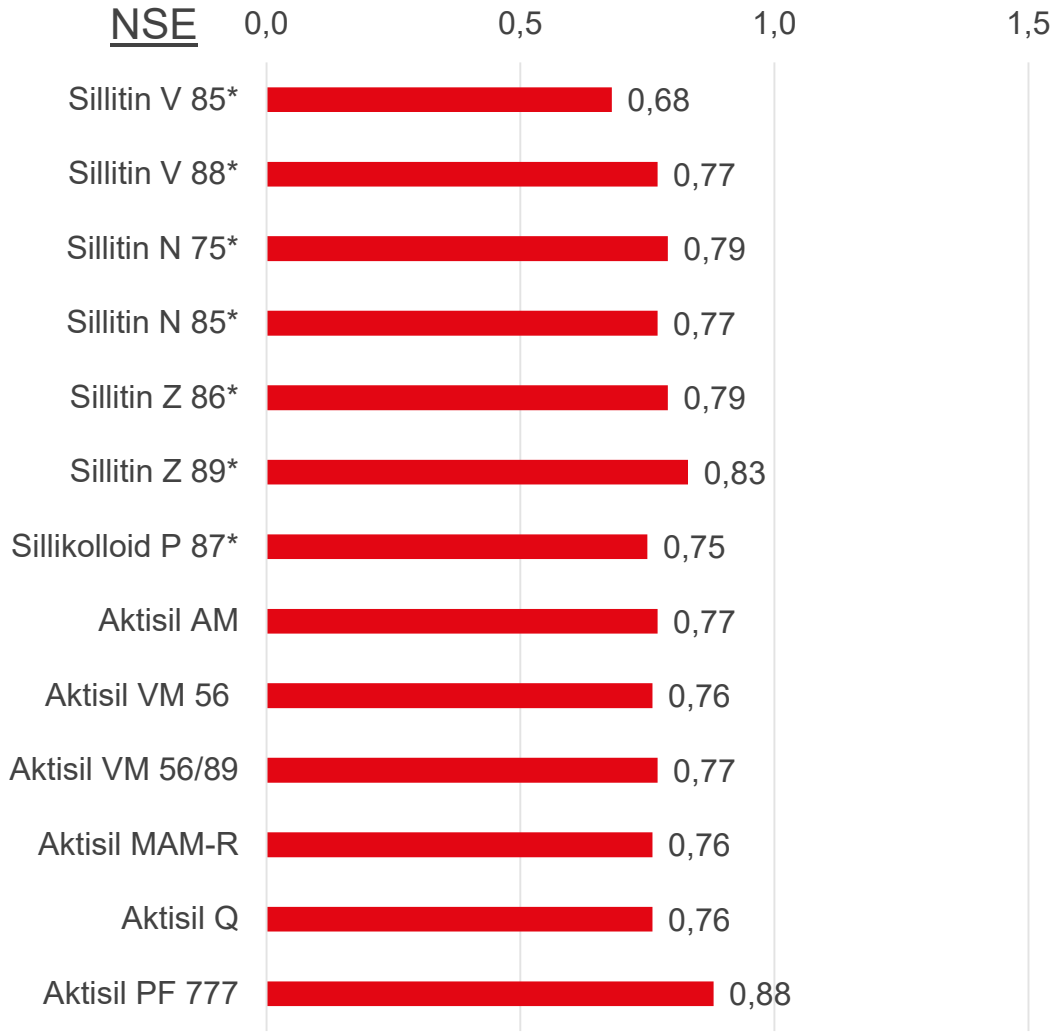
Rotorless curemeter, 180 °C
Max. speed of cure in Nm/min.

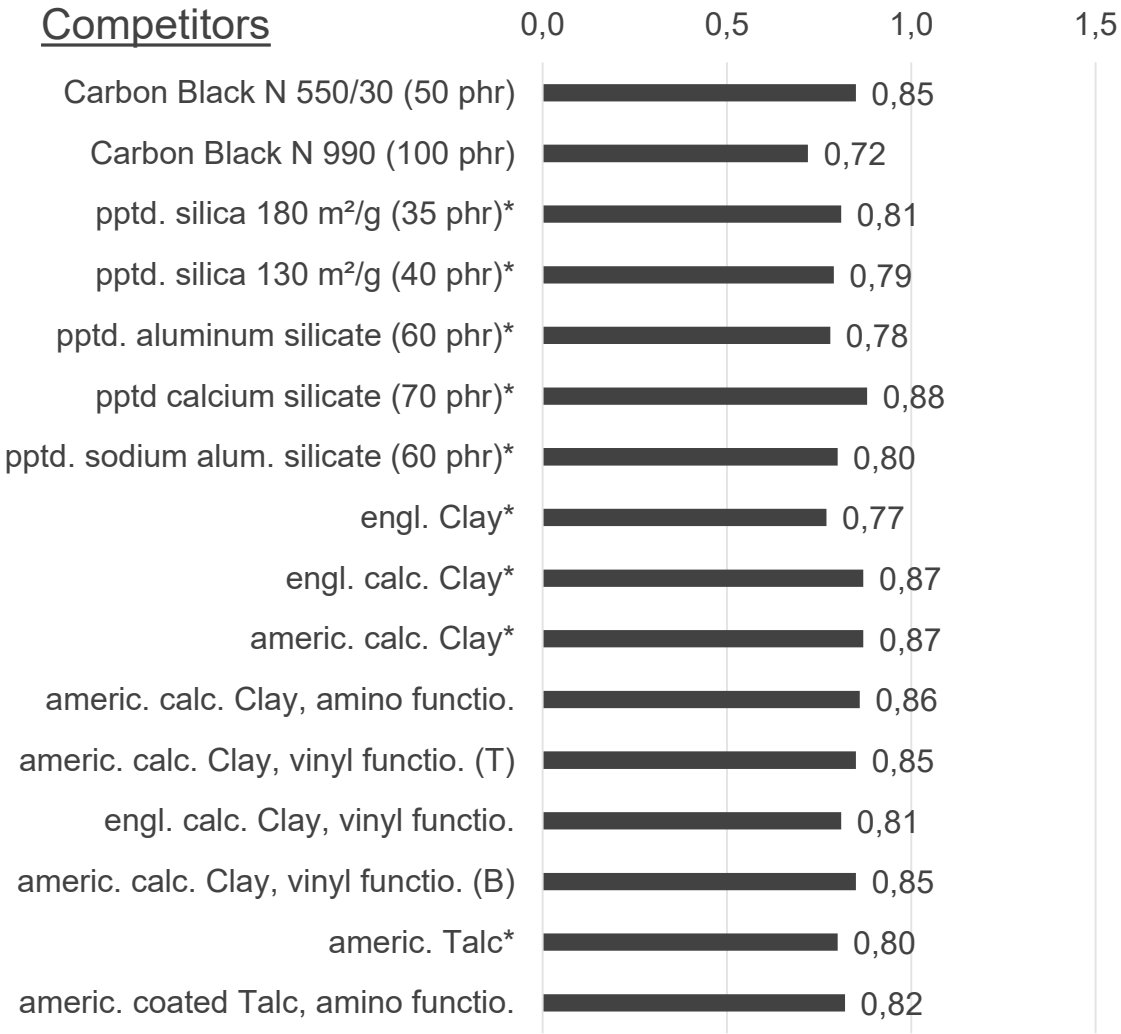
* with silane addition



Rotorless curemeter, 180 °C
Time until max. speed of cure in min.

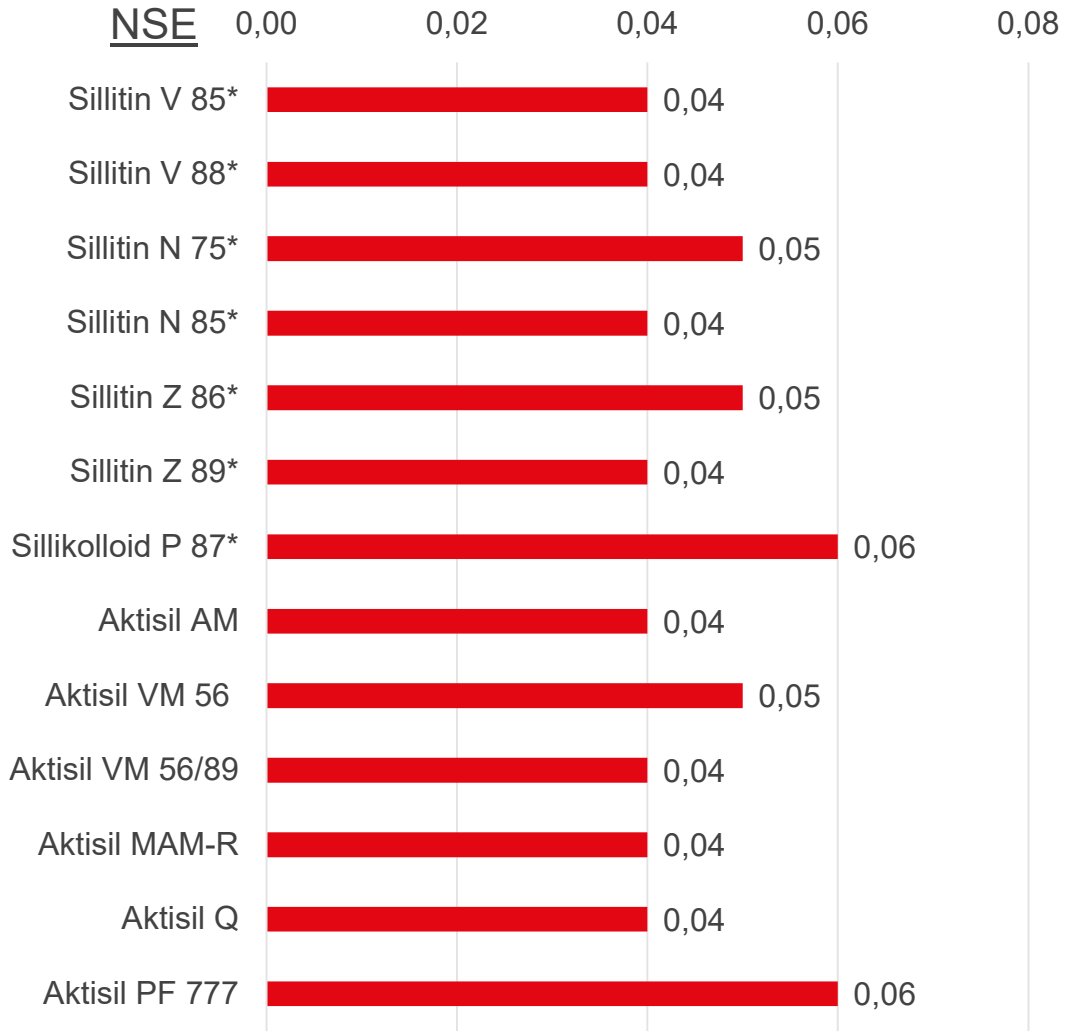
* with silane addition

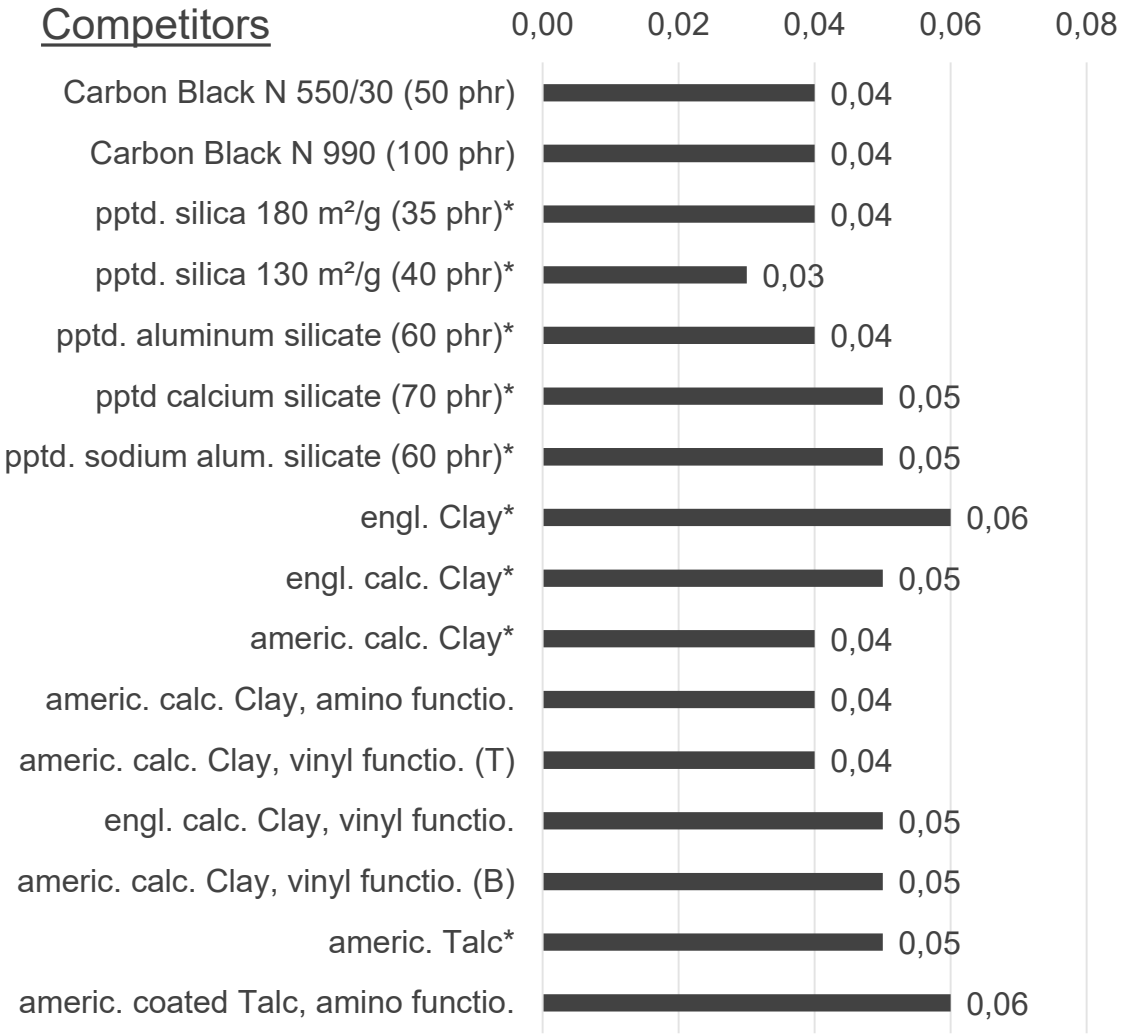


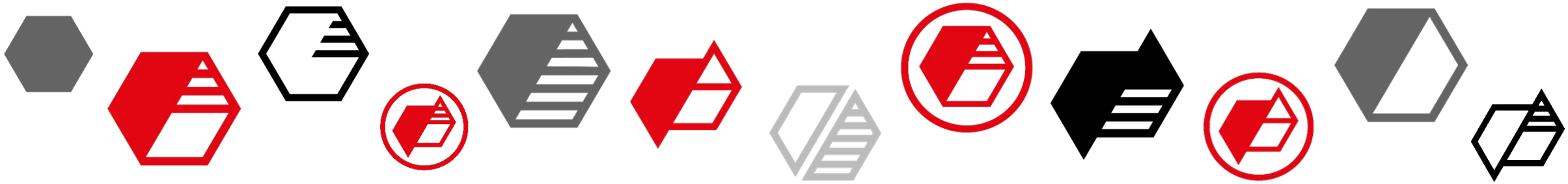


Rotorless curemeter, 180 °C
tan δ, end of test

* with silane addition







→ back to „Results“

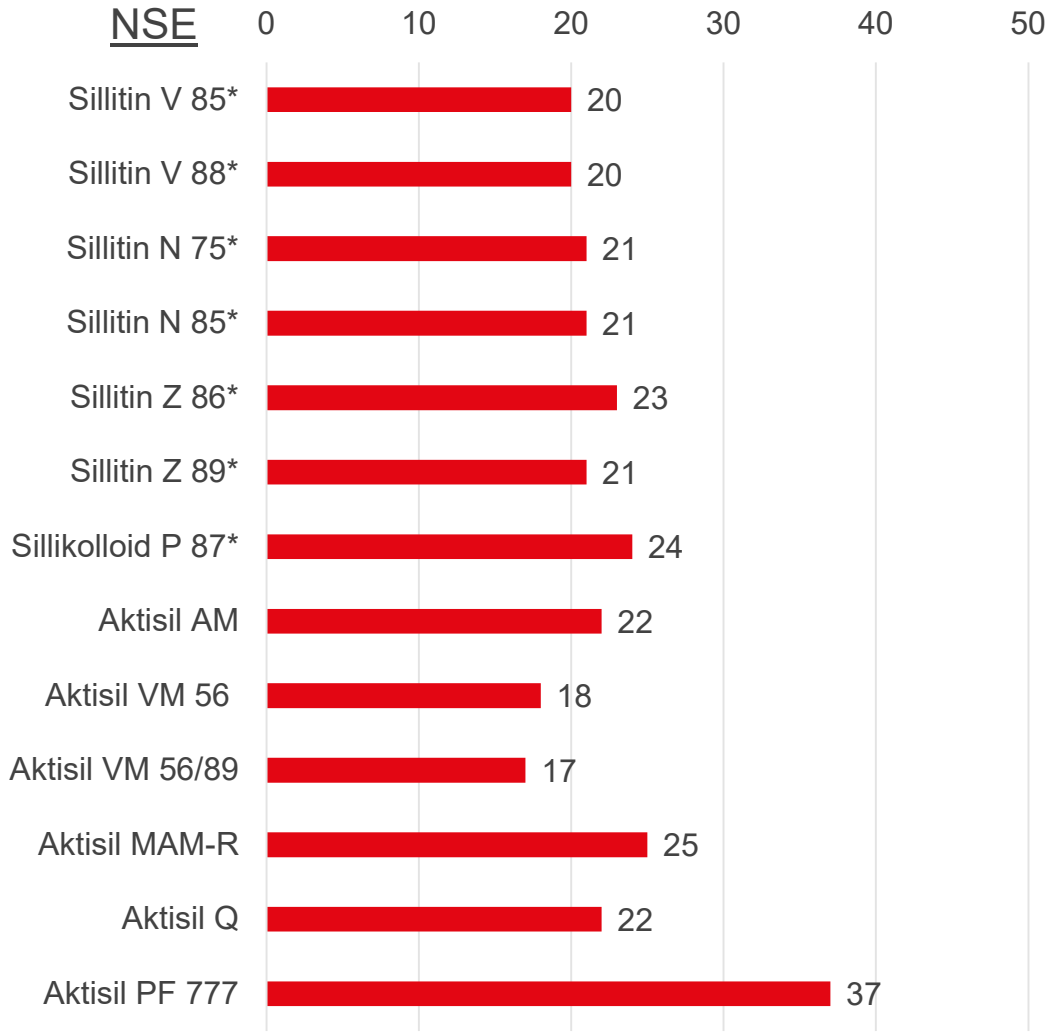
Properties of vulcanizate
(test specimen non post cured)

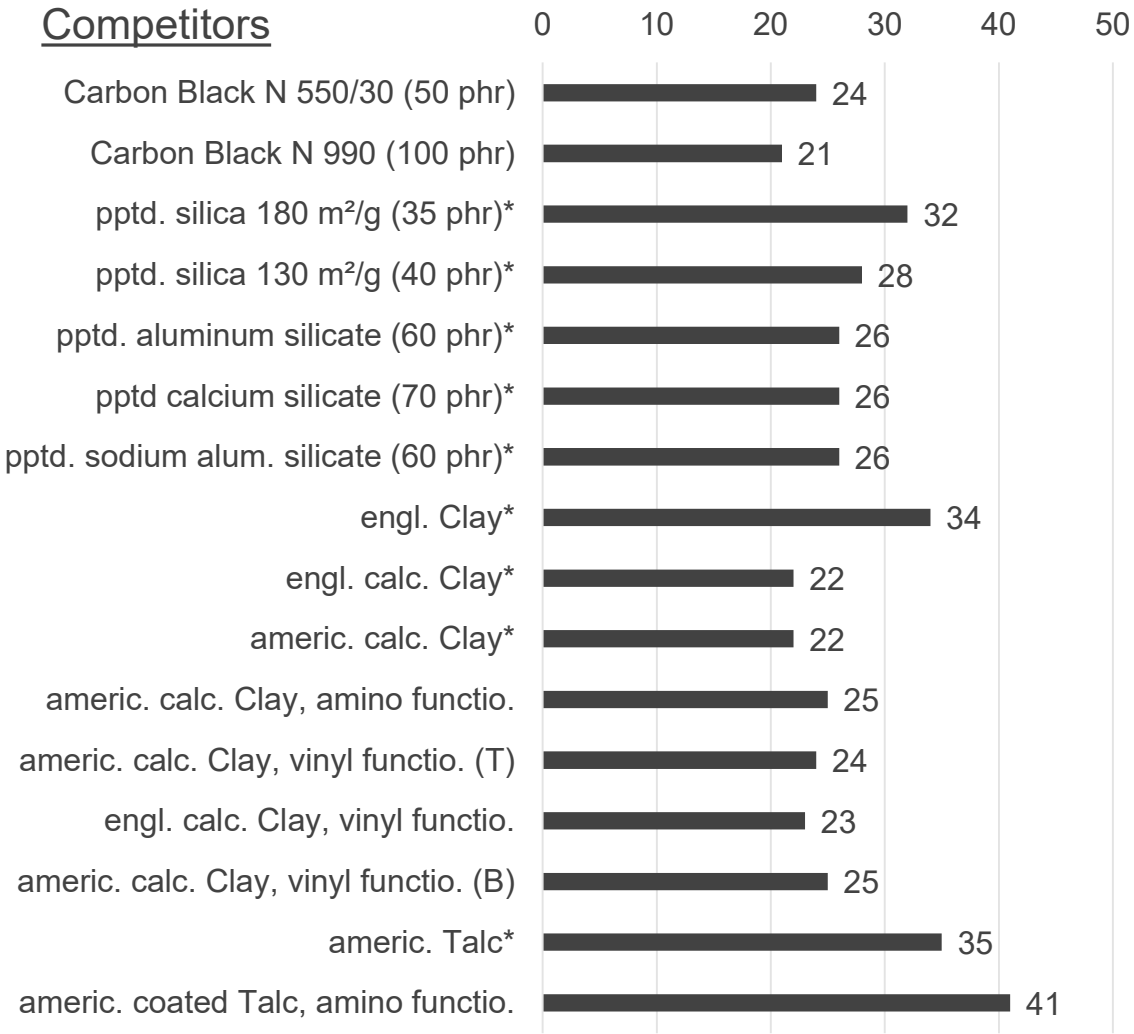
HOFFMANN MINERAL®
We supply materials for good ideas

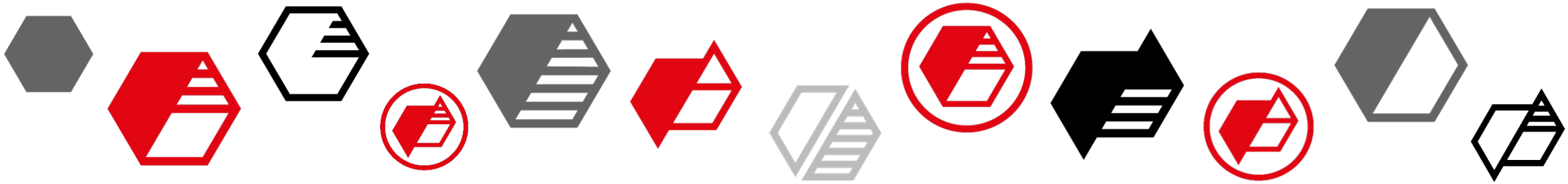
Compression set in % (24 h / 150 °C / 25 % Def.)

DIN ISO 815-1, Type B

* with silane addition







→ back to „Results“

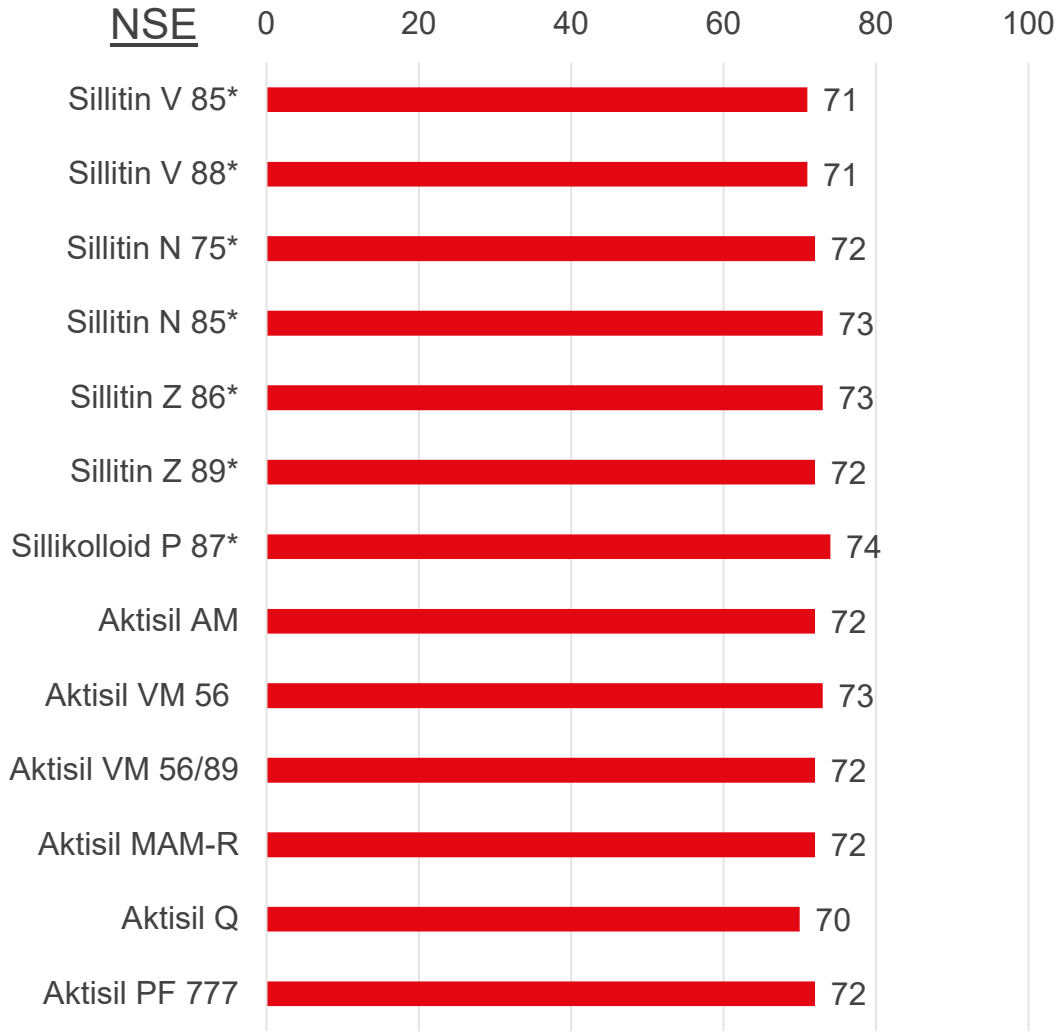
Properties of vulcanizate
(test specimen post cured: 4 h / 150 °C)

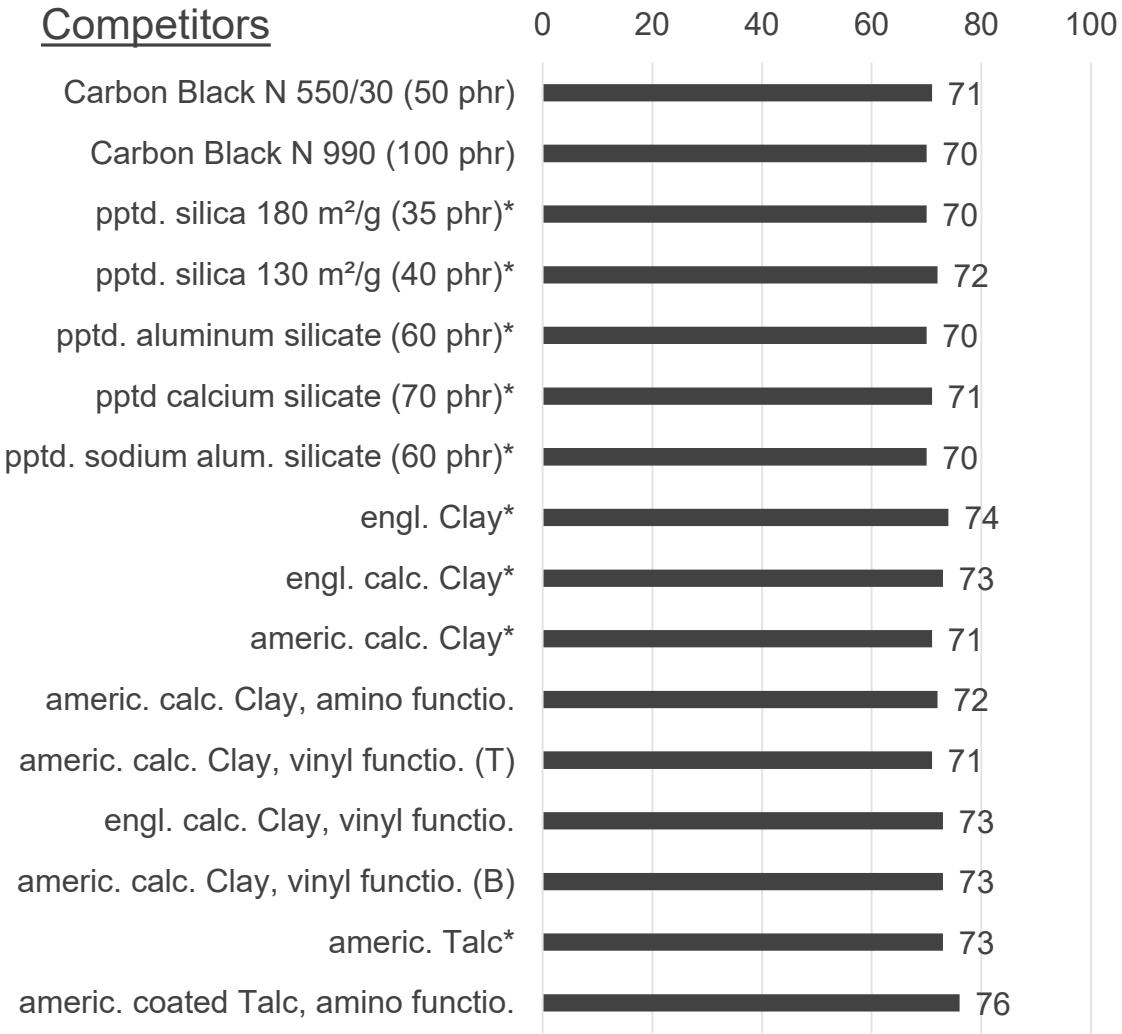
HOFFMANN MINERAL®
We supply materials for good ideas

Hardness – piled-up S2 dumbbells

DIN ISO 7619-1

* with silane addition

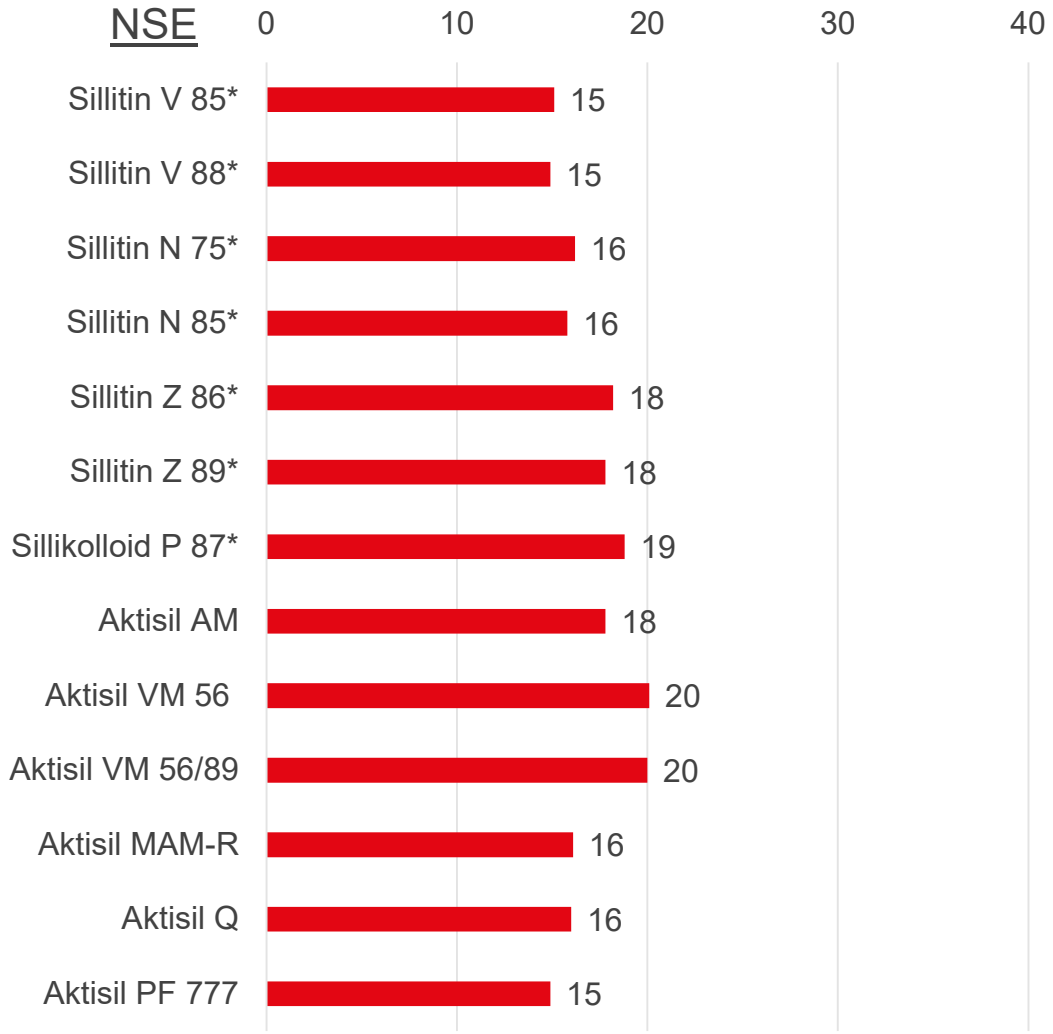


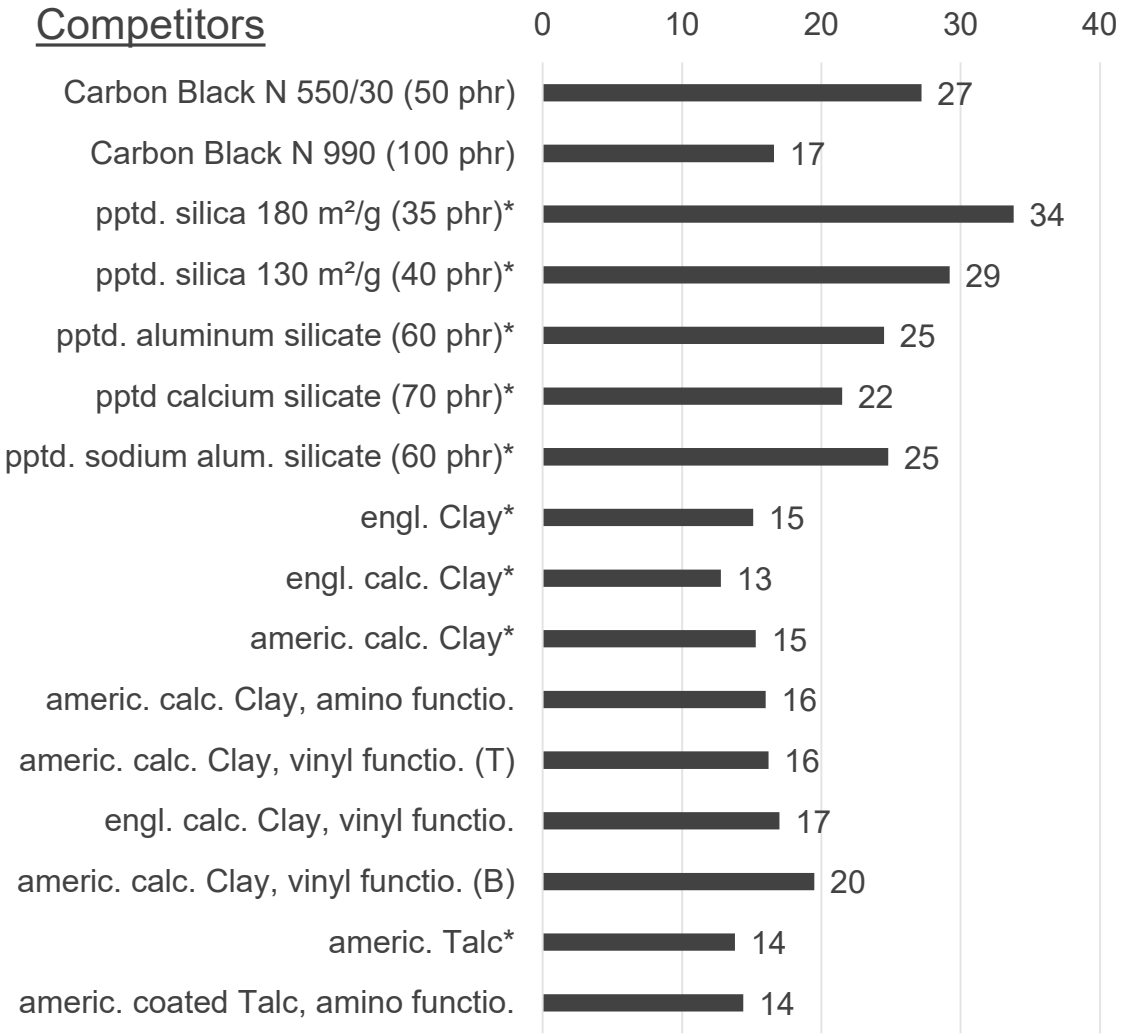


Tensile strength in MPa

DIN 53 504, S2

* with silane addition

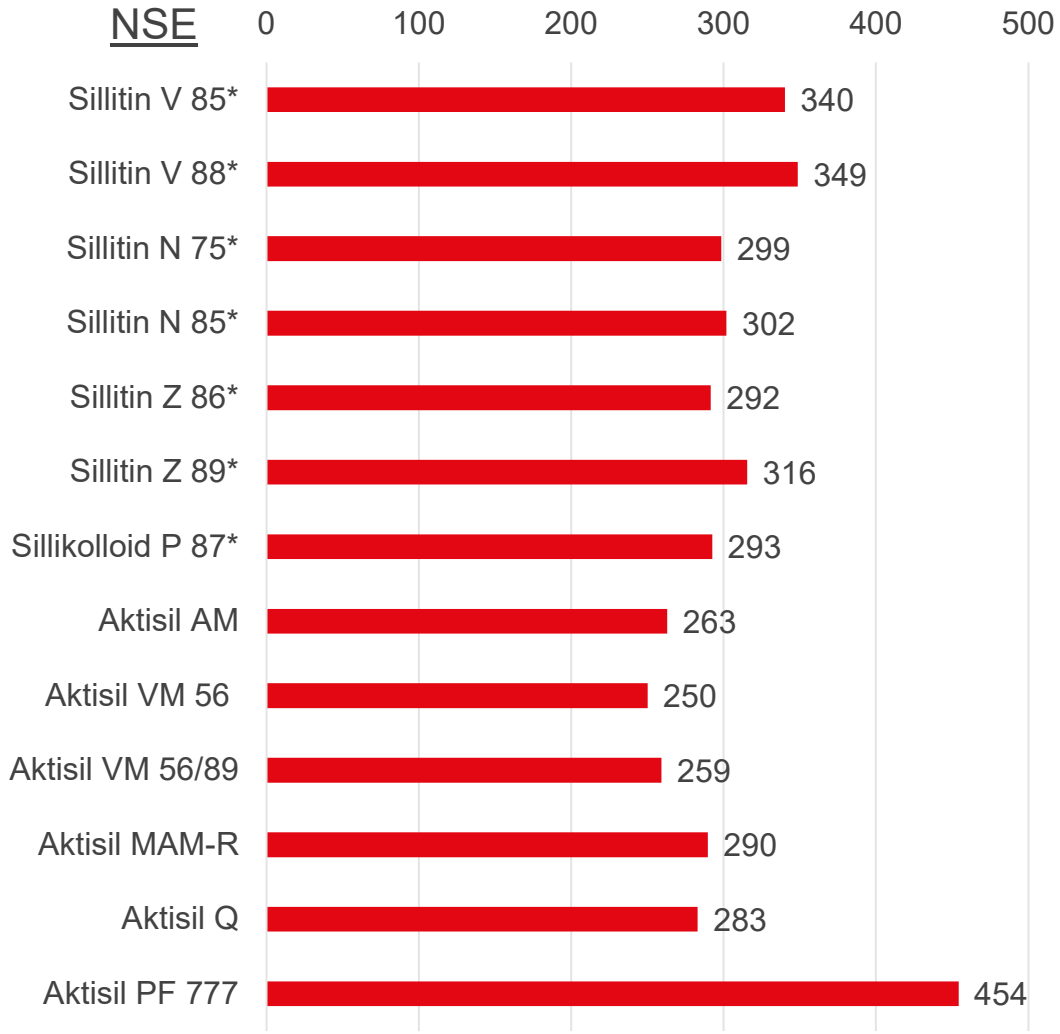


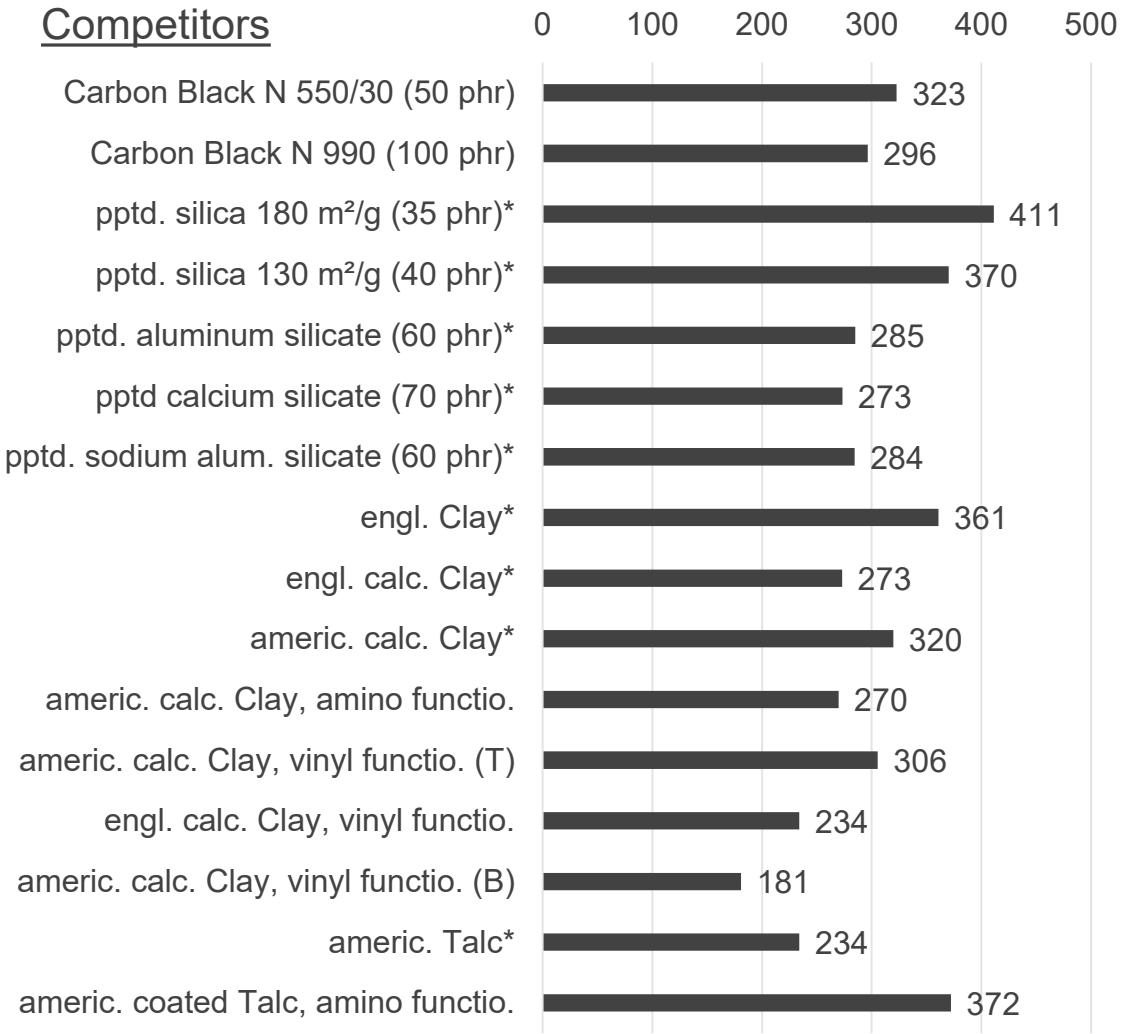


Elongation at break in %

DIN 53 504, S2

* with silane addition

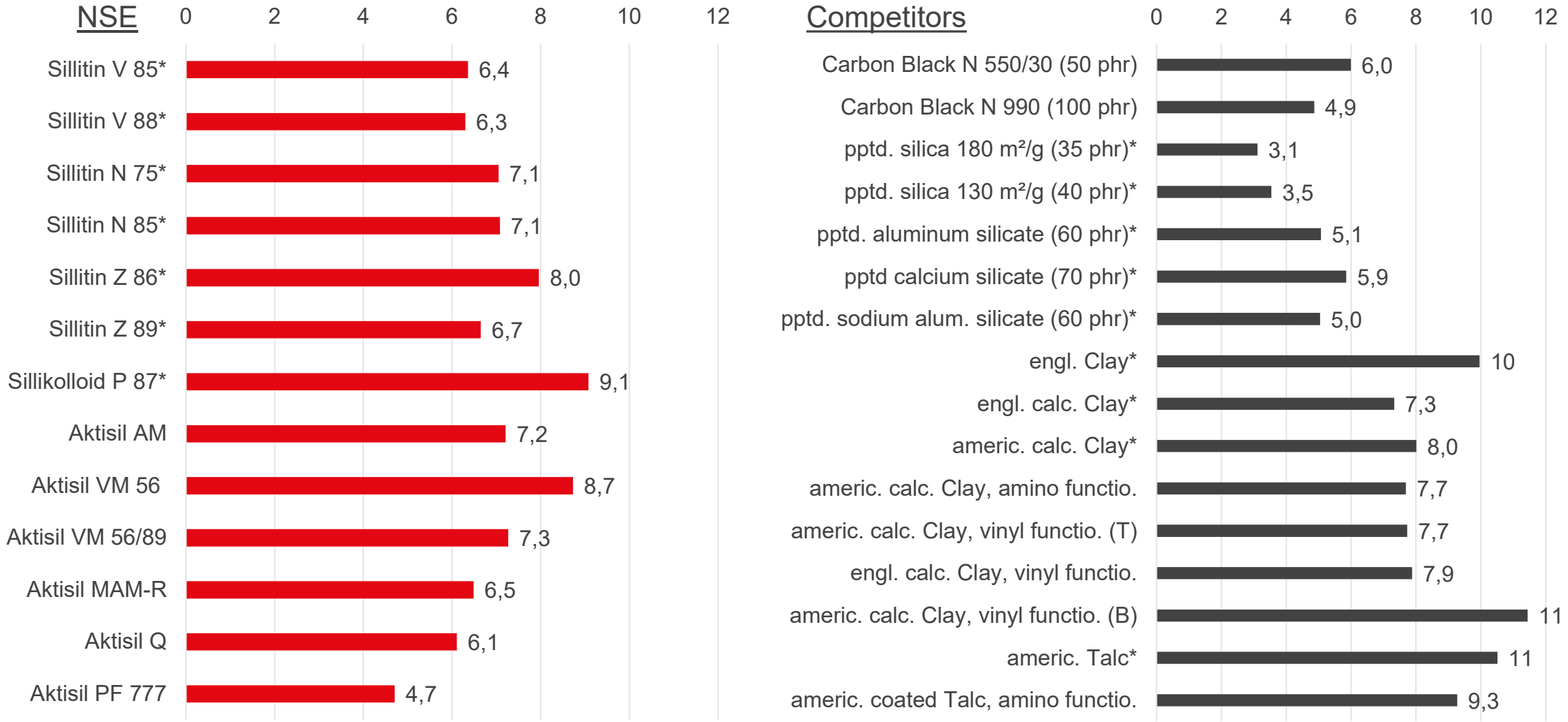




Modulus 100 % in MPa

DIN 53 504, S2

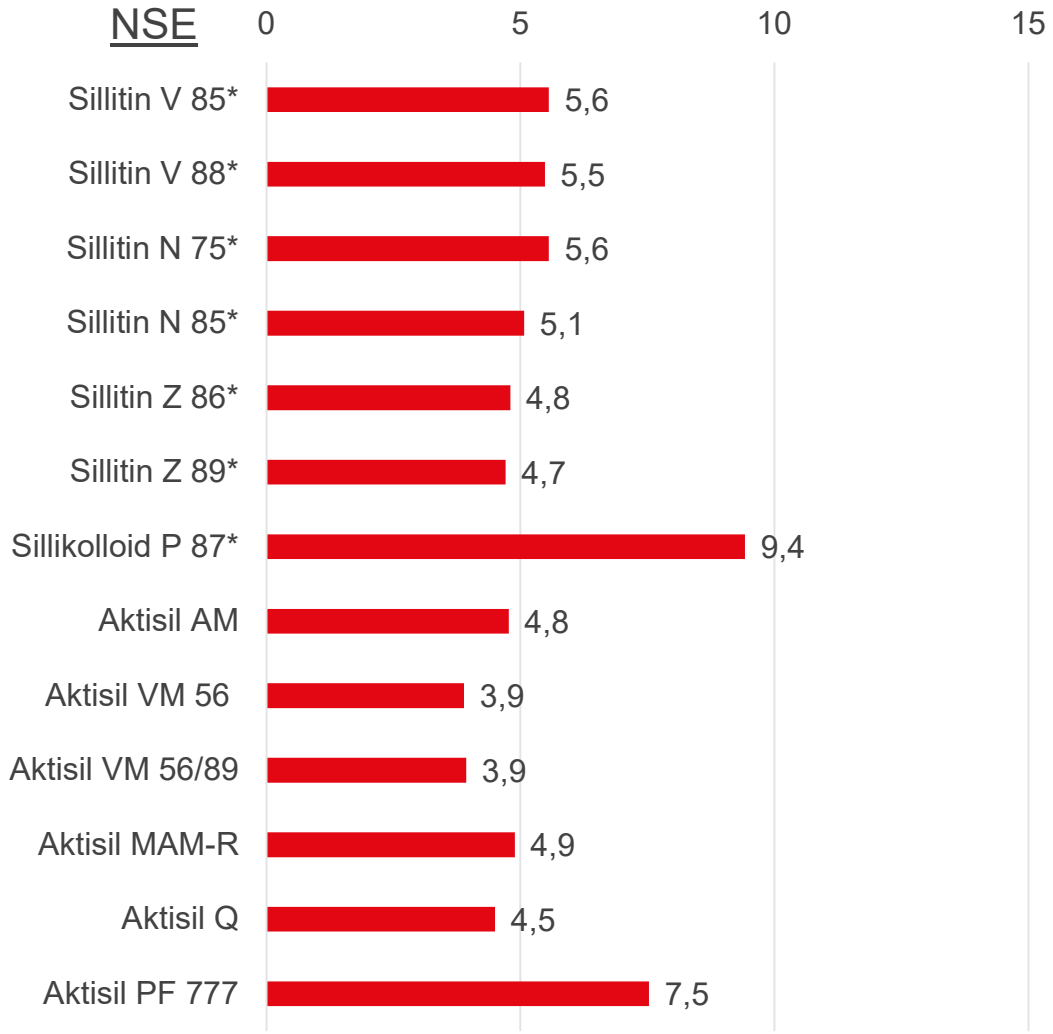
* with silane addition

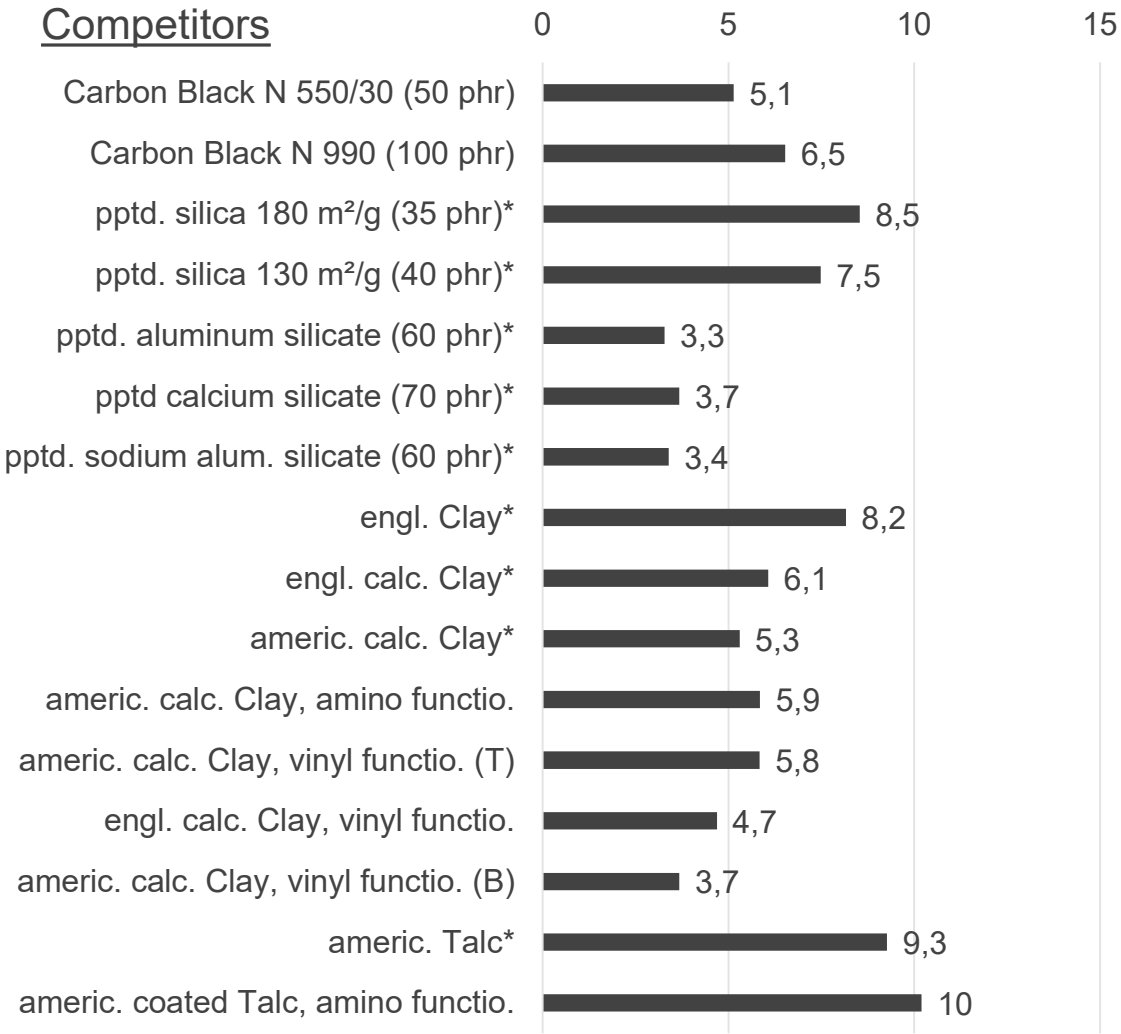


Tear resistance in N/mm – Trousers specimen

DIN ISO 34-1, A

* with silane addition

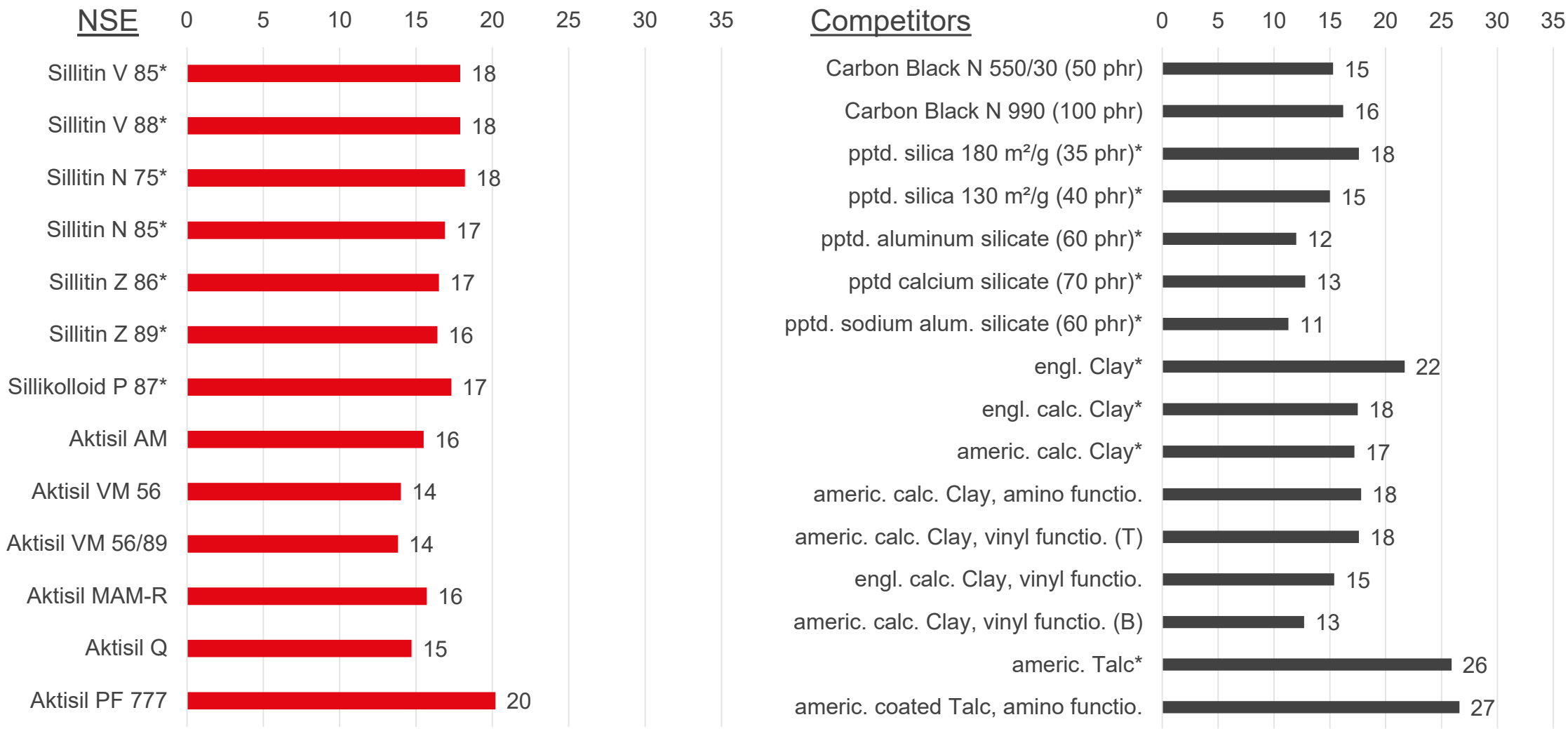




Tear resistance in N/mm – Graves specimen

DIN ISO 34-1, Bb

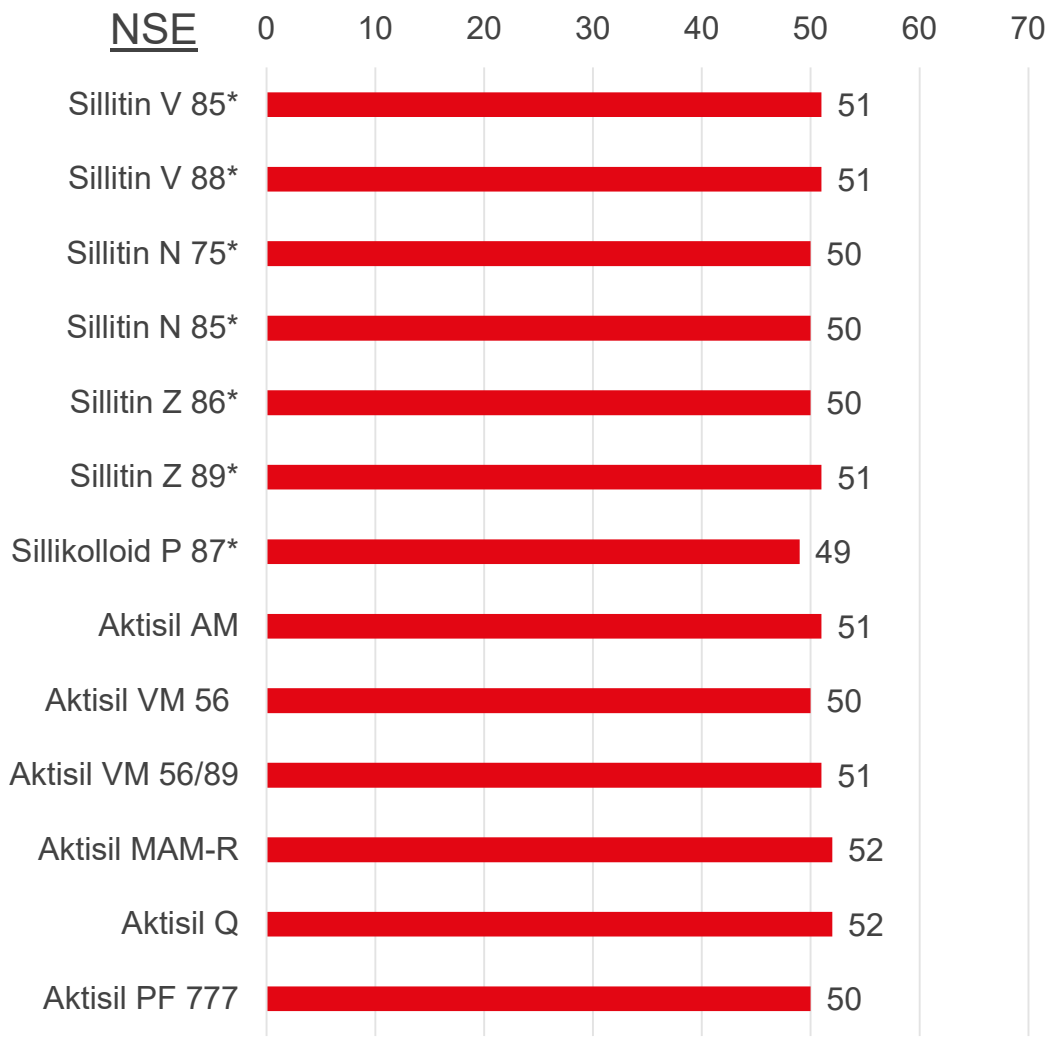
* with silane addition

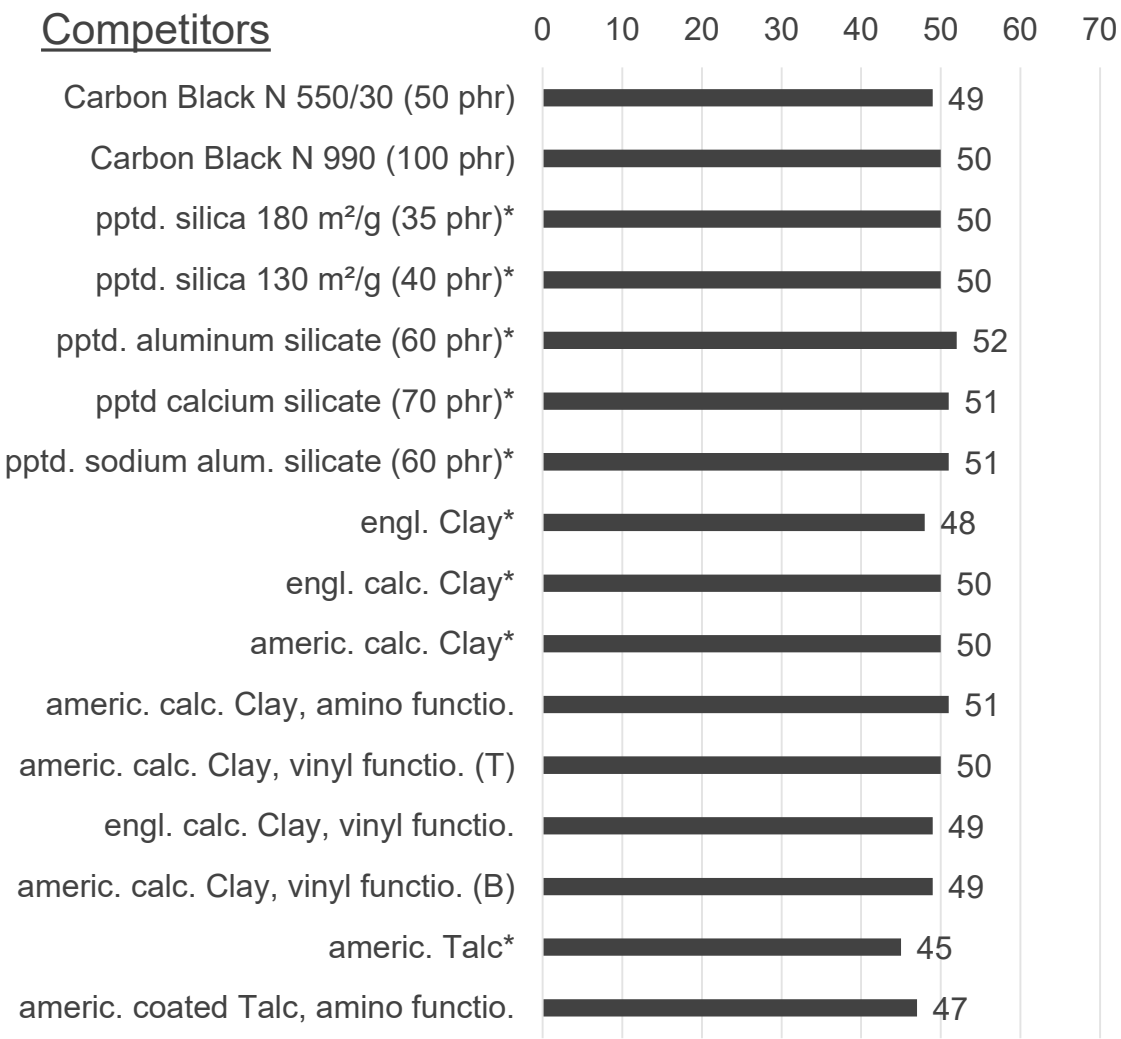


Rebound elasticity in %

DIN 53 512

* with silane addition

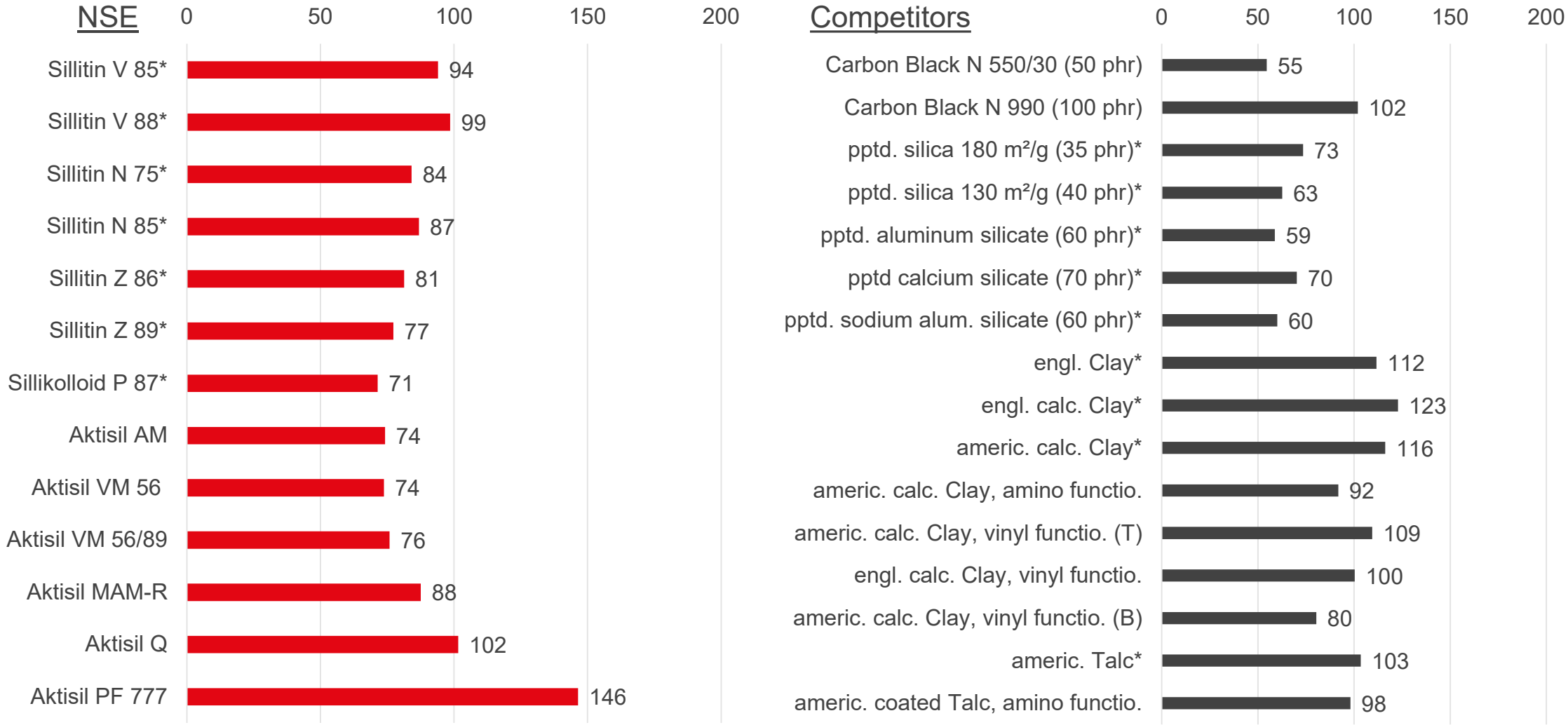




Abrasion loss in mm³

DIN ISO 4649, A

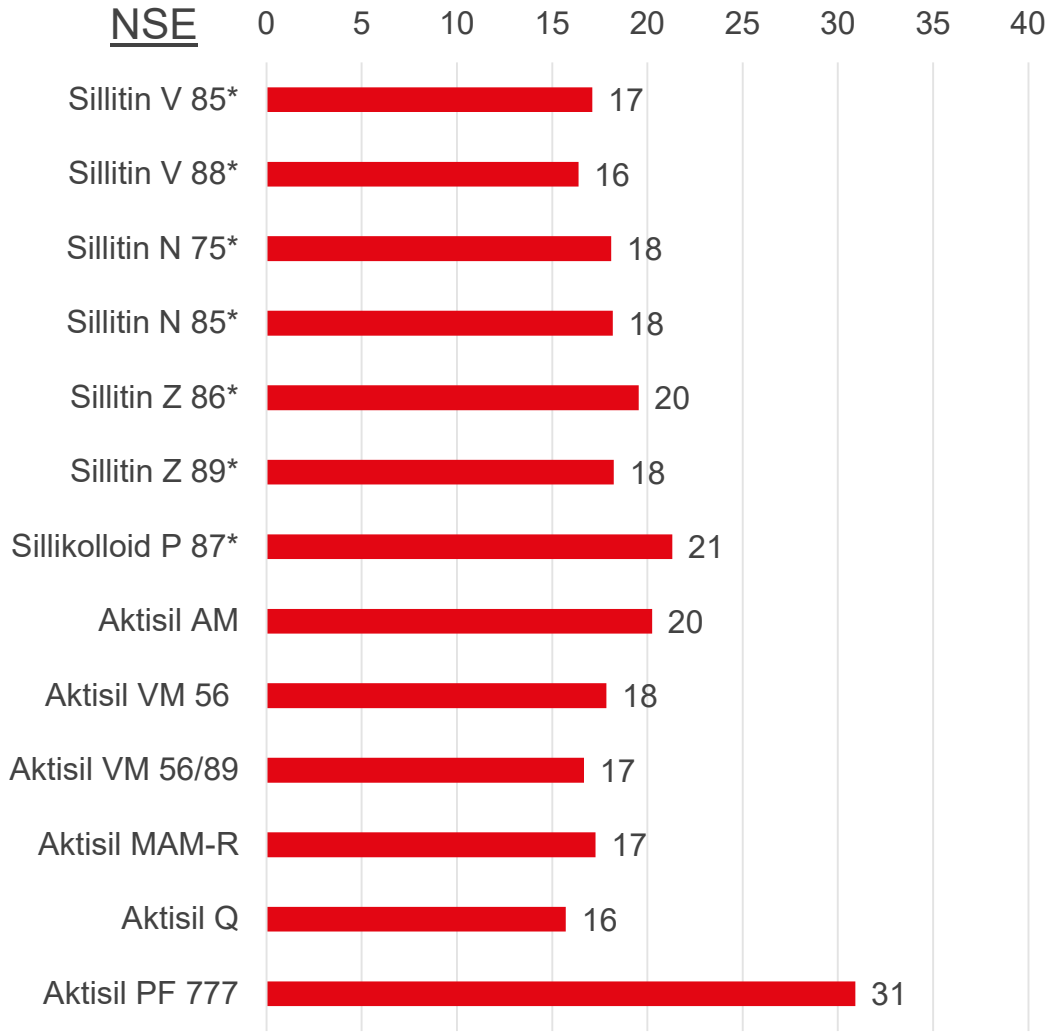
* with silane addition

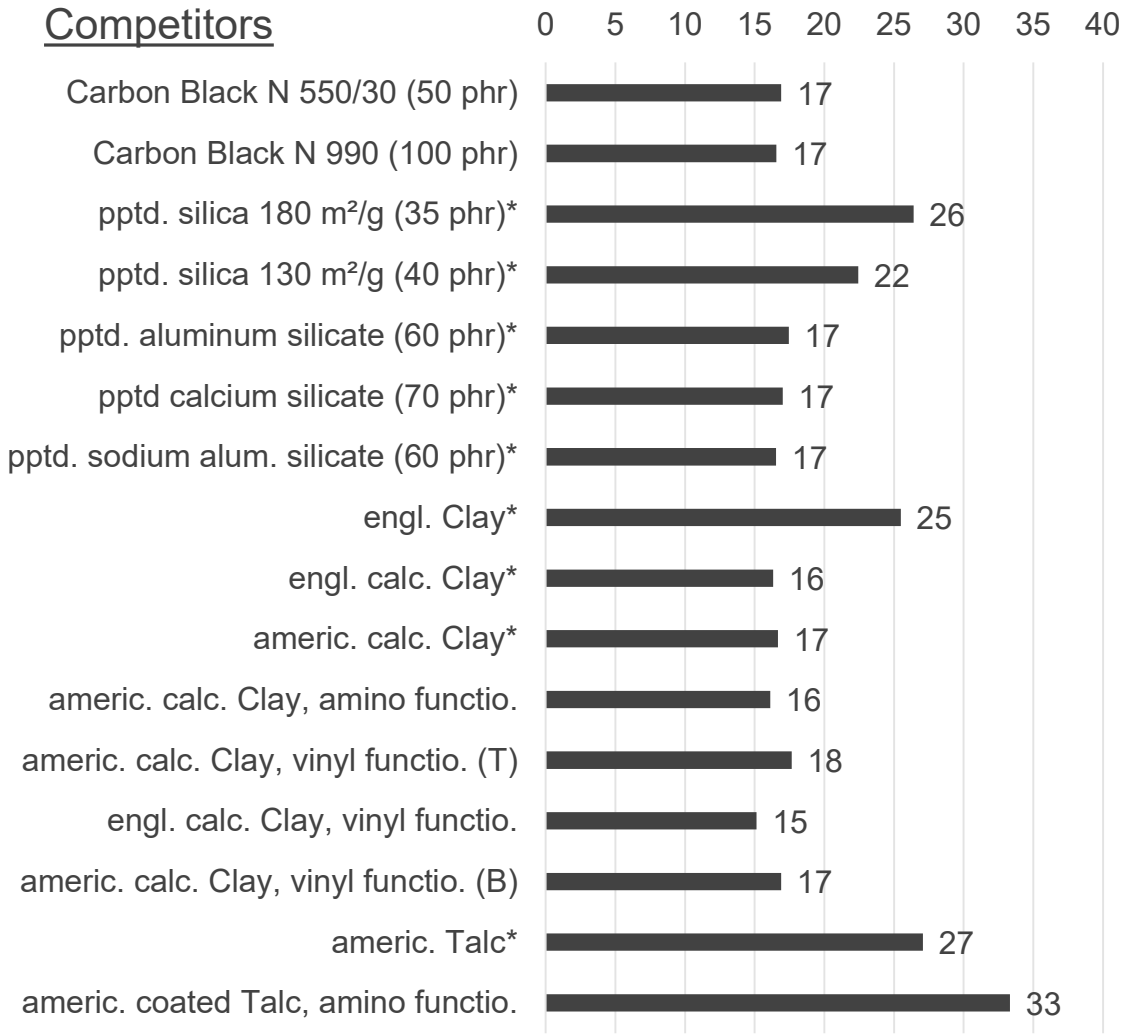


Compression set in % (24 h / 150 °C / 25 % Def.)

DIN ISO 815-1, Type B

* with silane addition

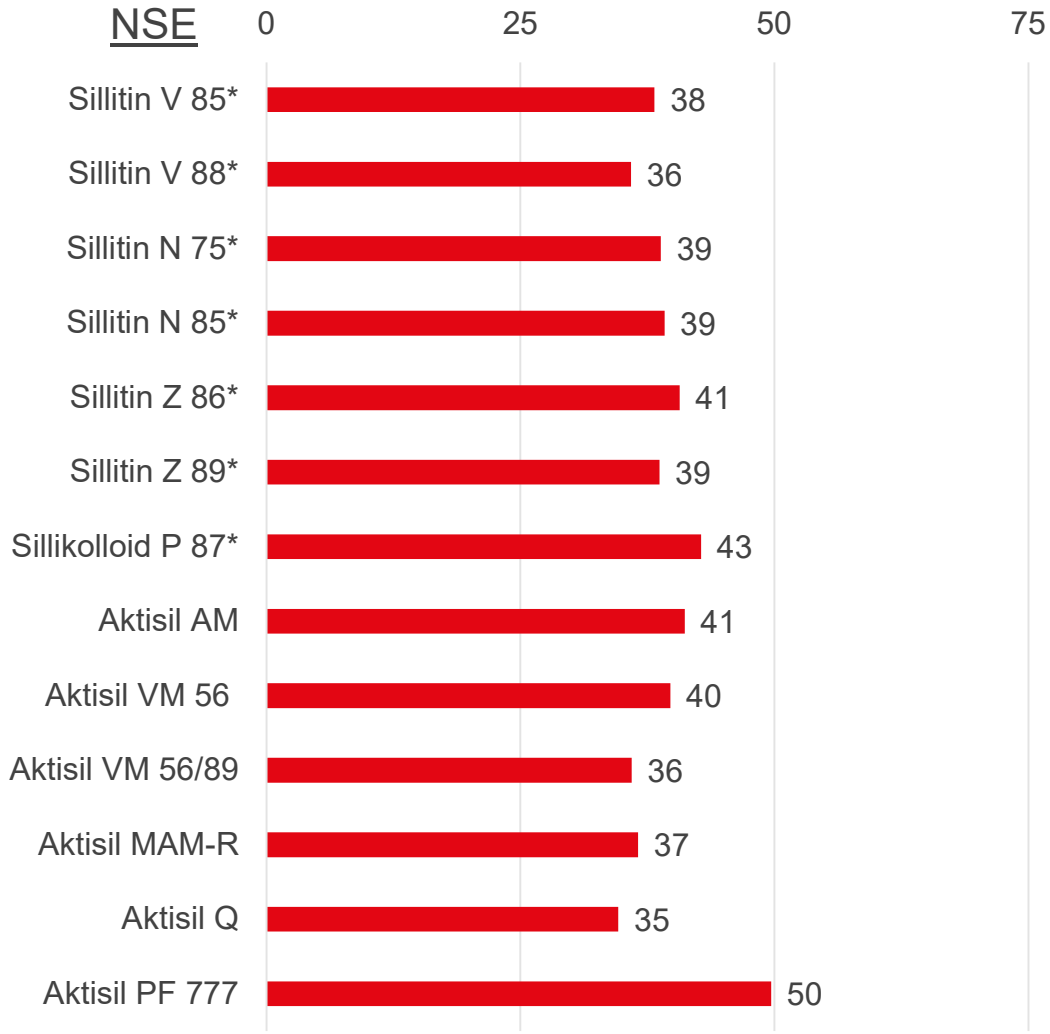


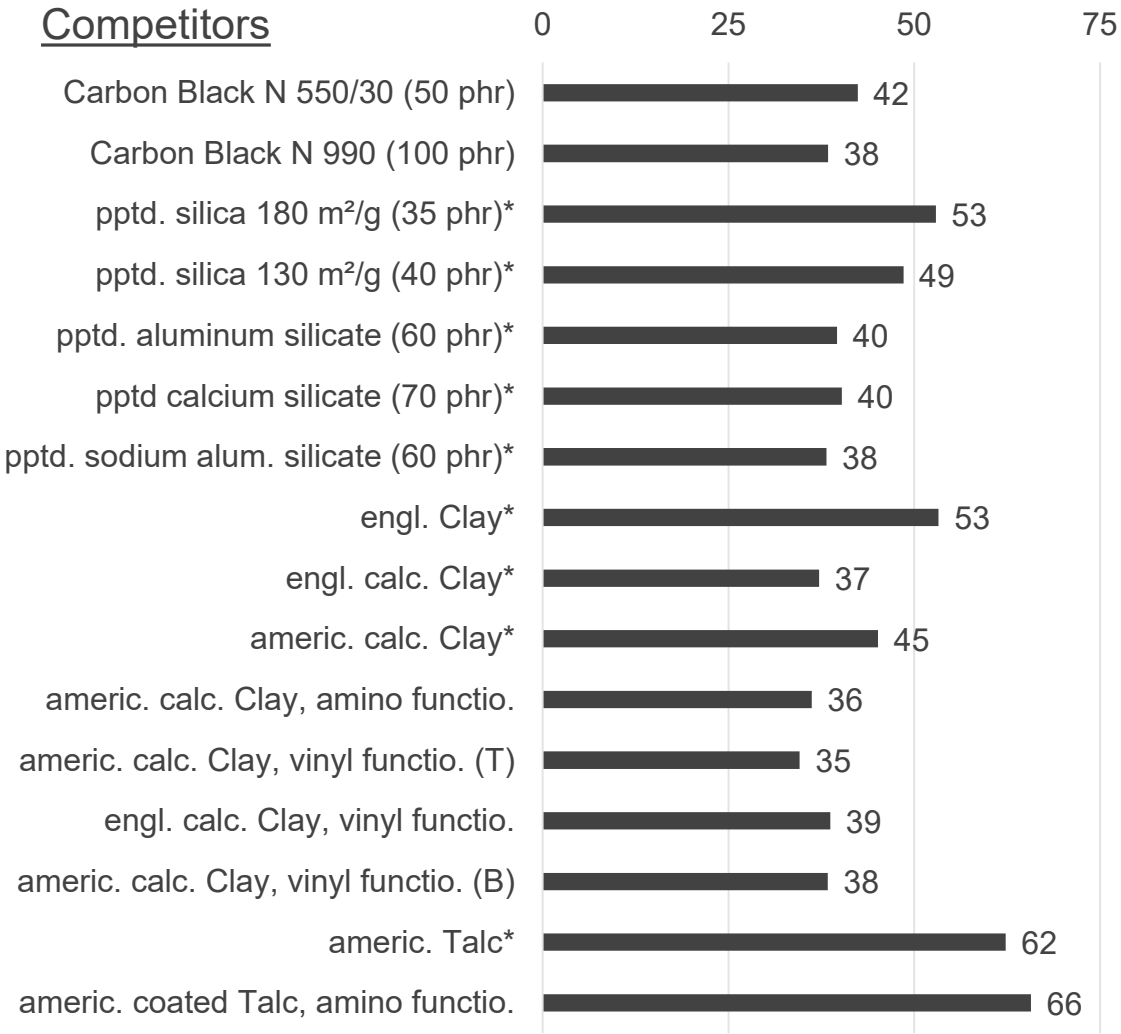


Compression set in % (168 h / 175 °C / 25 % Def.)

DIN ISO 815-1, Type B

* with silane addition





→ back to „Results“

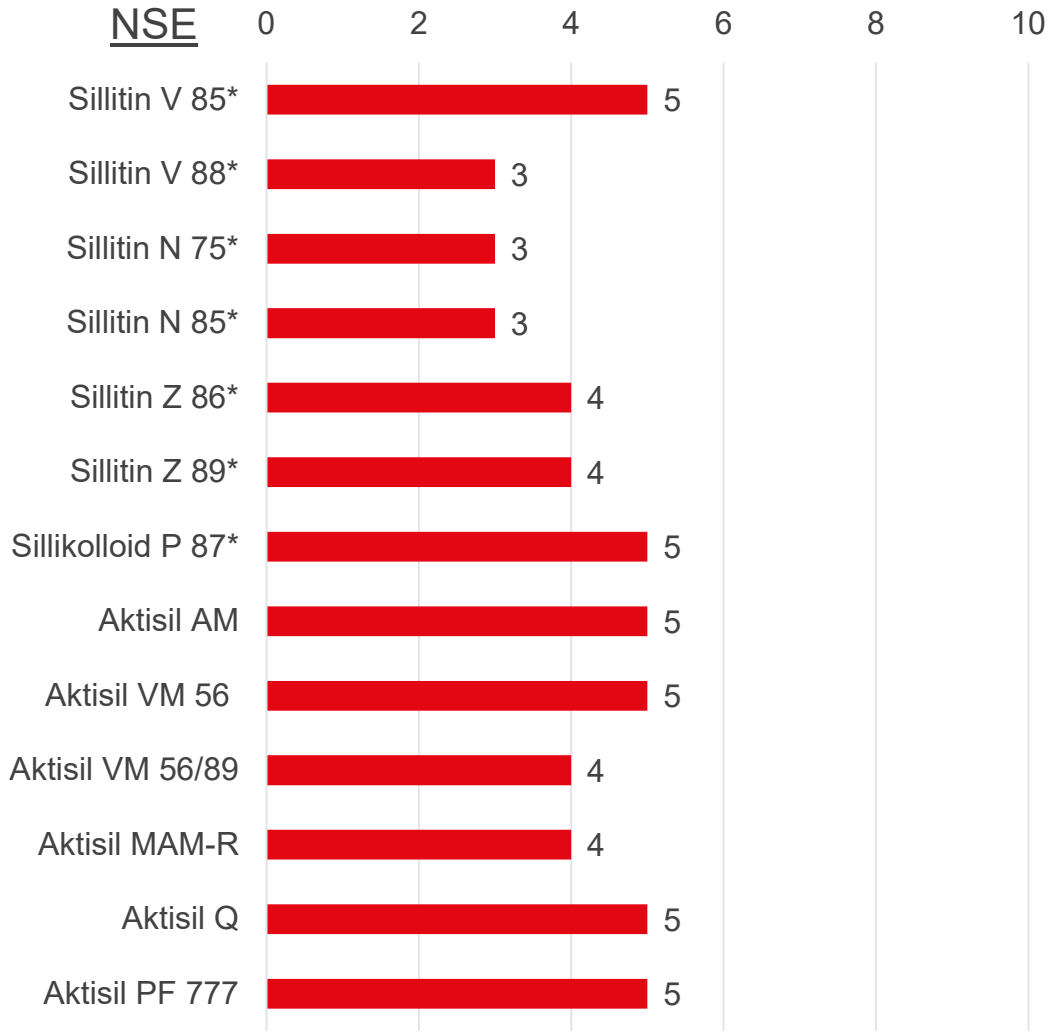
Hot air aging 168 h / 150 °C

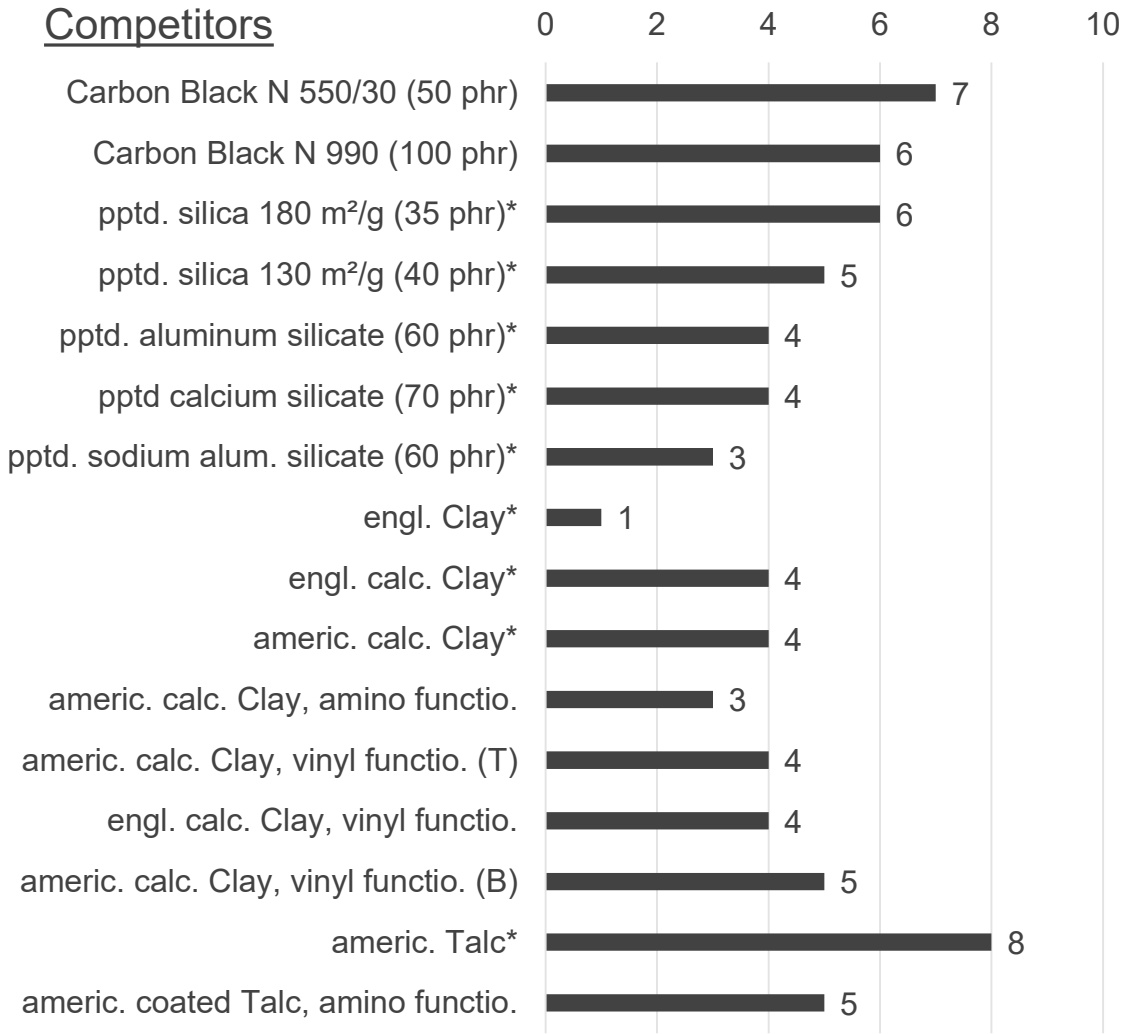
ISO 188, D

HOFFMANN MINERAL®
We supply materials for good ideas

Hot air aging 168 h / 150 °C
Change of hardness in Shore A – piled up S2 dumbbells

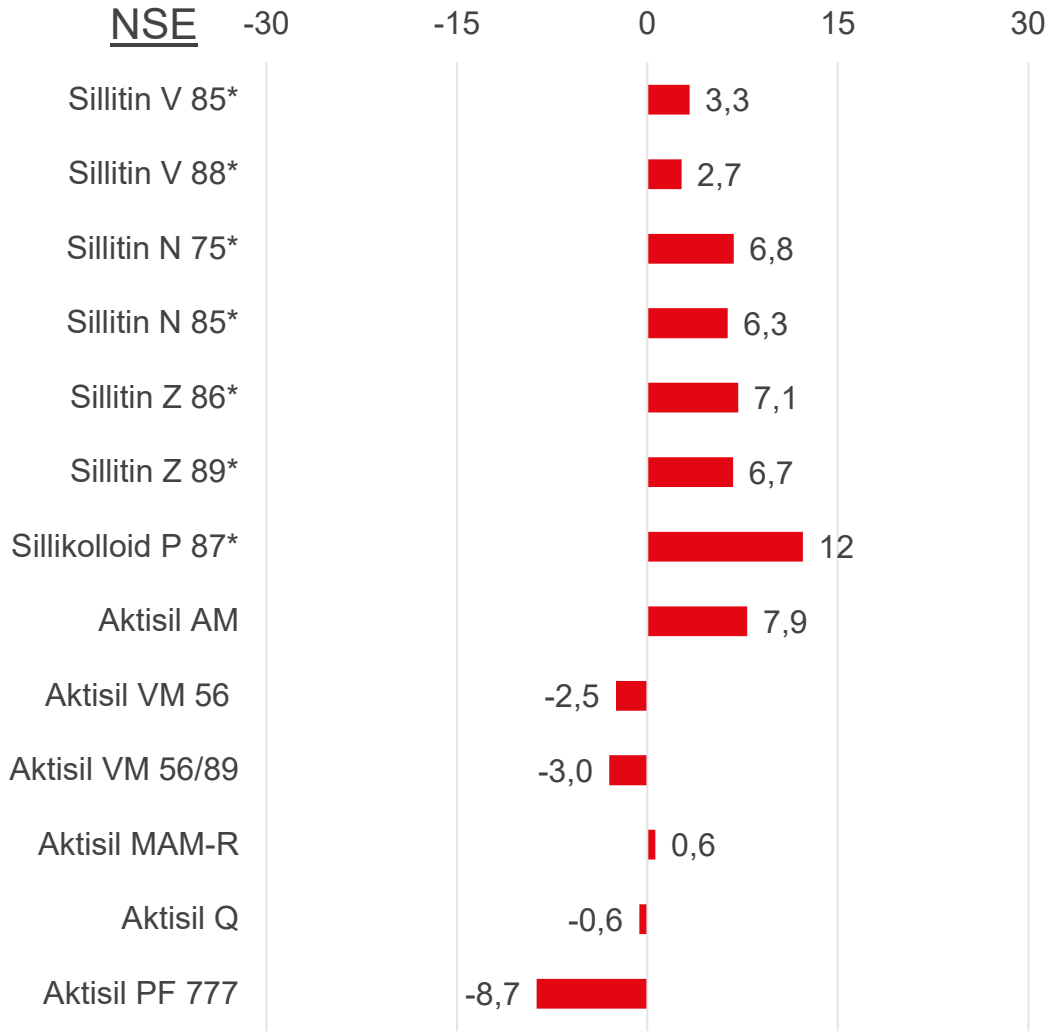
* with silane addition

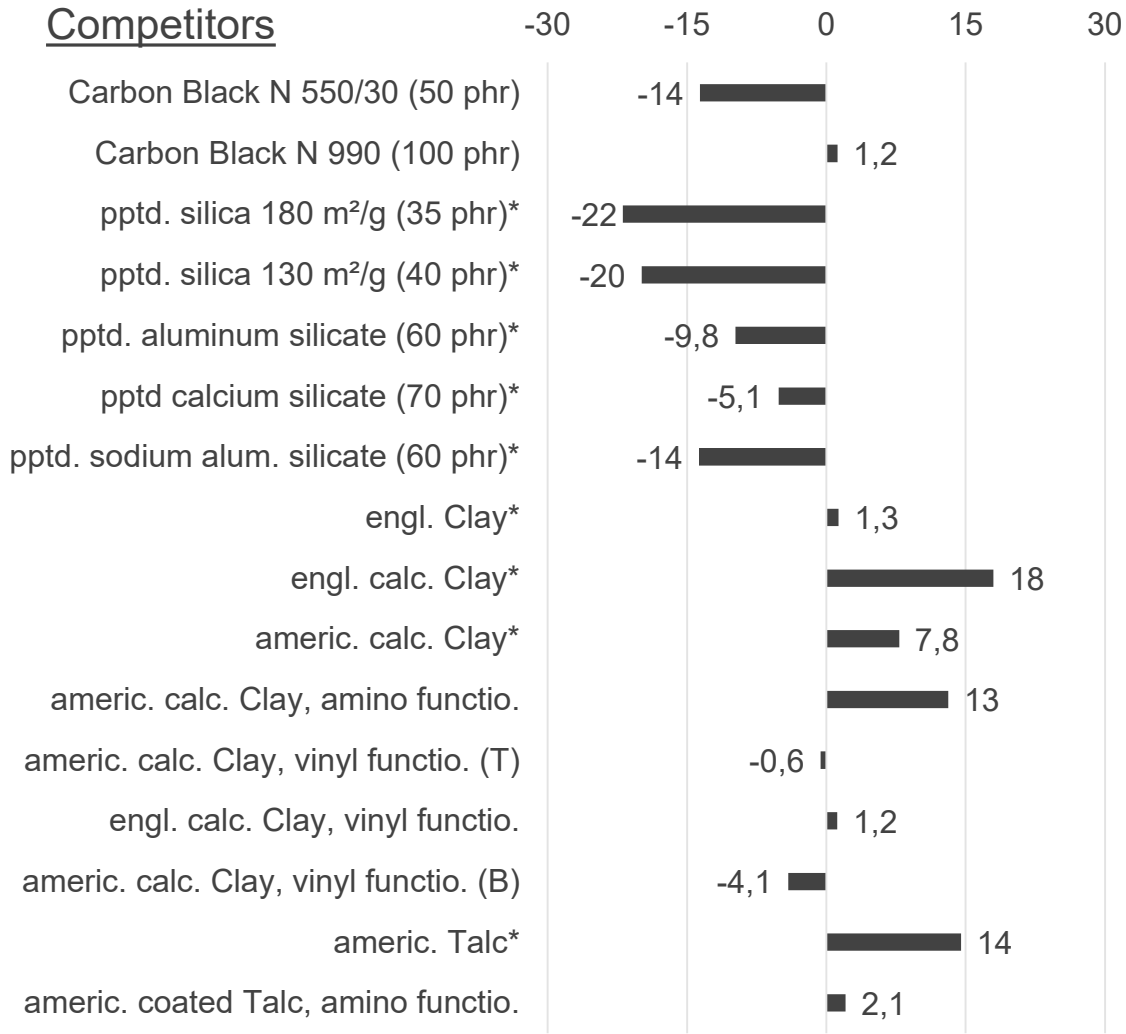




Hot air aging 168 h / 150 °C
Change of tensile strength in %

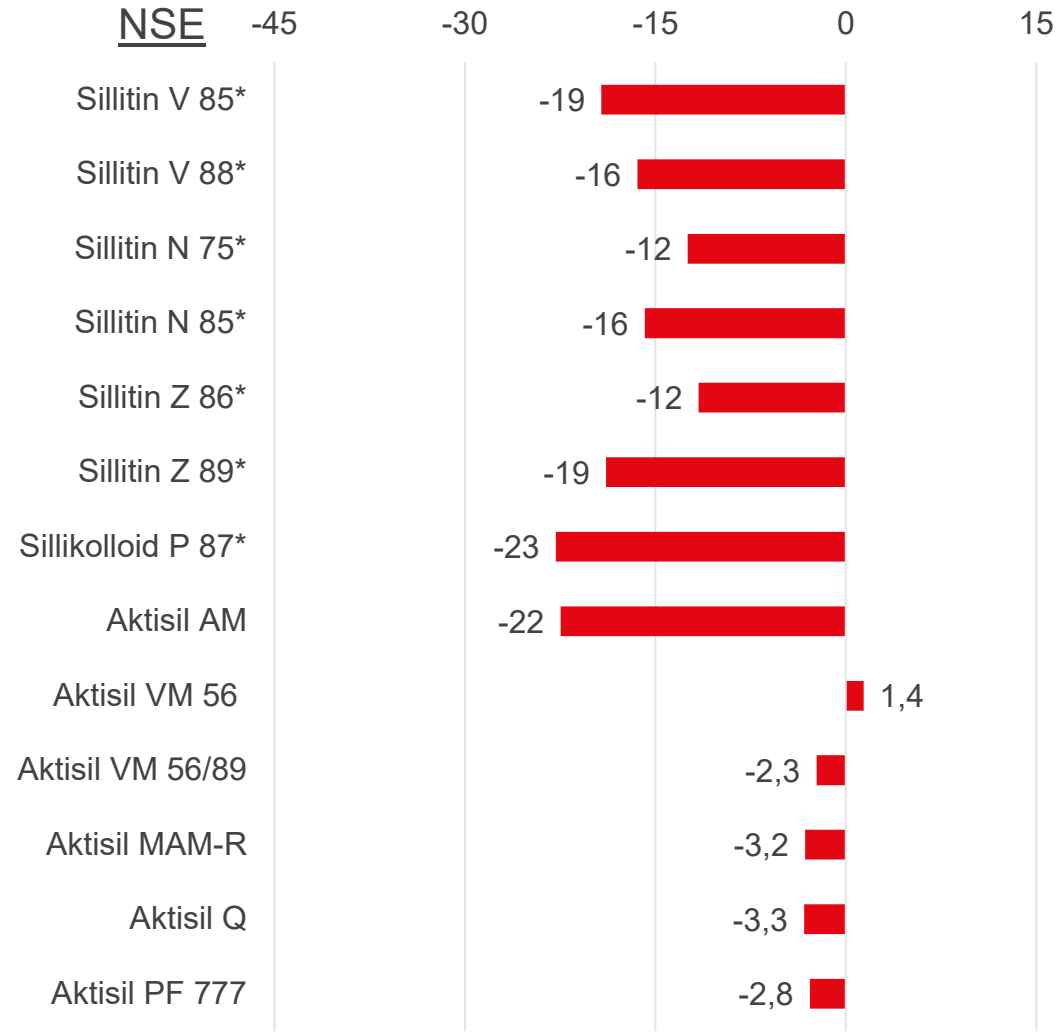
* with silane addition

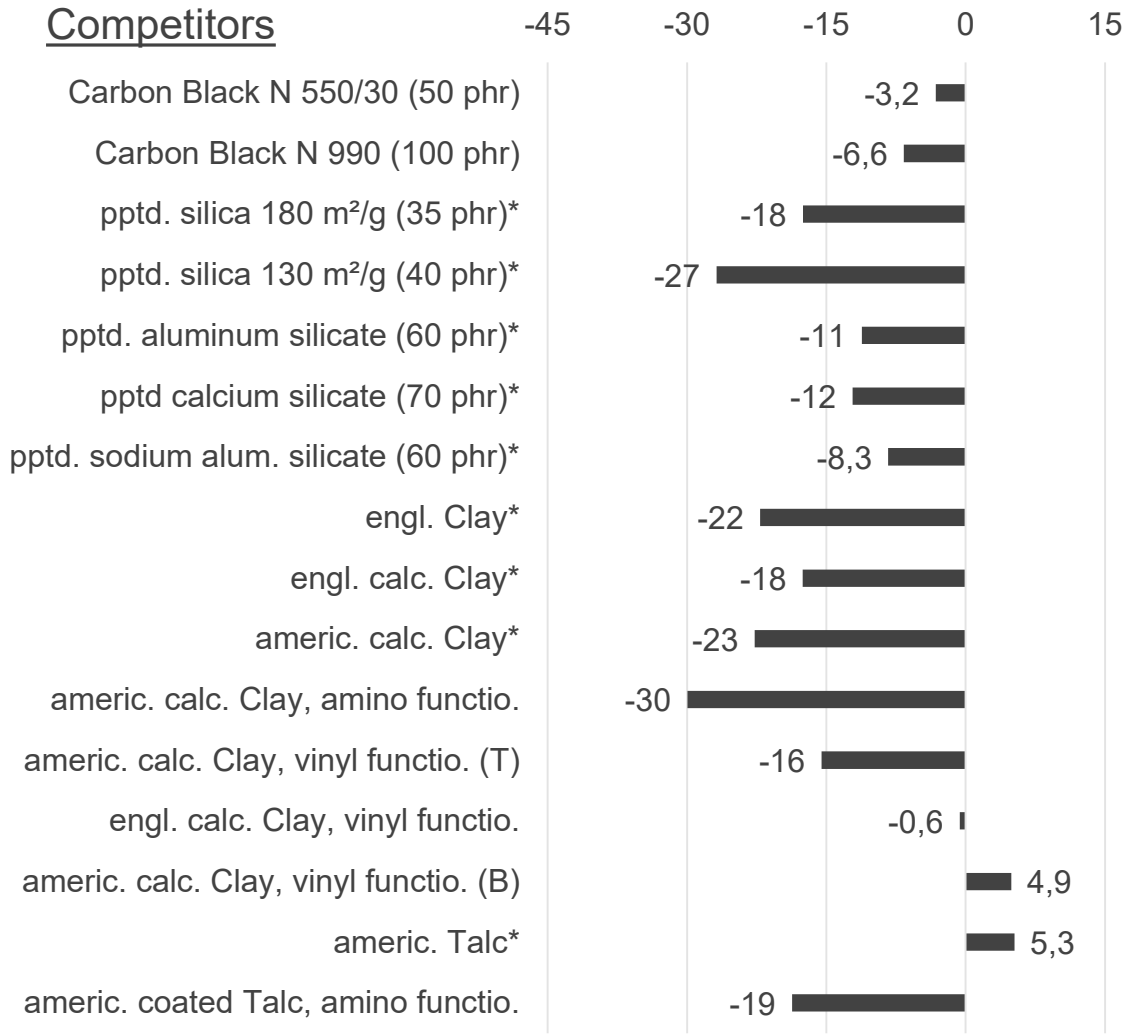




Hot air aging 168 h / 150 °C
Change of elongation at break in rel.%

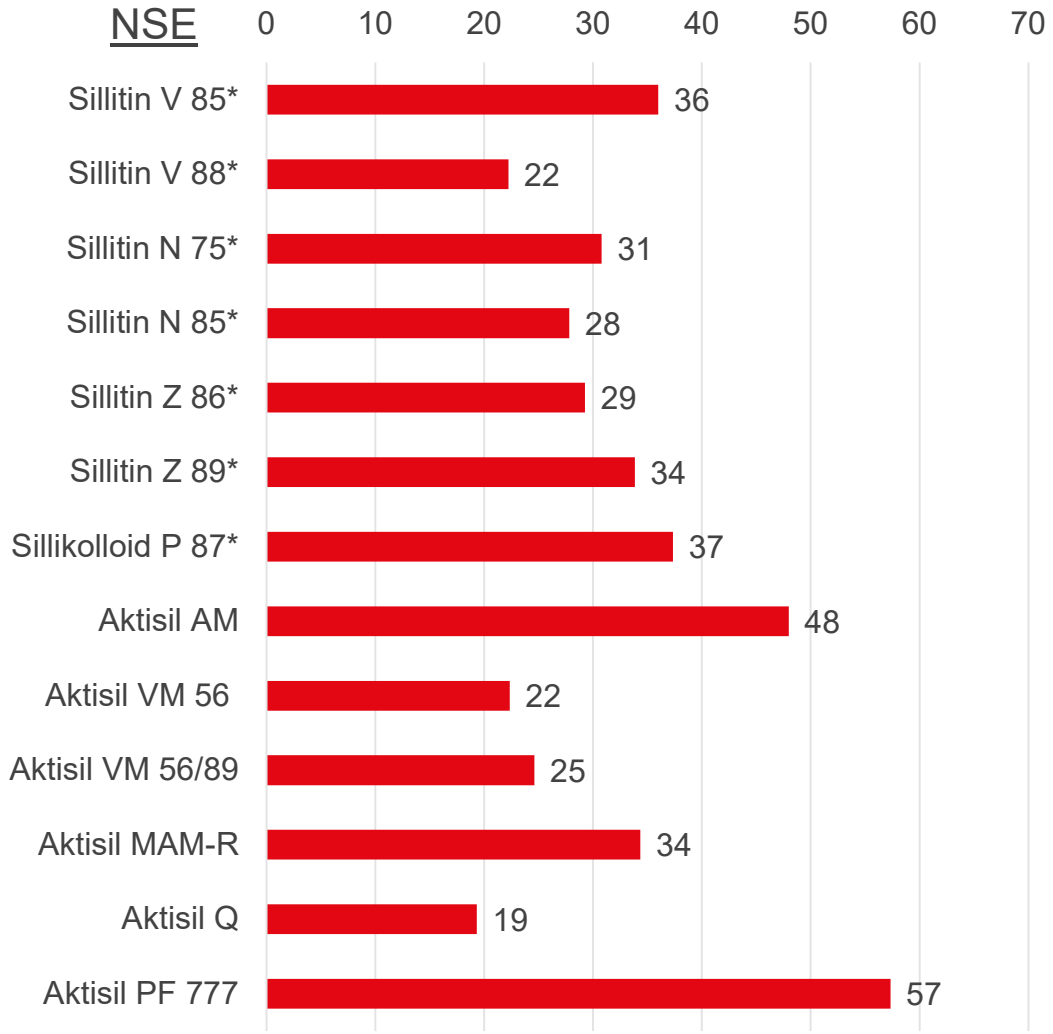
* with silane addition

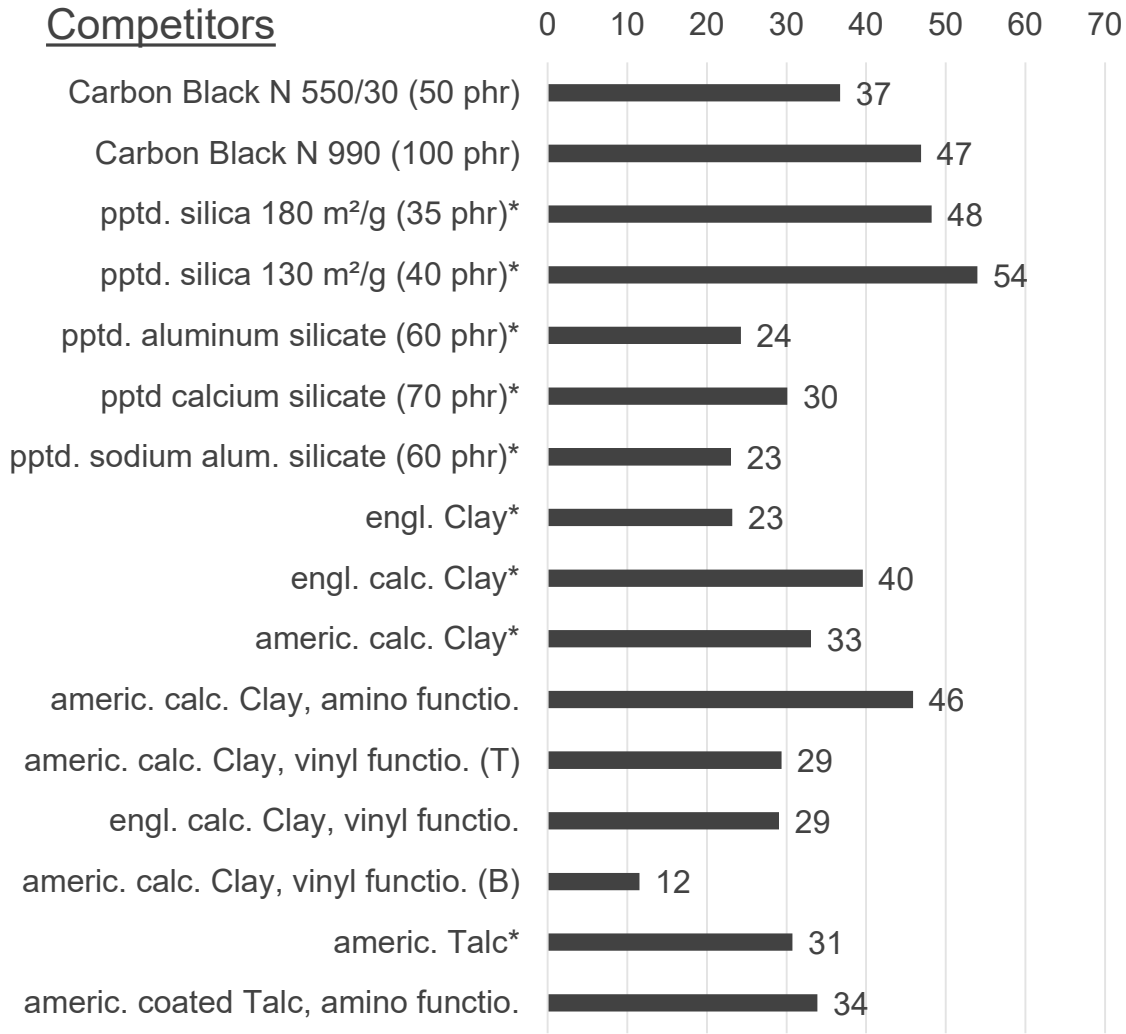




Hot air aging 168 h / 150 °C
Change of modulus 100 % in %

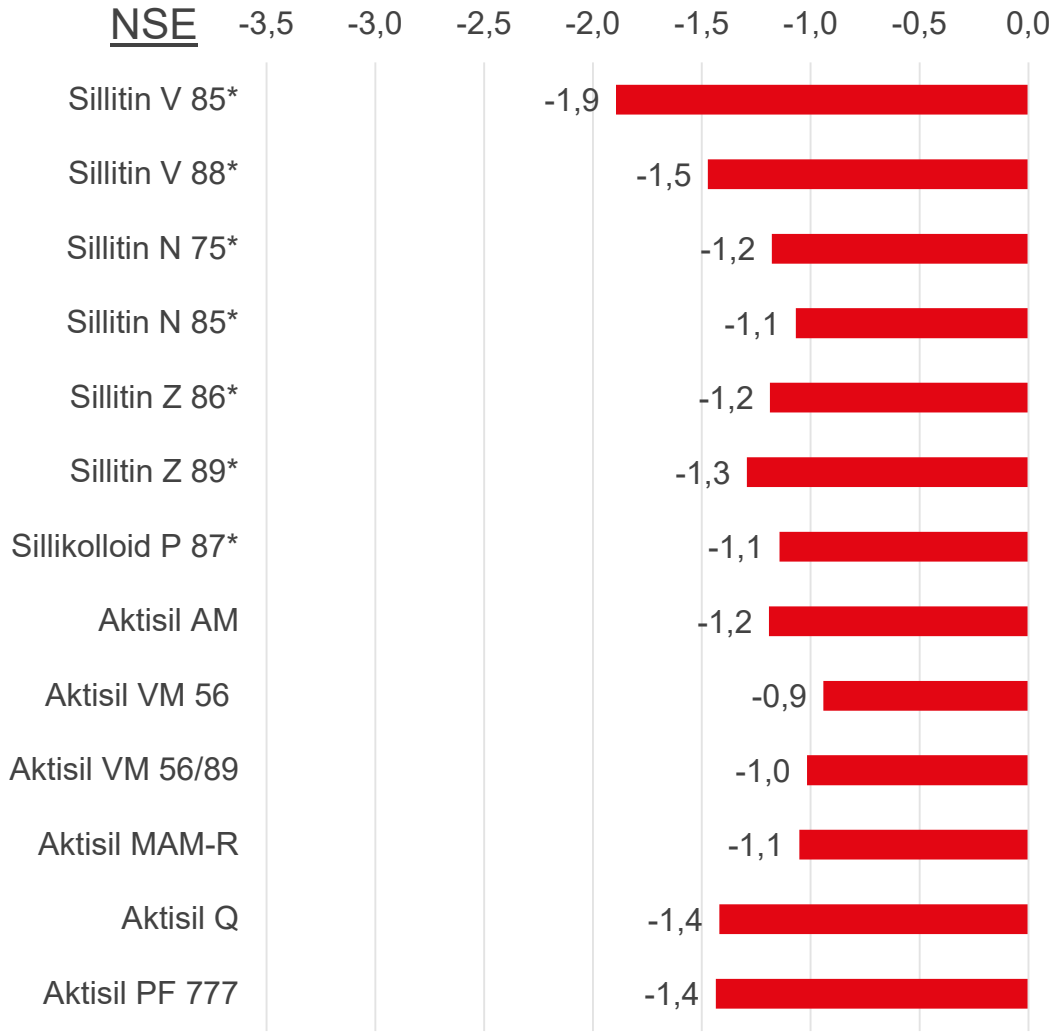
* with silane addition

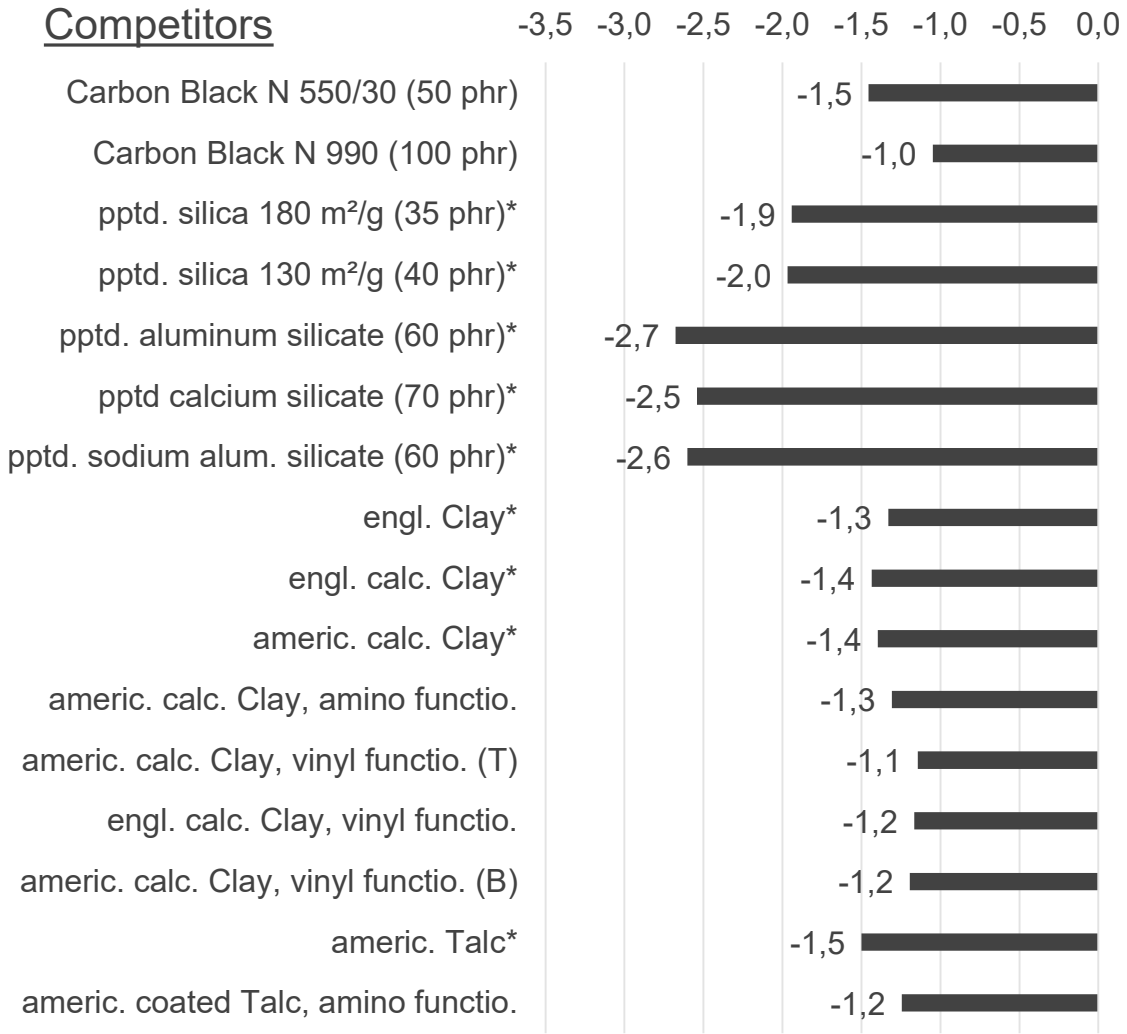




Hot air aging 168 h / 150 °C
Change of weight in %

* with silane addition





→ back to „Results“

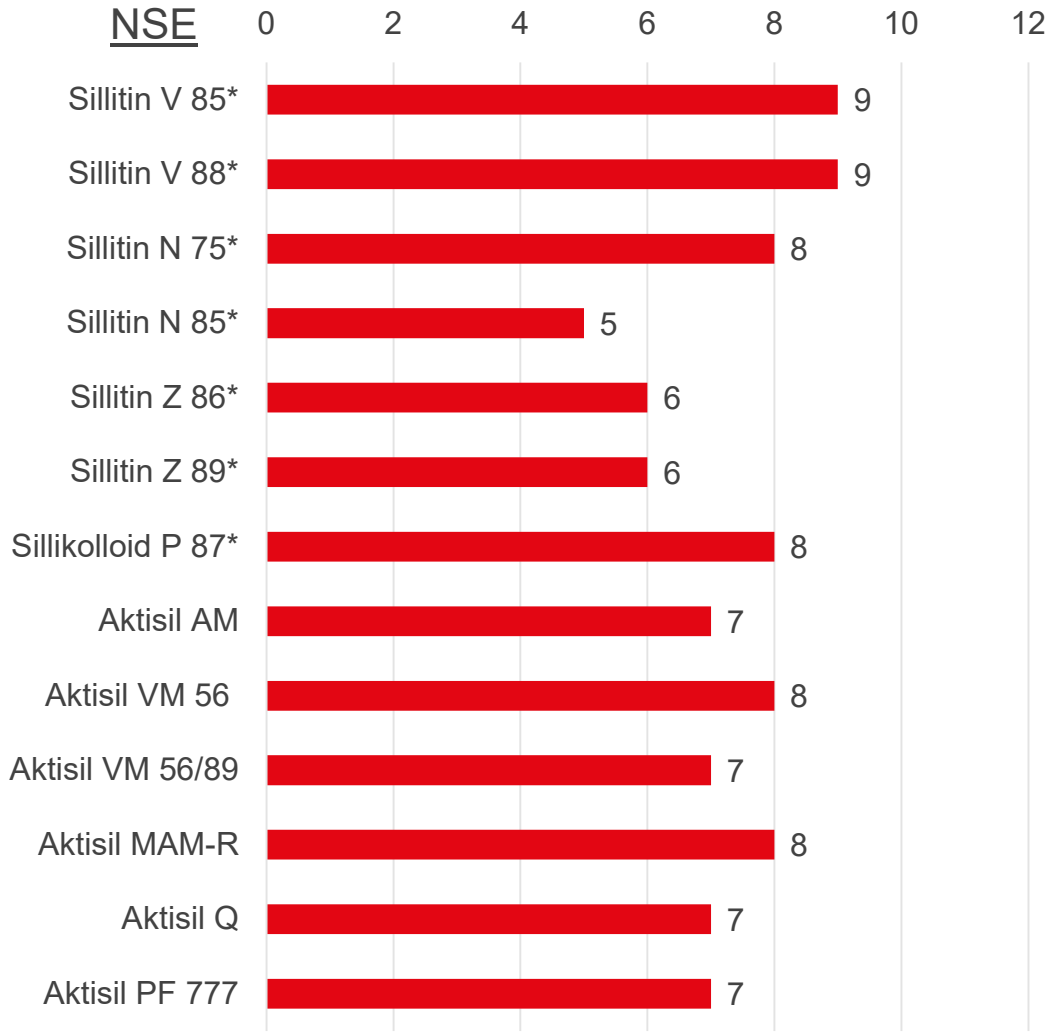
Hot air aging 504 h / 150 °C

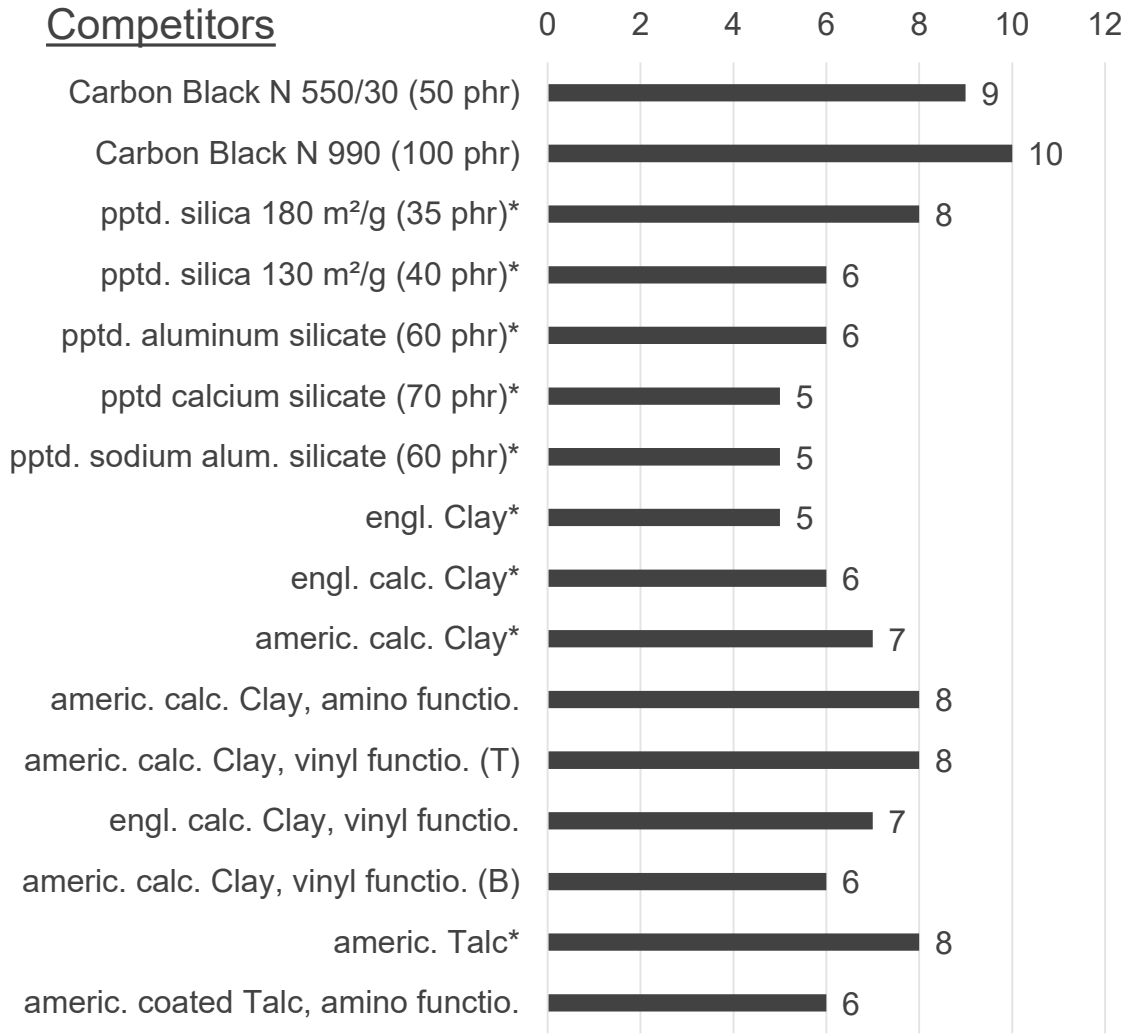
ISO 188, D

HOFFMANN MINERAL®
We supply materials for good ideas

Hot air aging 504 h / 150 °C
Change of hardness in Shore A – piled up S2 dumbbells

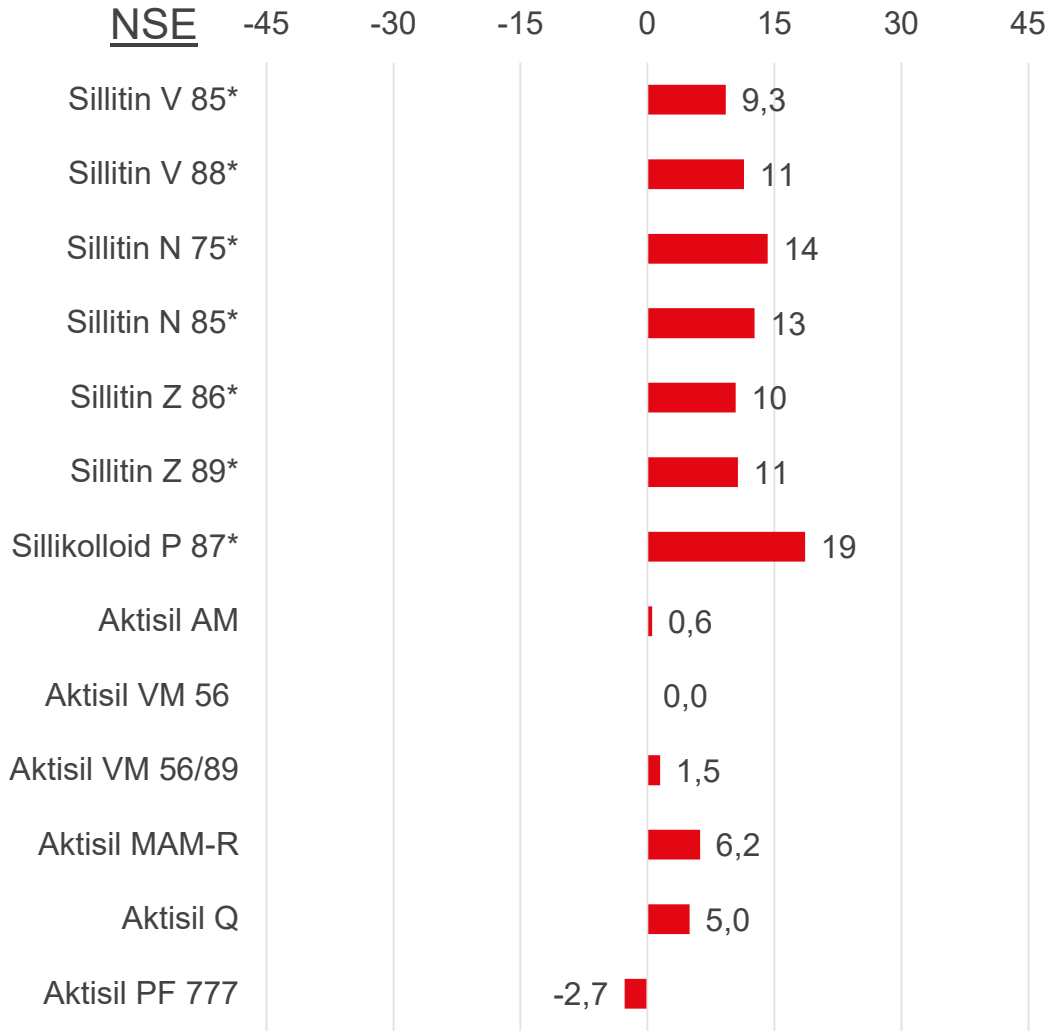
* with silane addition

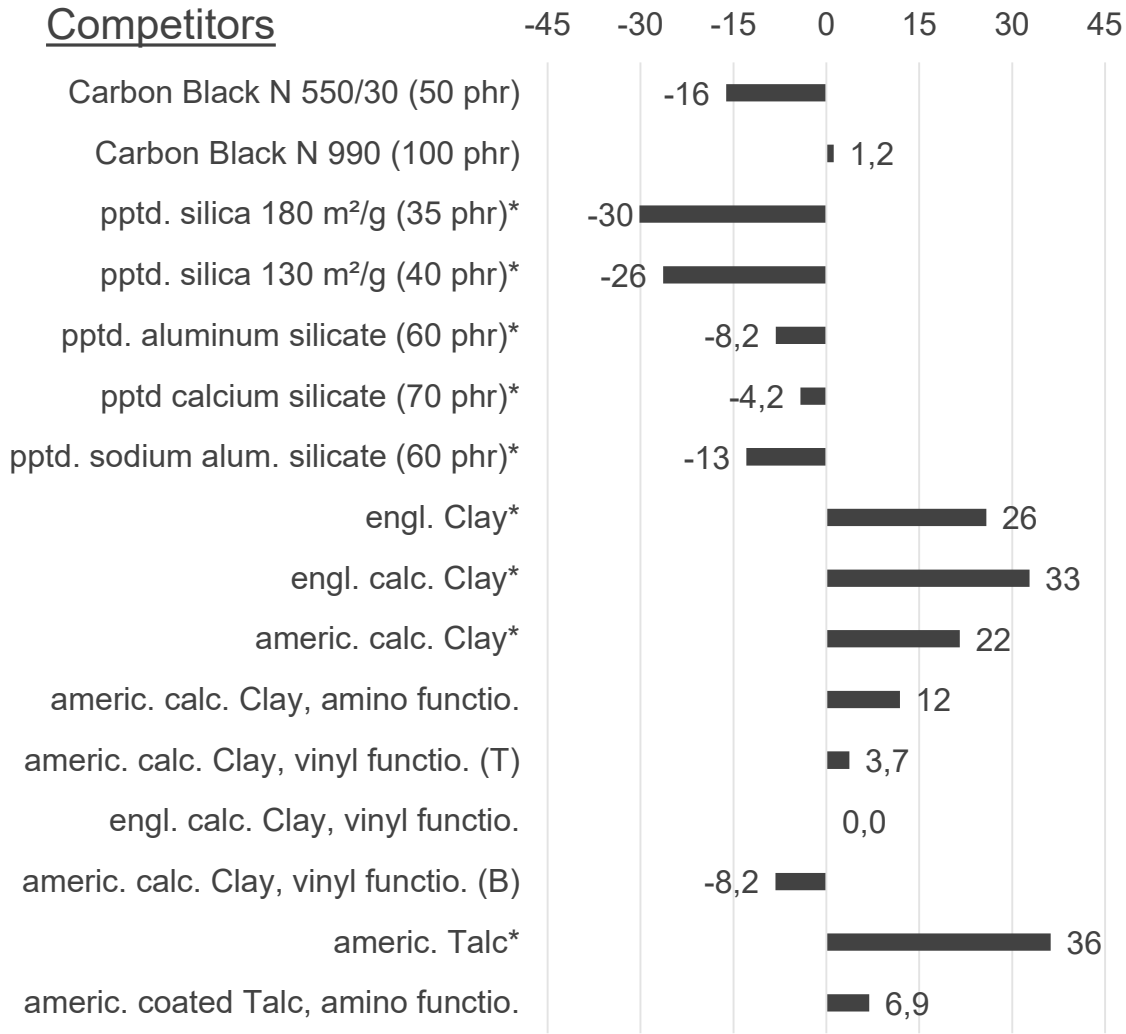




Hot air aging 504 h / 150 °C
Change of tensile strength in %

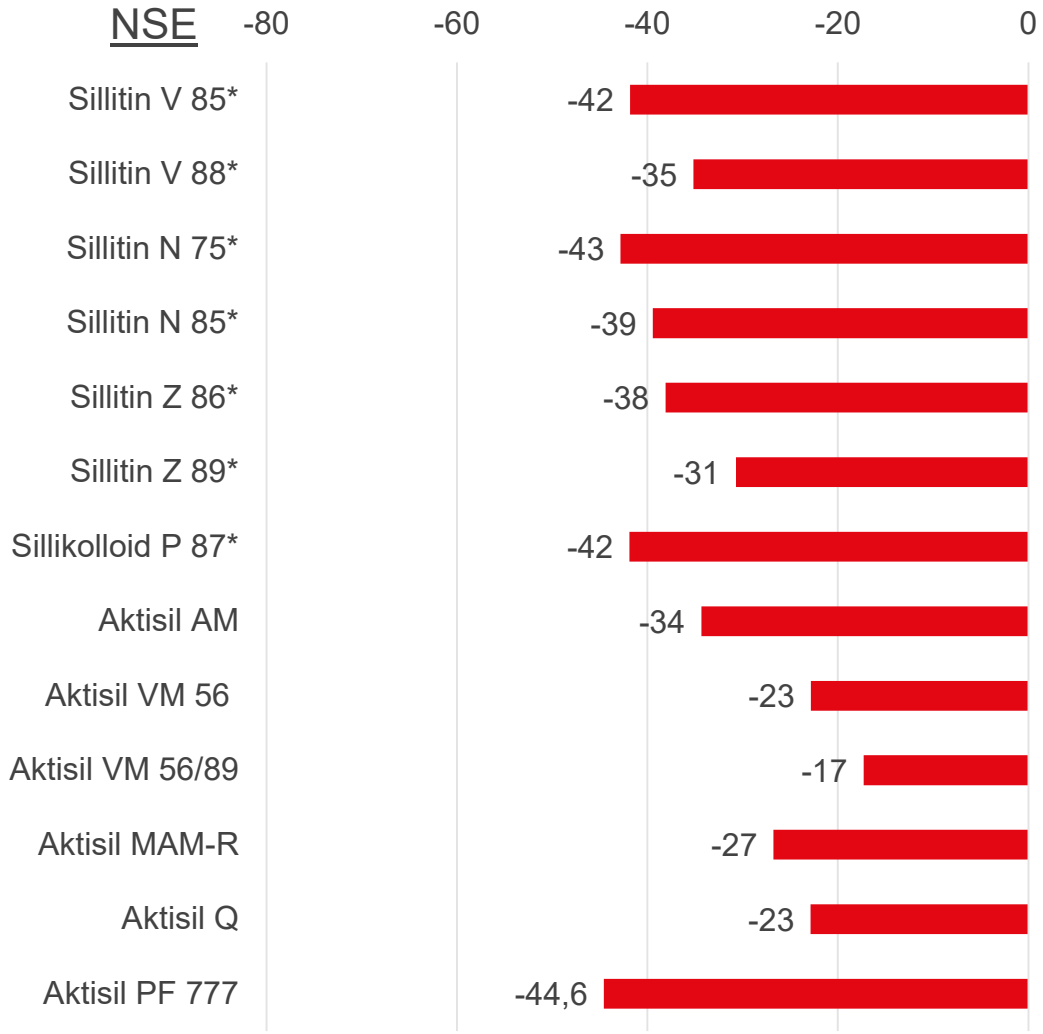
* with silane addition

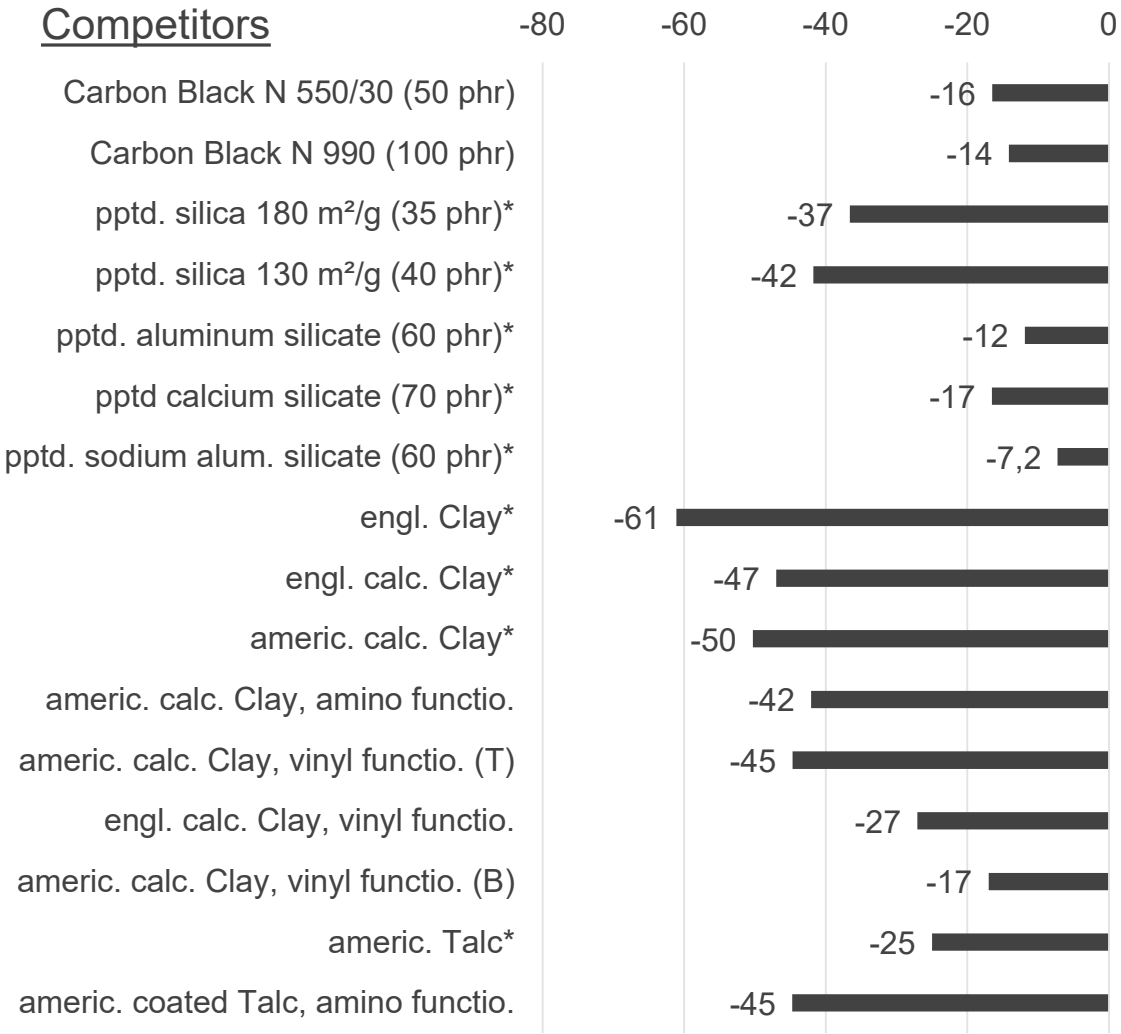




Hot air aging 504 h / 150 °C
Change of elongation at break in rel.%

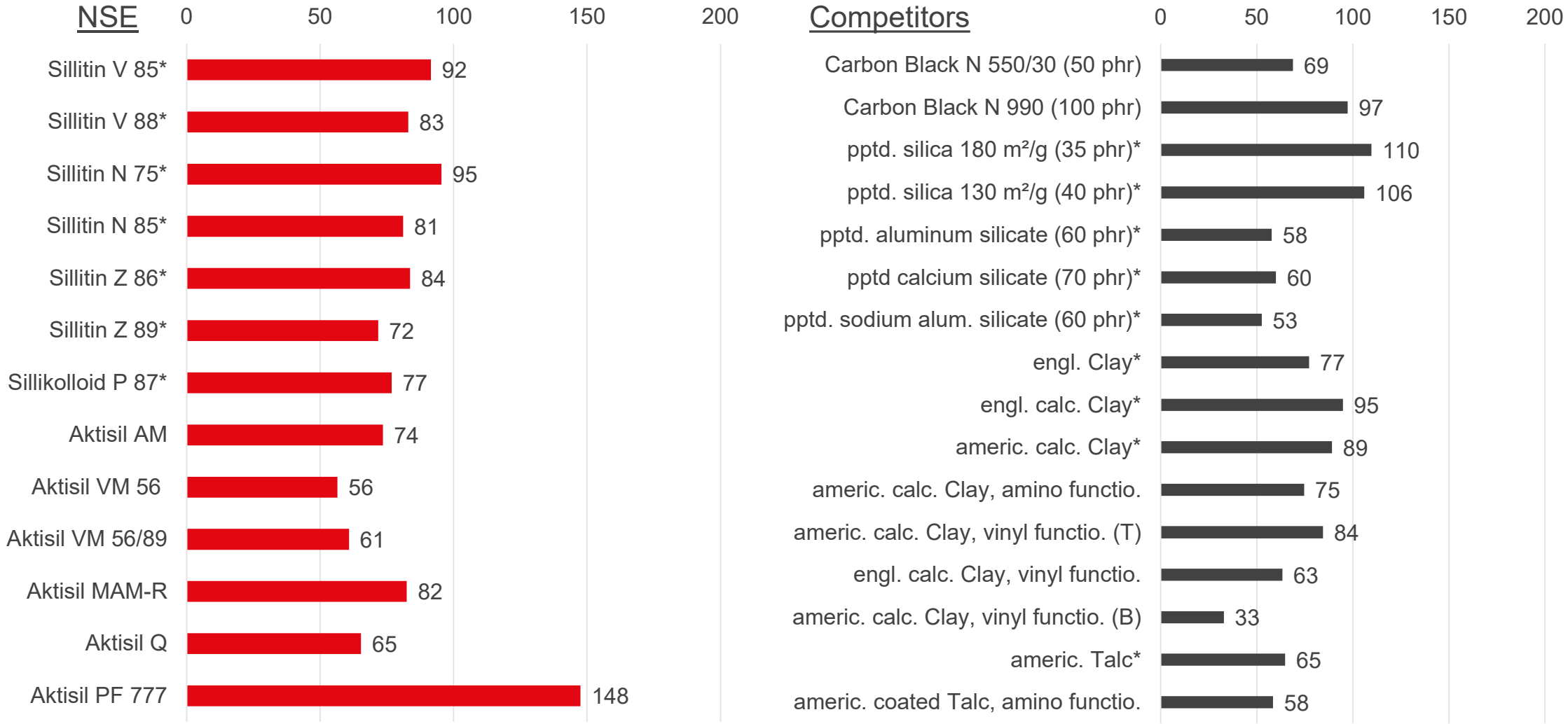
* with silane addition





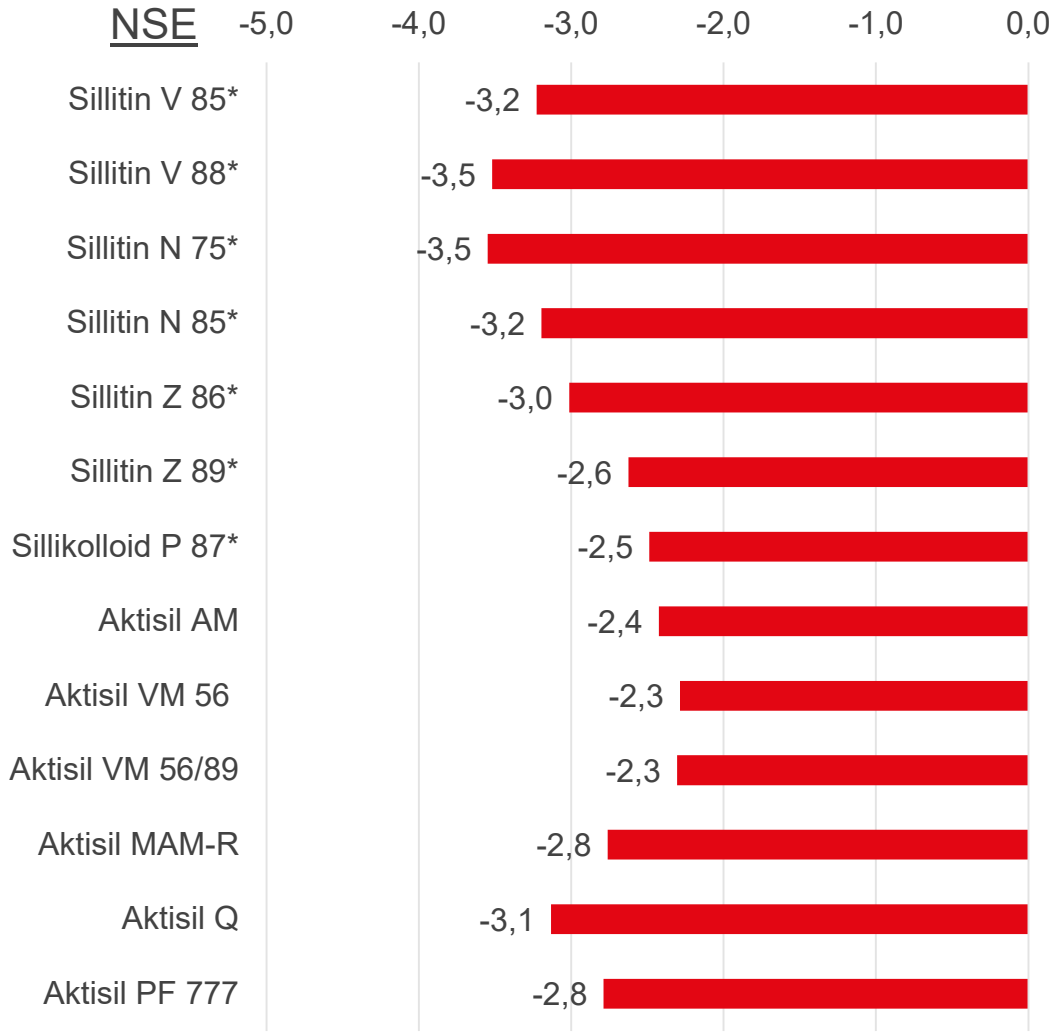
Hot air aging 504 h / 150 °C
Change of modulus 100 % in %

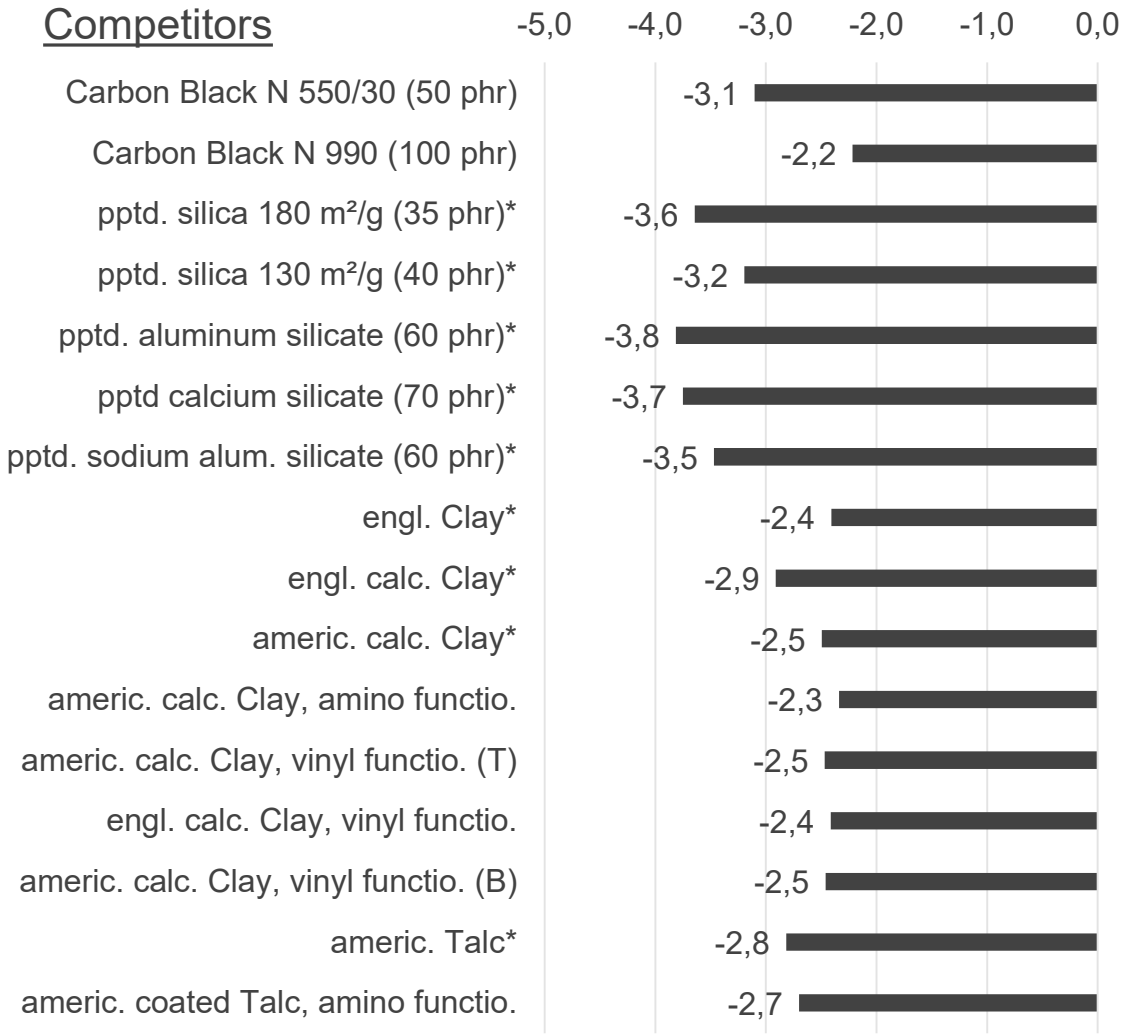
* with silane addition



Hot air aging 504 h / 150 °C
Change of weight in %

* with silane addition





→ back to „Results“

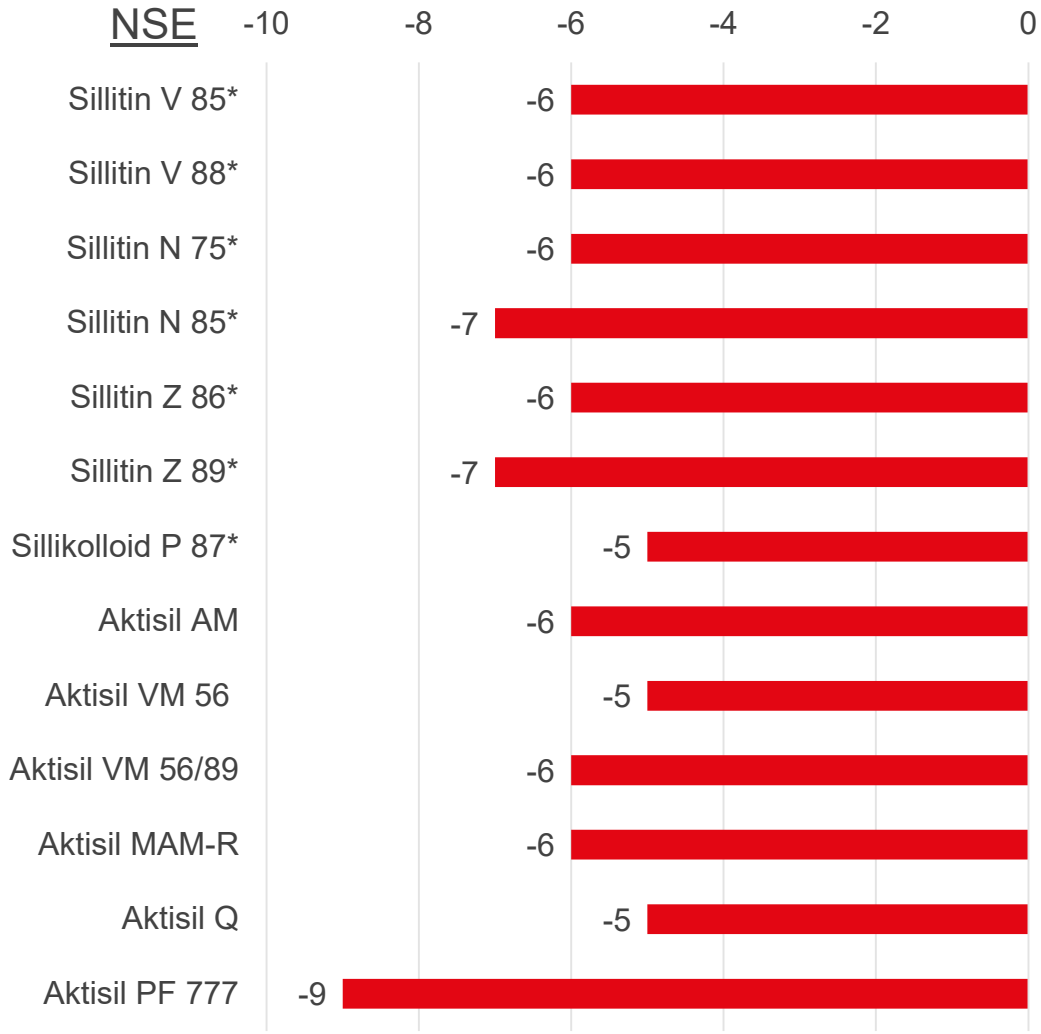
Immersion in reference oil IRM 903 168 h / 150 °C

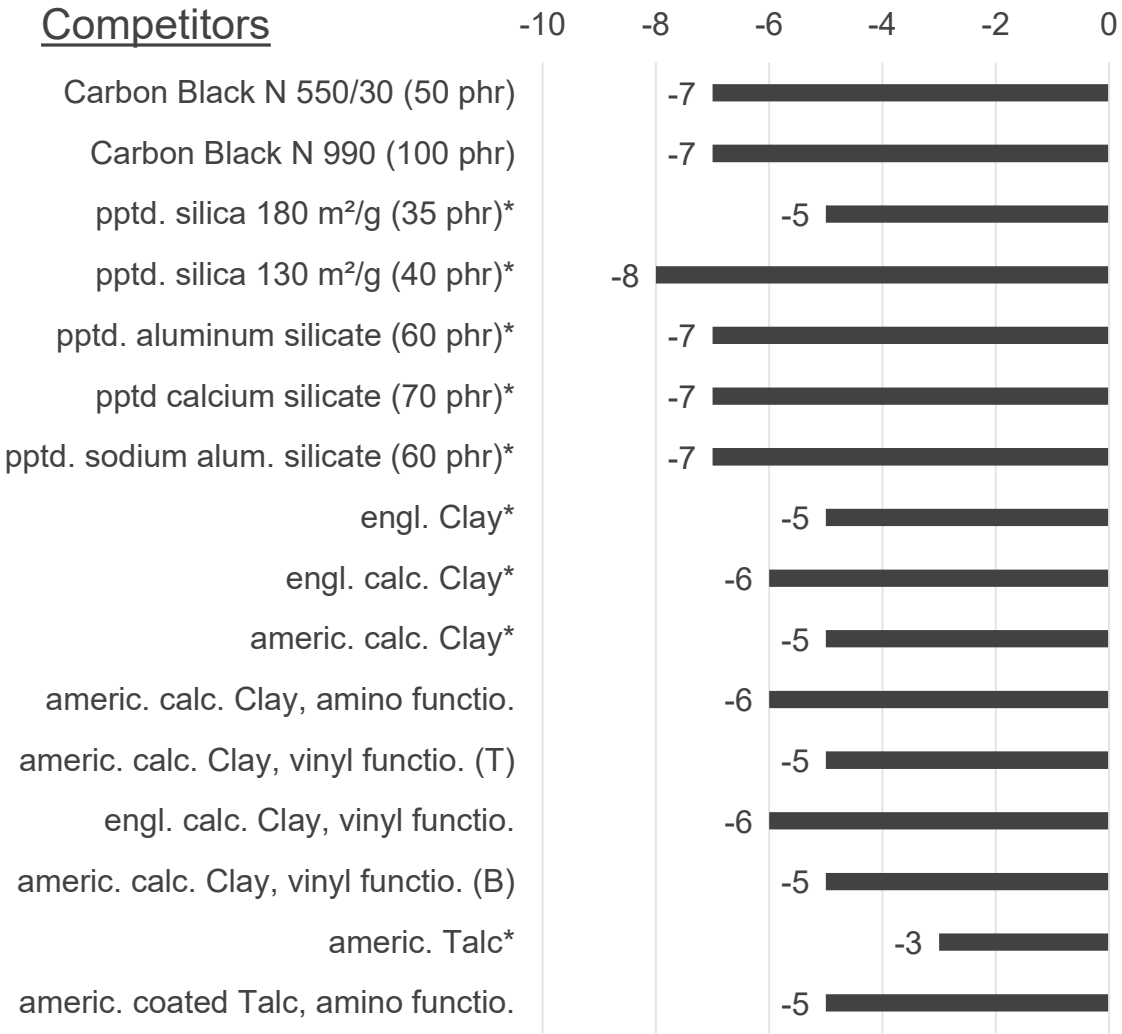
DIN ISO 1817

HOFFMANN MINERAL®
We supply materials for good ideas

Immersion in reference oil IRM 903 168 h / 150 °C
Change of hardness in Shore A – piled up S2 dumbbells

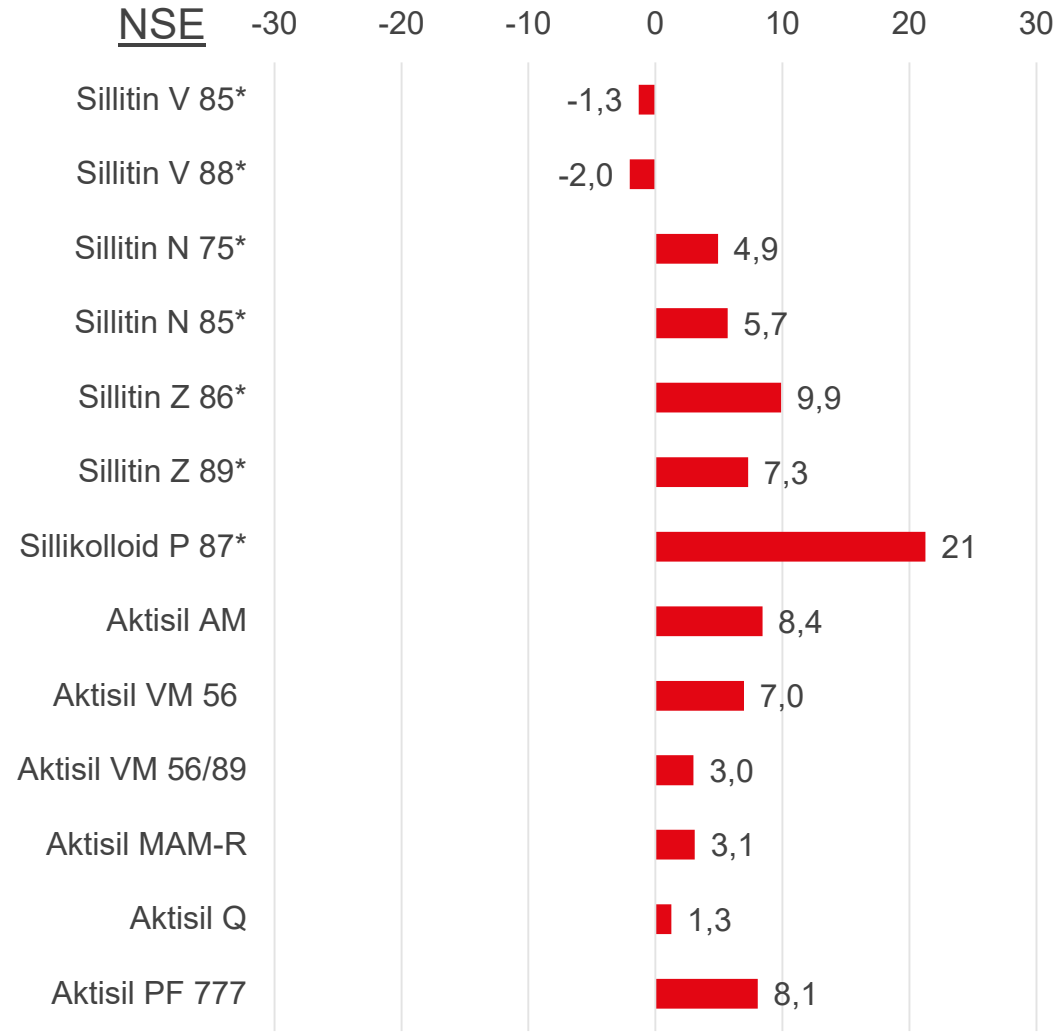
* with silane addition

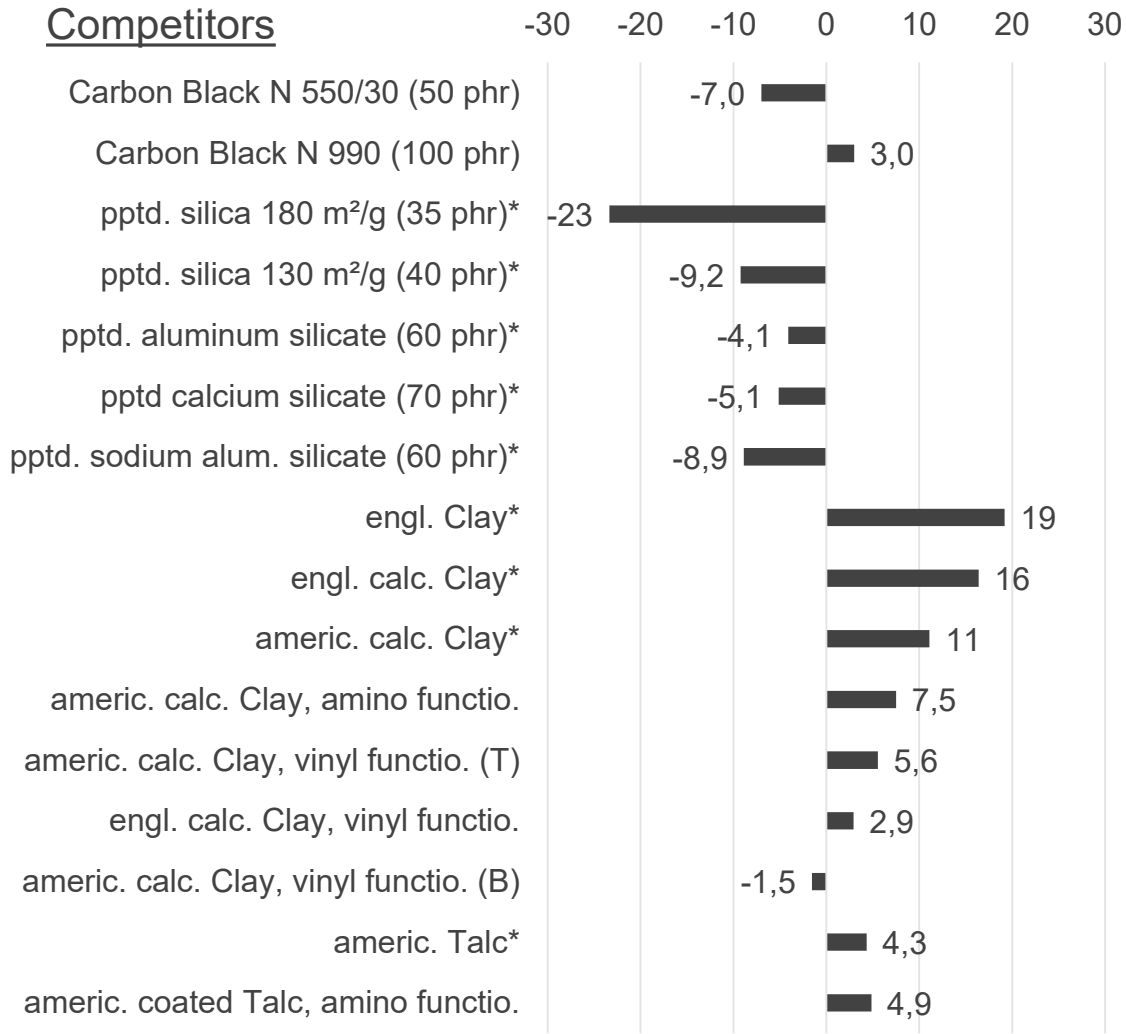




Immersion in reference oil IRM 903 168 h / 150 °C
Change of tensile strength in %

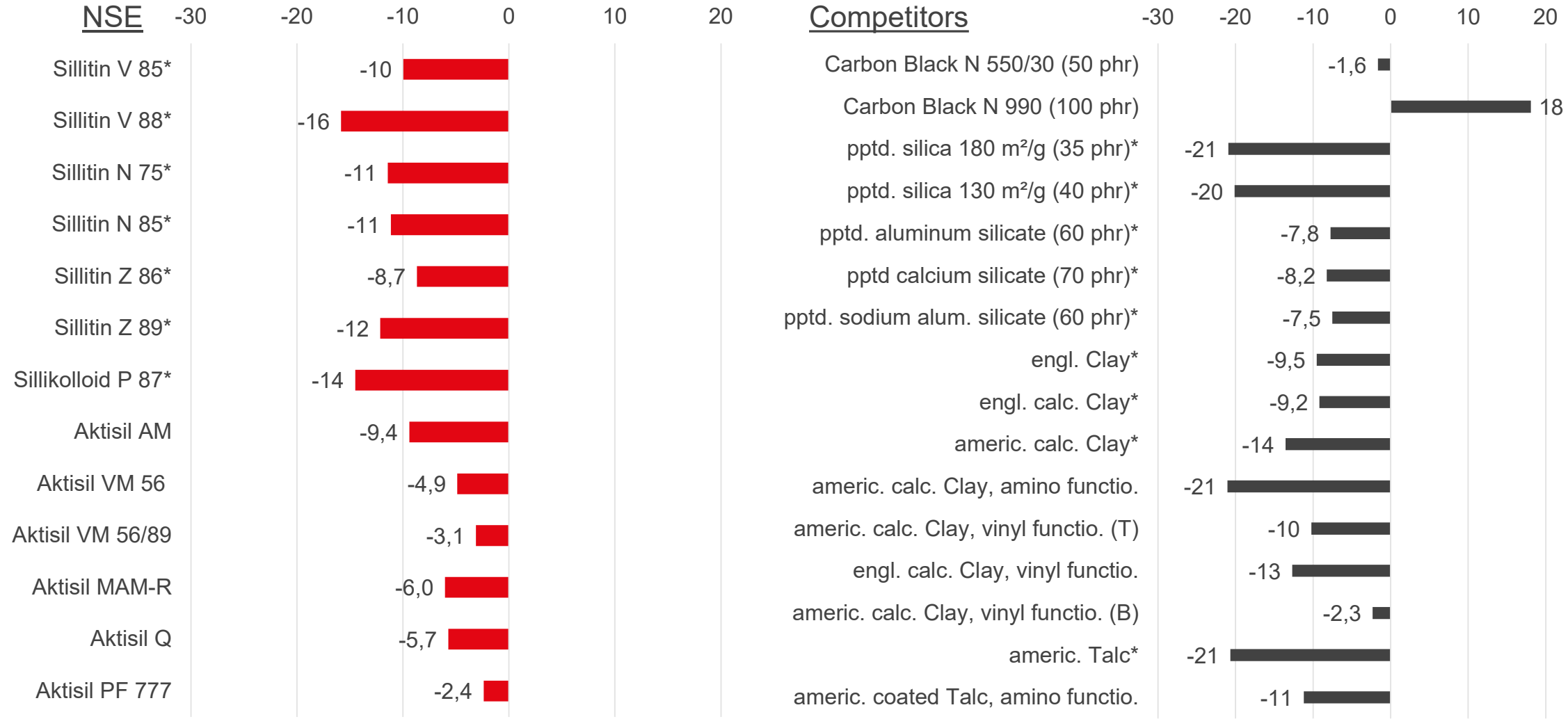
* with silane addition





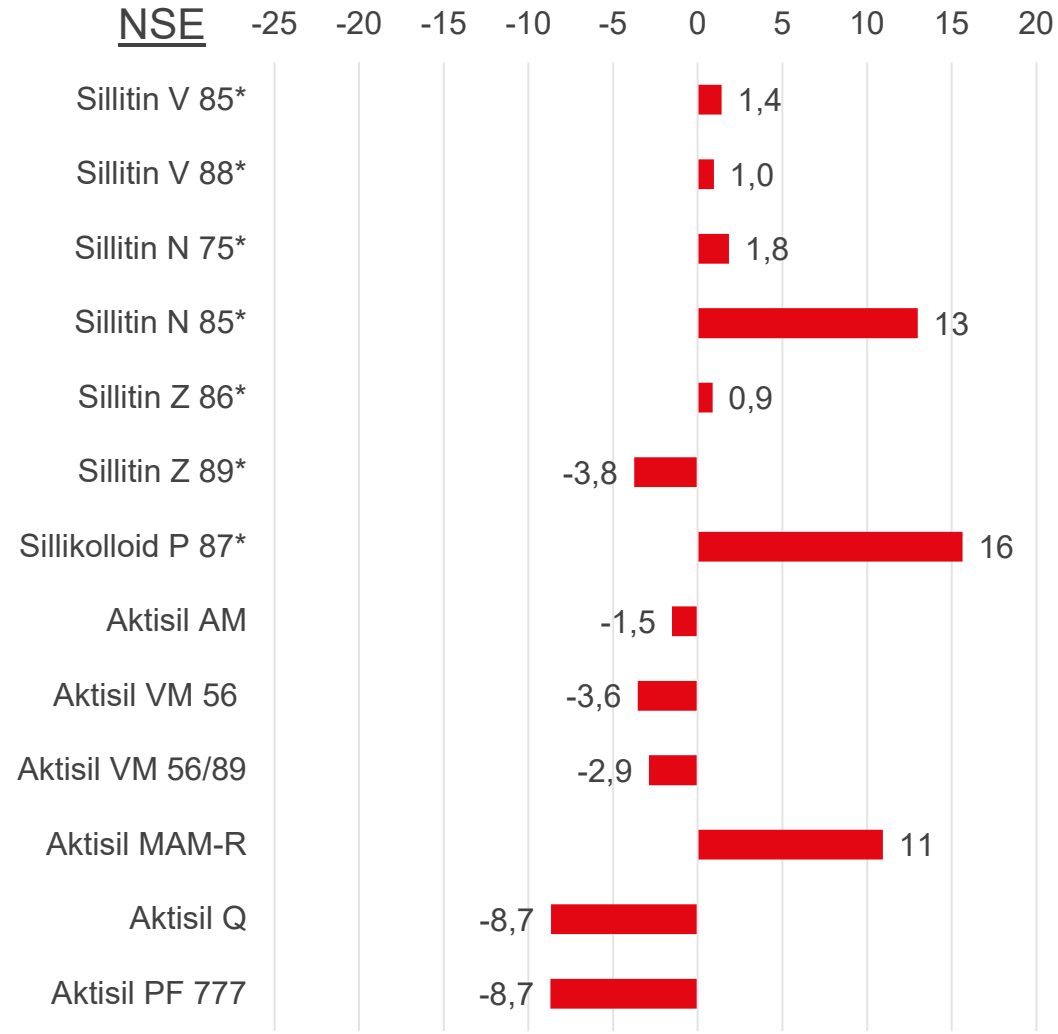
Immersion in reference oil IRM 903 168 h / 150 °C
Change of elongation at break in rel.%

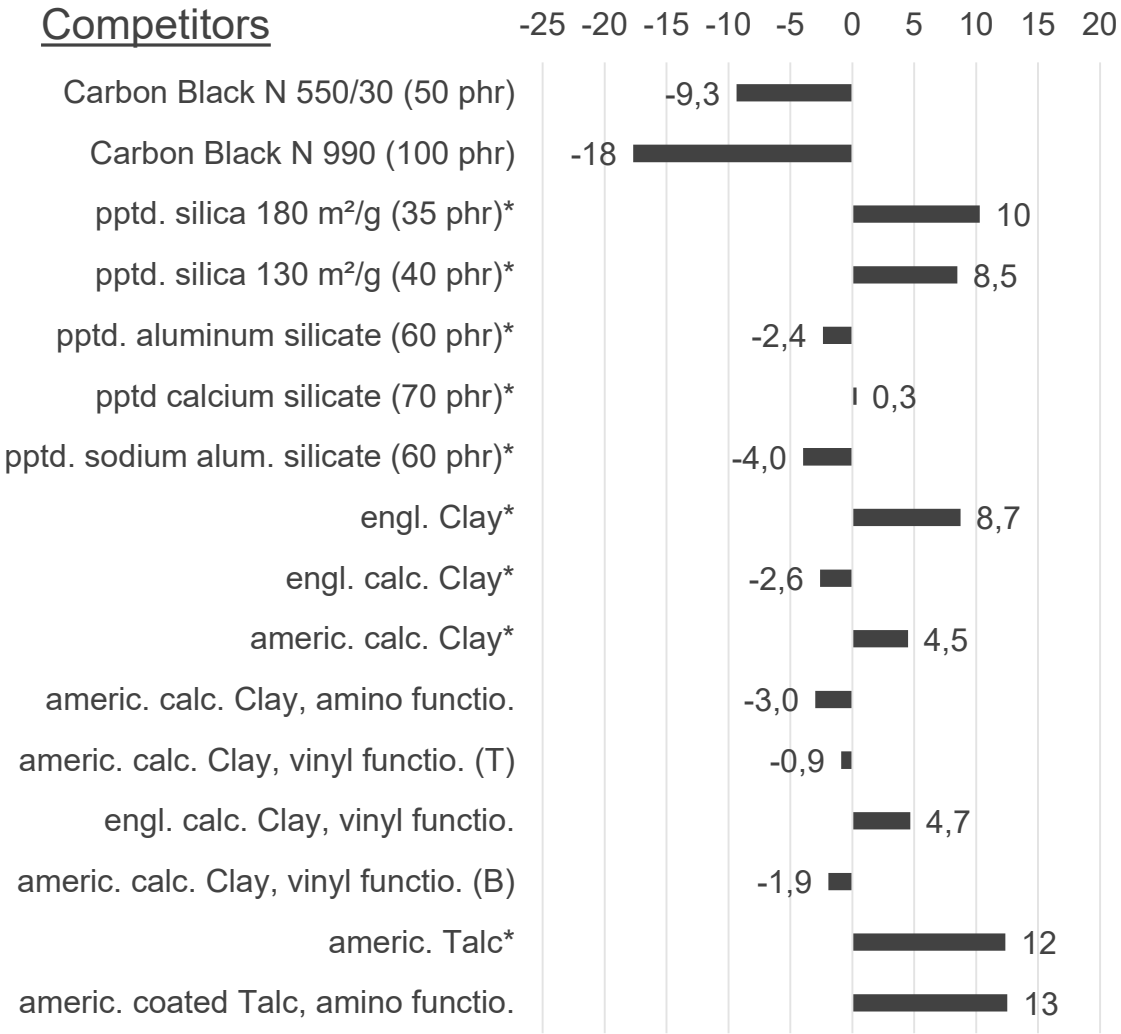
* with silane addition



Immersion in reference oil IRM 903 168 h / 150 °C
Change of modulus 100 % in %

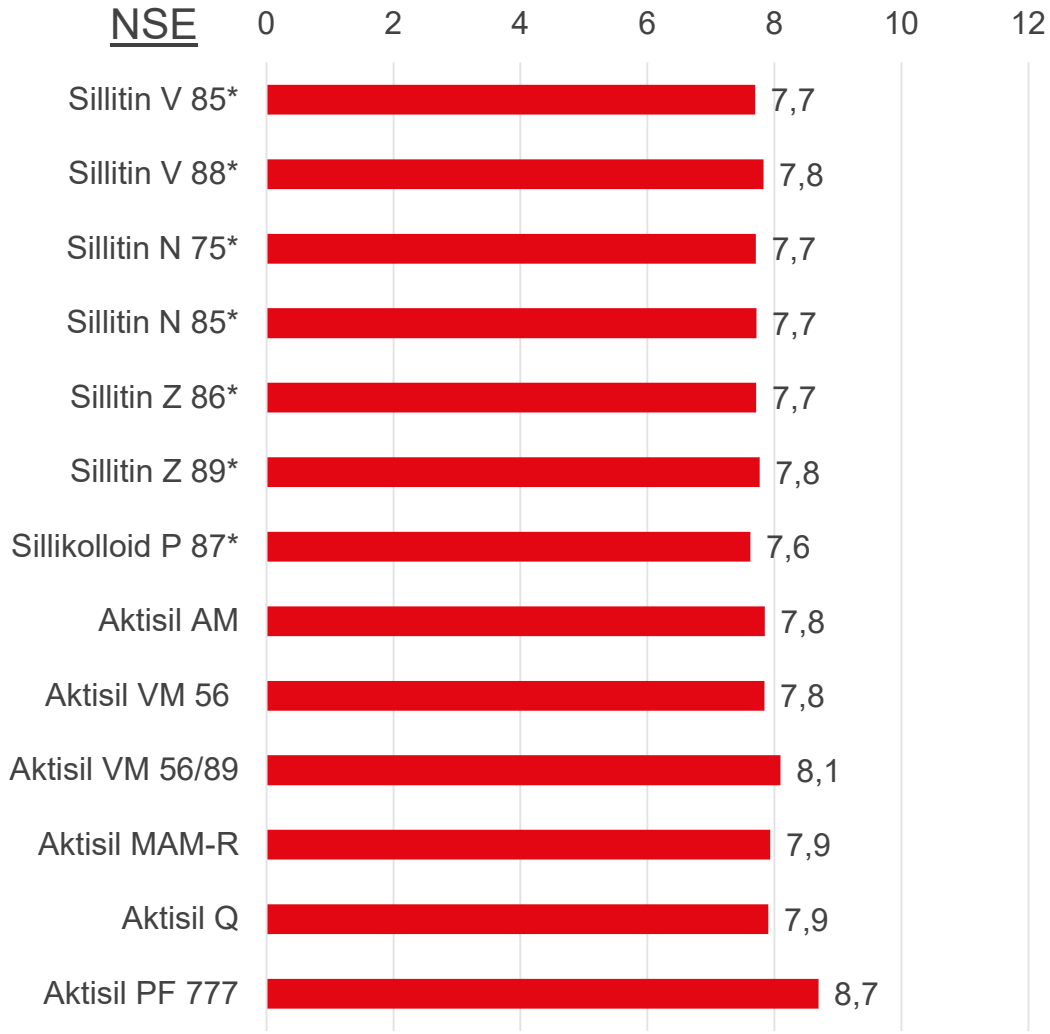
* with silane addition

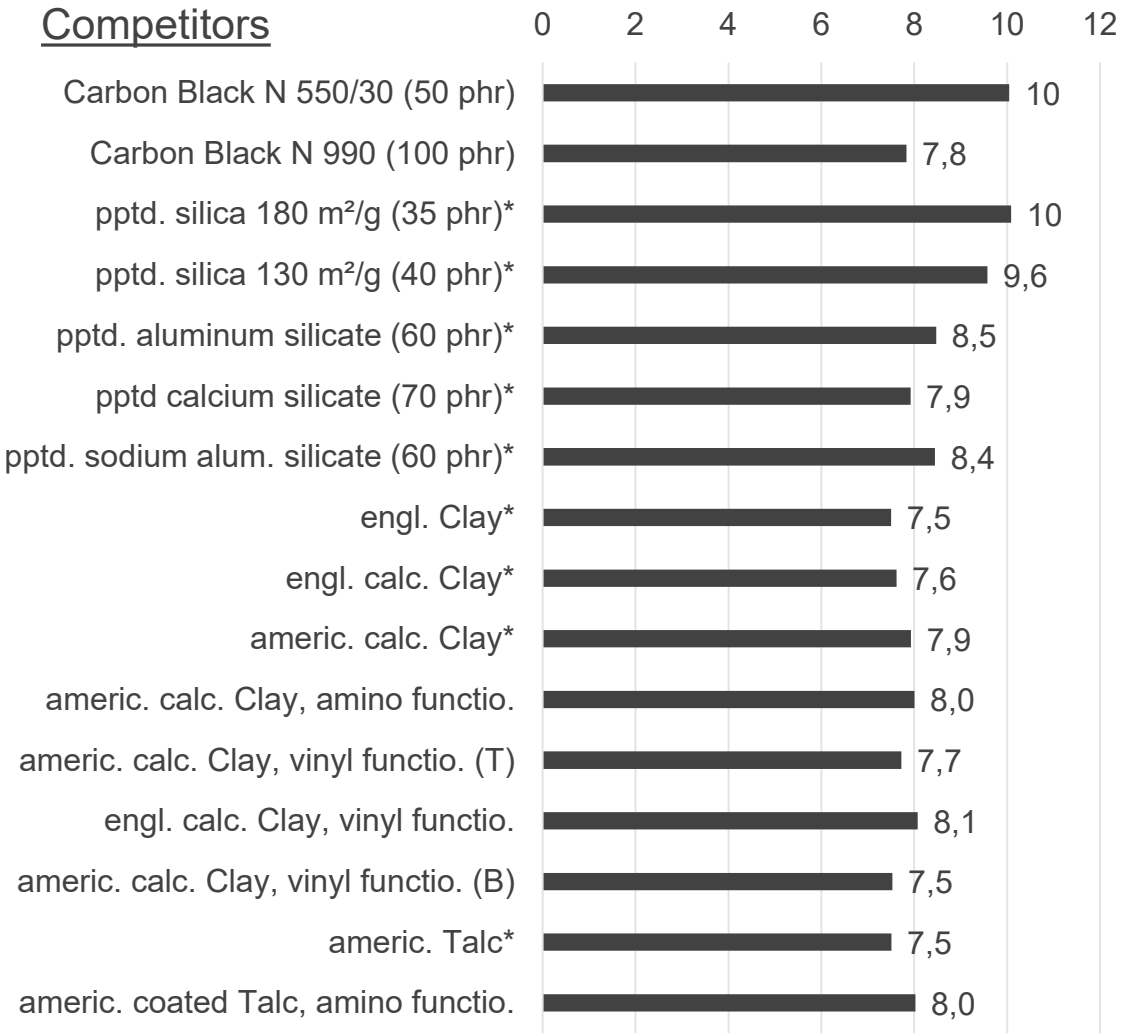




Immersion in reference oil IRM 903 168 h / 150 °C
Change of weight in %

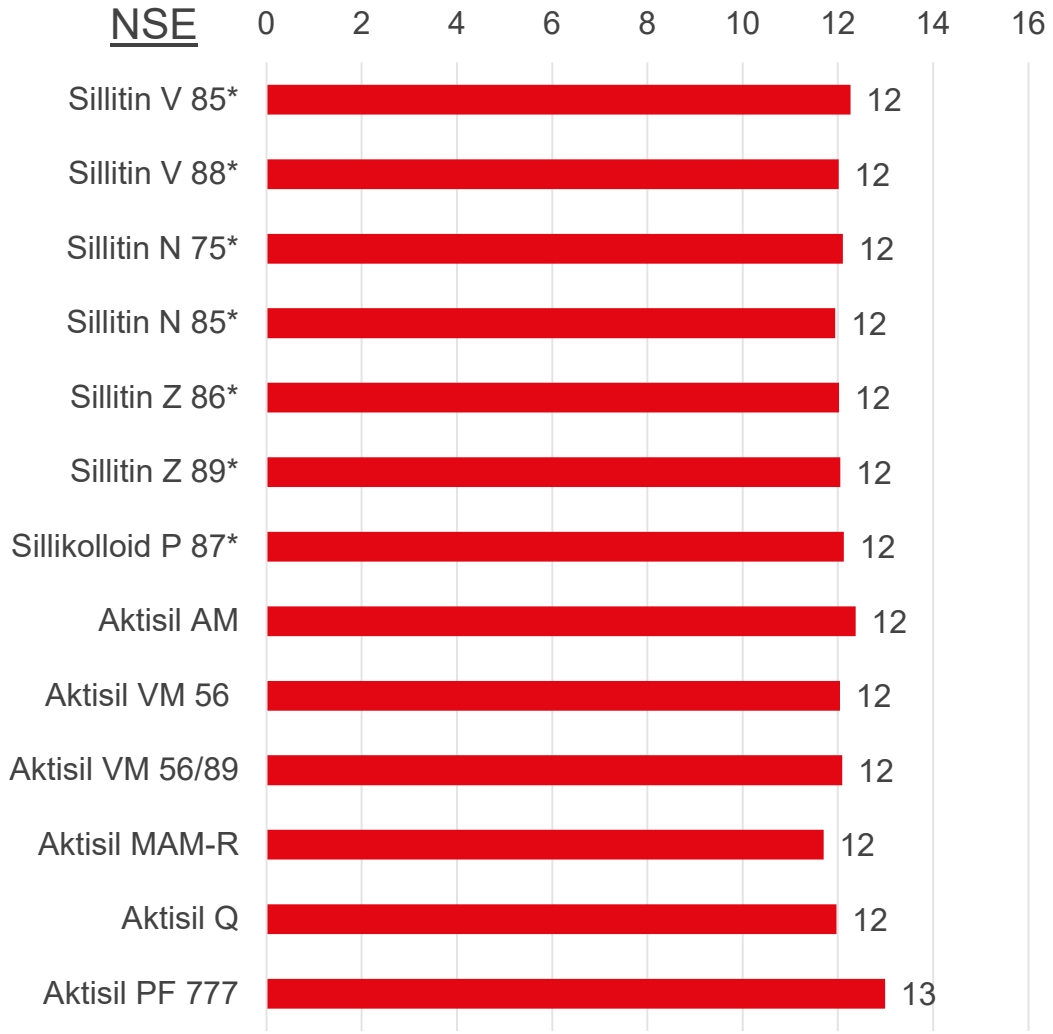
* with silane addition

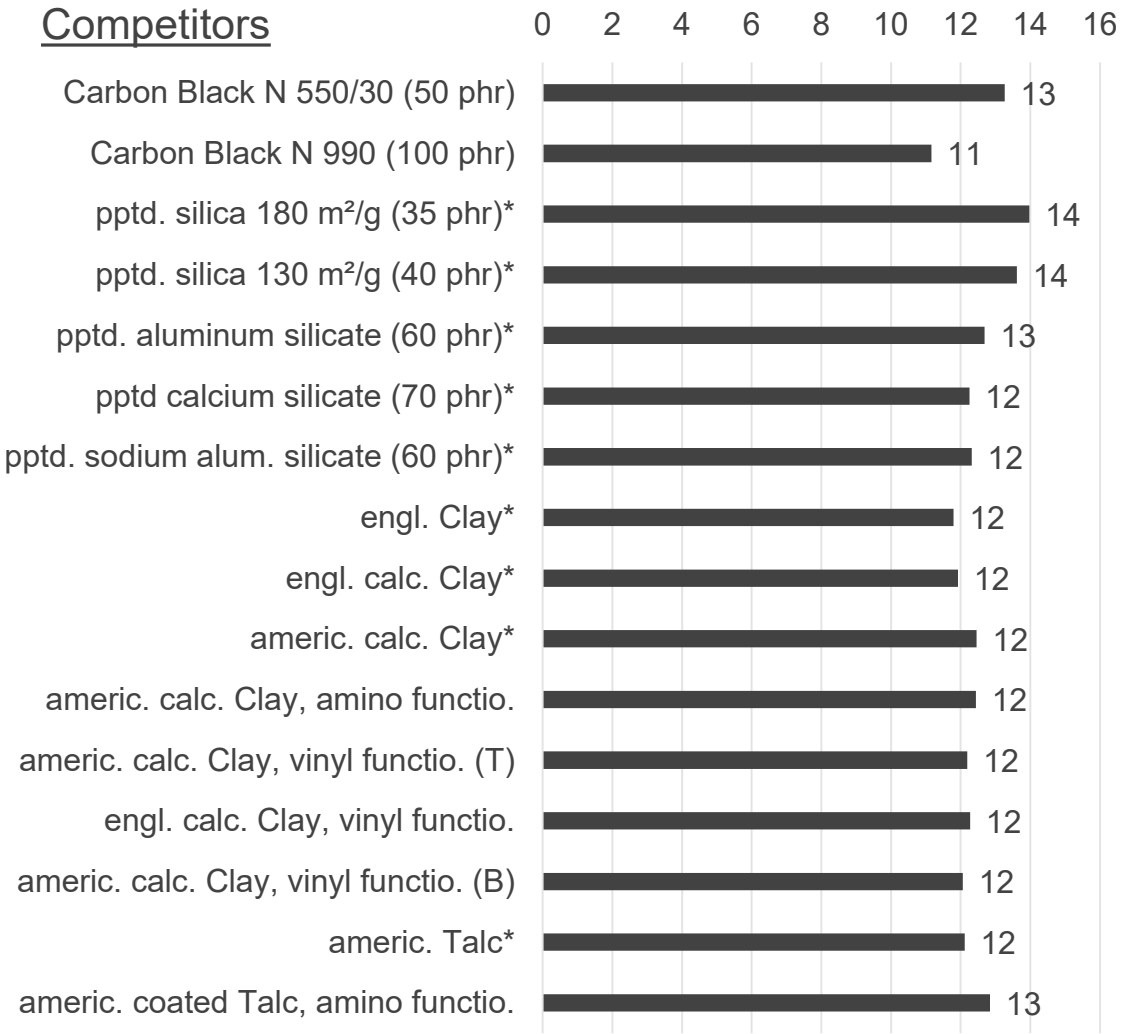




Immersion in reference oil IRM 903 168 h / 150 °C
Change of volume in %

* with silane addition





Summary: Special features …

… of the products based on Neuburg Siliceous Earth (NSE) in peroxide cross-linked HNBR-Rubber (Sillitin, Aktisil)

Rheology and vulcanization with NSE:

- medium viscosities, good processing properties and short conversion times during vulcanization for NSE

Tensile test Neuburg Siliceous Earth:

- medium tensile strength and elongation at break and high modulus 100 % with Sillikolloid P 87, Aktisil VM 56 and Sillitin Z 86
- Aktisil PF 777 achieves the highest elongation at break of all fillers tested

Abrasion resistance Neuburg Siliceous Earth vs. competitors:

- very good abrasion resistance with almost all Neuburg Siliceous Earth grades
- Sillikolloid P 87, Aktisil AM, Aktisil VM 56 and Aktisil VM 56/89 are comparable to precipitated silica (130 m^2/g) and achieve better values than all other tested natural fillers and also than carbon black N 990

Tear resistance trouser test specimen:

- the values of the pptd. aluminum silica, calcium silica and sodium aluminum silica are exceeded by all Neuburg Siliceous Earth grades
- best tear resistance is achieved with Sillikolloid P 87, even better than the pptd. silica (130 m^2/g) and the pptd. silica (180 m^2/g)

Summary: Special features …

… of the products based on Neuburg Siliceous Earth (NSE) in peroxide cross-linked HNBR-Rubber (Sillitin, Aktisil)

Compression set (non post cured and post cured):

- very good values with Sillitin V 85 and V 88, methacryl-functionalized Aktisil and vinyl-functionalized Aktisil
- similar and better values as carbon black N 550, N 990, pptd. silica (aluminum; calcium; sodium aluminum) and calcined kaolin
- the non post cured NSE compounds even achieve similarly good values as competitors post cured → the best values are achieved here with Aktisil VM 56 and Aktisil VM 56/89

Hot air aging 150 °C NSE vs. competitors:

- very good resistance to hot air with vinyl and methacryl functionalized Aktisil → very little to no change in tensile strength, elongation at break and modulus 100 %
- better resistance even against many of the tested competitors
- weight loss after hot air aging of the NSE is comparable to the competitors with the exception of pptd. Silica (130 m^2/g and 180 m^2/g) and especially compared to pptd. aluminum silica, calcium silica and sodium aluminum silica, which show a slightly higher weight loss

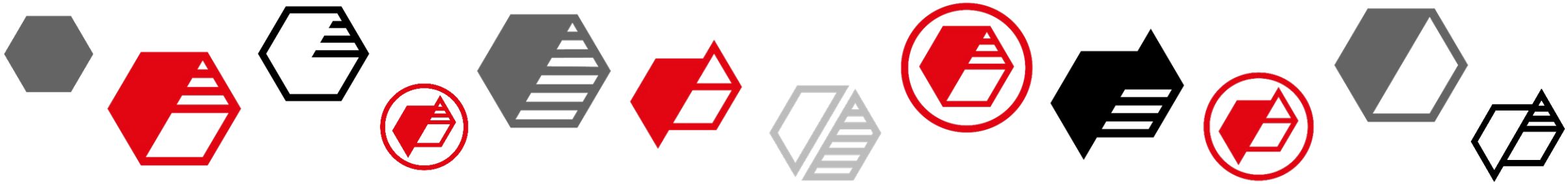
Immersion in reference oil IRM 903 168 h / 150 °C:

- good oil resistance with almost all NSE products, very good resistance with Aktisil VM 56 and Aktisil VM 56/89
- low increase in weight/volume with Neuburg Siliceous Earth, lower weight increase than carbon black N 990 and pptd. silica

We supply materials for good ideas!

HOFFMANN MINERAL GmbH
Muenchener Straße 75
DE-86633 Neuburg (Donau)

Phone: +49 8431 53-0
Internet: www.hoffmann-mineral.com
E-mail: info@hoffmann-mineral.com



→ back to „Results“

→ back to „Contents“

Results in tabular form

HOFFMANN MINERAL®
We supply materials for good ideas

Properties of raw compound – Mooney Viscosity und Scorch

* with silane addition

NSE	Mooney Viscosity ML 1+4 100 °C [MU]	Mooney Scorch ML+5 120 °C [mins.]
Sillitin V 85*	79	9.6
Sillitin V 88*	83	9.5
Sillitin N 75*	83	9.7
Sillitin N 85*	87	9.8
Sillitin Z 86*	84	9.0
Sillitin Z 89*	80	11.4
Sillikolloid P 87*	86	11.8
Aktisil AM	91	8.3
Aktisil VM 56	90	8.5
Aktisil VM 56/89	87	9.6
Aktisil MAM-R	83	8.9
Aktisil Q	83	7.7
Aktisil PF 777	81	10.9

Competitors	Mooney Viscosity ML 1+4 100 °C [MU]	Mooney Scorch ML+5 120 °C [mins.]
Carbon Black N 550/30 (50 phr)	83	7.9
Carbon Black N 990 (100 phr)	76	9.0
pptd. silica 180 m²/g (35 phr)*	89	> 90 mins.
pptd. silica 130 m²/g (40 phr)*	87	> 90 mins.
pptd. aluminum silicate (60 phr)*	88	12.6
pptd calcium silicate (70 phr)*	82	17.1
pptd. sodium alum. silicate (60 phr)*	83	13.9
engl. Clay*	69	15.3
engl. calc. Clay*	85	9.5
americ. calc. Clay*	79	11.9
americ. calc. Clay, amino functio.	81	10.1
americ. calc. Clay, vinyl functio. (T)	83	11.8
engl. calc. Clay, vinyl functio.	85	10.2
americ. calc. Clay, vinyl functio. (B)	81	15.5
americ. Talc*	64	20.0
americ. coated Talc, amino functio.	70	14.3

Remark: rapid and slight increase in viscosity at the beginning, up to 15 MU between minute 5 and minute 25 of the measuring time. The curve then flattens out sharply and remains largely constant until the end of the 90-minutes measurement period. Mooney Scorch ML +35 is not achieved with any compound.

Properties of raw compound – Neuburg Siliceous Earth

* with silane addition

Rotorless curemeter 180 °C	Torque minimum [Nm]	Cross-linking yield [Nm]	Conversion time t5 [min.]	Conversion time t90 [min.]	Max. speed of vulcanization [Nm/min.]	Time until max. speed of vulcanization [min.]	tan δ
Sillitin V 85*	0.038	0.48	0.45	3.31	0.32	0.68	0.04
Sillitin V 88*	0.038	0.50	0.44	3.49	0.32	0.77	0.04
Sillitin N 75*	0.041	0.51	0.45	3.63	0.32	0.79	0.05
Sillitin N 85*	0.041	0.51	0.44	3.52	0.32	0.77	0.04
Sillitin Z 86*	0.042	0.50	0.44	3.55	0.32	0.79	0.05
Sillitin Z 89*	0.039	0.49	0.44	3.46	0.31	0.83	0.04
Sillikolloid P 87*	0.045	0.49	0.43	3.33	0.32	0.75	0.06
Aktisil AM	0.045	0.51	0.45	3.68	0.32	0.77	0.04
Aktisil VM 56	0.046	0.52	0.44	3.65	0.34	0.76	0.05
Aktisil VM 56/89	0.043	0.51	0.43	3.60	0.33	0.77	0.04
Aktisil MAM-R	0.040	0.50	0.43	3.39	0.33	0.76	0.04
Aktisil Q	0.038	0.50	0.42	3.42	0.32	0.76	0.04
Aktisil PF 777	0.035	0.45	0.47	3.41	0.28	0.88	0.06

Properties of raw compound – Competitors

* with silane addition

Rotorless curemeter 180 °C	Torque minimum [Nm]	Cross-linking yield [Nm]	Conversion time t5 [min.]	Conversion time t90 [min.]	Max. speed of vulcanization [Nm/min.]	Time until max. speed of vulcanization [min.]	tan δ
Carbon Black N 550/30 (50 phr)	0.040	0.52	0.43	4.04	0.29	0.85	0.04
Carbon Black N 990 (100 phr)	0.036	0.52	0.43	3.78	0.30	0.72	0.04
pptd. silica 180 m²/g (35 phr)*	0.055	0.57	0.42	3.62	0.36	0.81	0.04
pptd. silica 130 m²/g (40 phr)*	0.060	0.60	0.42	3.57	0.37	0.79	0.03
pptd. aluminum silicate (60 phr)*	0.048	0.47	0.47	2.60	0.36	0.78	0.04
pptd calcium silicate (70 phr)*	0.038	0.42	0.49	2.36	0.32	0.88	0.05
pptd. sodium alum. silicate (60 phr)*	0.046	0.46	0.47	2.64	0.34	0.80	0.05
engl. Clay*	0.037	0.39	0.46	3.32	0.26	0.77	0.06
engl. calc. Clay*	0.042	0.49	0.48	3.52	0.31	0.87	0.05
americ. calc. Clay*	0.038	0.46	0.47	3.60	0.29	0.87	0.04
americ. calc. Clay, amino functio.	0.042	0.48	0.47	3.69	0.29	0.86	0.04
americ. calc. Clay, vinyl functio. (T)	0.040	0.48	0.49	3.66	0.29	0.85	0.04
engl. calc. Clay, vinyl functio.	0.044	0.48	0.46	3.53	0.31	0.81	0.05
americ. calc. Clay, vinyl functio. (B)	0.041	0.49	0.47	3.74	0.31	0.85	0.05
americ. Talc*	0.034	0.40	0.48	3.70	0.25	0.80	0.05
americ. coated Talc, amino functio.	0.039	0.39	0.47	3.91	0.22	0.82	0.06

Properties of vulcanizate (test specimen non post cured) – Neuburg Siliceous Earth

* with silane addition

	Compression set 24 h / 150 °C / 25 % Def. [%]
Sillitin V 85*	20.3
Sillitin V 88*	19.7
Sillitin N 75*	21.4
Sillitin N 85*	21.1
Sillitin Z 86*	23.2
Sillitin Z 89*	21.1
Sillikolloid P 87*	23.6
Aktisil AM	21.7
Aktisil VM 56	18.4
Aktisil VM 56/89	17.3
Aktisil MAM-R	25.5
Aktisil Q	22.2
Aktisil PF 777	37.3

	Compression set 24 h / 150 °C / 25 % Def. [%]
Carbon Black N 550/30 (50 phr)	24.0
Carbon Black N 990 (100 phr)	20.7
pptd. silica 180 m²/g (35 phr)*	32.0
pptd. silica 130 m²/g (40 phr)*	28.4
pptd. aluminum silicate (60 phr)*	25.7
pptd calcium silicate (70 phr)*	25.7
pptd. sodium alum. silicate (60 phr)*	26.1
engl. Clay*	33.6
engl. calc. Clay*	22.1
americ. calc. Clay*	22.2
americ. calc. Clay, amino functio.	25.4
americ. calc. Clay, vinyl functio. (T)	23.8
engl. calc. Clay, vinyl functio.	22.6
americ. calc. Clay, vinyl functio. (B)	24.6
americ. Talc*	34.6
americ. coated Talc, amino functio.	40.6

Properties of vulcanizate (test specimen post cured: 4 h / 150 °C) – Neuburg Siliceous Earth

* with silane addition

	Hardness [Shore A]	Tensile strength [MPa]	Elongation at break [%]	Modulus 100 % [%]	Tear resistance Trousers specimen [N/mm]	Tear resistance Graves specimen [N/mm]	Rebound elasticity [%]	Abrasion loss 10 N [mm³]	Compression set 24 h / 150 °C / 25 % Def. [%]	Compression set 168 h / 175 °C / 25 % Def. [%]
Sillitin V 85*	71	15.1	340	6.4	5.6	17.9	51	94	17.1	38.2
Sillitin V 88*	71	14.9	349	6.3	5.5	17.9	51	99	16.4	35.9
Sillitin N 75*	72	16.2	299	7.1	5.6	18.2	50	84	18.1	38.8
Sillitin N 85*	73	15.8	302	7.1	5.1	16.9	50	87	18.2	39.2
Sillitin Z 86*	73	18.2	292	8.0	4.8	16.5	50	81	19.5	40.7
Sillitin Z 89*	72	17.8	316	6.7	4.7	16.4	51	77	18.2	38.7
Sillikolloid P 87*	74	18.8	293	9.1	9.4	17.3	49	71	21.3	42.8
Aktisil AM	72	17.8	263	7.2	4.8	15.5	51	74	20.2	41.2
Aktisil VM 56	73	20.1	250	8.7	3.9	14.0	50	74	17.8	39.8
Aktisil VM 56/89	72	20.0	259	7.3	3.9	13.8	51	76	16.7	35.9
Aktisil MAM-R	72	16.1	290	6.5	4.9	15.7	52	88	17.3	36.6
Aktisil Q	70	16.0	283	6.1	4.5	14.7	52	102	15.7	34.6
Aktisil PF 777	72	14.9	454	4.7	7.5	20.2	50	146	30.9	49.7

Properties of vulcanizate (test specimen post cured: 4 h / 150 °C) – Competitors

* with silane addition

	Hardness [Shore A]	Tensile strength [MPa]	Elongation at break [%]	Modulus 100 % [%]	Tear resistance Trousers specimen [N/mm]	Tear resistance Graves specimen [N/mm]	Rebound elasticity [%]	Abrasion loss 10 N [mm³]	Compression set 24 h / 150 °C / 25 % Def. [%]	Compression set 168 h / 175 °C / 25 % Def. [%]
Carbon Black N 550/30 (50 phr)	71	27.2	323	6.0	5.1	15.3	49	55	16.9	42.4
Carbon Black N 990 (100 phr)	70	16.6	296	4.9	6.5	16.2	50	102	16.6	38.4
pptd. silica 180 m²/g (35 phr)*	70	33.8	411	3.1	8.5	17.6	50	73	26.4	52.9
pptd. silica 130 m²/g (40 phr)*	72	29.2	370	3.5	7.5	15.0	50	63	22.4	48.6
pptd. aluminum silicate (60 phr)*	70	24.5	285	5.1	3.3	12.0	52	59	17.5	39.6
pptd calcium silicate (70 phr)*	71	21.5	273	5.9	3.7	12.8	51	70	17.0	40.3
pptd. sodium alum. silicate (60 phr)*	70	24.8	284	5.0	3.4	11.3	51	60	16.5	38.2
engl. Clay*	74	15.1	361	10.0	8.2	21.7	48	112	25.5	53.3
engl. calc. Clay*	73	12.8	273	7.3	6.1	17.5	50	123	16.3	37.2
americ. calc. Clay*	71	15.3	320	8.0	5.3	17.2	50	116	16.7	45.1
americ. calc. Clay, amino functio.	72	16.0	270	7.7	5.9	17.8	51	92	16.1	36.2
americ. calc. Clay, vinyl functio. (T)	71	16.2	306	7.7	5.8	17.6	50	109	17.7	34.6
engl. calc. Clay, vinyl functio.	73	17.0	234	7.9	4.7	15.4	49	100	15.1	38.7
americ. calc. Clay, vinyl functio. (B)	73	19.5	181	11.4	3.7	12.7	49	80	16.9	38.4
americ. Talc*	73	13.8	234	10.5	9.3	25.9	45	103	27.1	62.3
americ. coated Talc, amino functio.	76	14.4	372	9.3	10.2	26.6	47	98	33.3	65.7

Hot air aging 168 h / 150 °C – Neuburg Siliceous Earth

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]
Sillitin V 85*	5	3.3	-19.3	36.0	-1.89
Sillitin V 88*	3	2.7	-16.4	22.2	-1.47
Sillitin N 75*	3	6.8	-12.5	30.8	-1.18
Sillitin N 85*	3	6.3	-15.8	27.8	-1.07
Sillitin Z 86*	4	7.1	-11.6	29.3	-1.19
Sillitin Z 89*	4	6.7	-18.9	33.8	-1.29
Sillikolloid P 87*	5	12.2	-22.8	37.3	-1.14
Aktisil AM	5	7.9	-22.5	48.0	-1.19
Aktisil VM 56	5	-2.5	1.4	22.3	-0.94
Aktisil VM 56/89	4	-3.0	-2.3	24.6	-1.02
Aktisil MAM-R	4	0.6	-3.2	34.4	-1.05
Aktisil Q	5	-0.6	-3.3	19.3	-1.42
Aktisil PF 777	5	-8.7	-2.8	57.3	-1.44

Hot air aging 168 h / 150 °C – Competitors

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]
Carbon Black N 550/30 (50 phr)	7	-13.6	-3.2	36.7	-1.45
Carbon Black N 990 (100 phr)	6	1.2	-6.6	46.9	-1.05
pptd. silica 180 m²/g (35 phr)*	6	-21.9	-17.5	48.2	-1.94
pptd. silica 130 m²/g (40 phr)*	5	-19.9	-26.8	54.0	-1.97
pptd. aluminum silicate (60 phr)*	4	-9.8	-11.2	24.3	-2.68
pptd calcium silicate (70 phr)*	4	-5.1	-12.2	30.1	-2.54
pptd. sodium alum. silicate (60 phr)*	3	-13.7	-8.3	23.0	-2.60
engl. Clay*	1	1.3	-22.1	23.2	-1.33
engl. calc. Clay*	4	18.0	-17.5	39.6	-1.43
americ. calc. Clay*	4	7.8	-22.7	33.1	-1.40
americ. calc. Clay, amino functio.	3	13.1	-30.0	45.9	-1.31
americ. calc. Clay, vinyl functio. (T)	4	-0.6	-15.5	29.4	-1.14
engl. calc. Clay, vinyl functio.	4	1.2	-0.6	29.1	-1.17
americ. calc. Clay, vinyl functio. (B)	5	-4.1	4.9	11.5	-1.19
americ. Talc*	8	14.5	5.3	30.7	-1.50
americ. coated Talc, amino functio.	5	2.1	-18.7	33.9	-1.24

Hot air aging 504 h / 150 °C – Neuburg Siliceous Earth

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]
Sillitin V 85*	9	9.3	-41.8	91.5	-3.23
Sillitin V 88*	9	11.4	-35.2	83.0	-3.52
Sillitin N 75*	8	14.2	-42.8	95.5	-3.55
Sillitin N 85*	5	12.7	-39.4	81.1	-3.20
Sillitin Z 86*	6	10.4	-38.1	83.7	-3.01
Sillitin Z 89*	6	10.7	-30.7	71.7	-2.62
Sillikolloid P 87*	8	18.6	-41.9	76.8	-2.49
Aktisil AM	7	0.6	-34.3	73.5	-2.42
Aktisil VM 56	8	0.0	-22.8	56.5	-2.29
Aktisil VM 56/89	7	1.5	-17.3	60.8	-2.30
Aktisil MAM-R	8	6.2	-26.8	82.4	-2.76
Aktisil Q	7	5.0	-22.9	65.3	-3.13
Aktisil PF 777	7	-2.7	-44.6	147.6	-2.79

Hot air aging 504 h / 150 °C – Competitors

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]
Carbon Black N 550/30 (50 phr)	9	-16.2	-16.5	68.8	-3.10
Carbon Black N 990 (100 phr)	10	1.2	-14.1	97.3	-2.22
pptd. silica 180 m²/g (35 phr)*	8	-30.2	-36.6	109.6	-3.64
pptd. silica 130 m²/g (40 phr)*	6	-26.4	-41.7	105.9	-3.20
pptd. aluminum silicate (60 phr)*	6	-8.2	-11.9	57.8	-3.81
pptd calcium silicate (70 phr)*	5	-4.2	-16.5	60.0	-3.75
pptd. sodium alum. silicate (60 phr)*	5	-12.9	-7.2	52.6	-3.47
engl. Clay*	5	25.8	-61.1	77.2	-2.41
engl. calc. Clay*	6	32.8	-47.0	94.8	-2.91
americ. calc. Clay*	7	21.6	-50.3	89.1	-2.49
americ. calc. Clay, amino functio.	8	11.9	-42.1	74.6	-2.34
americ. calc. Clay, vinyl functio. (T)	8	3.7	-44.7	84.5	-2.47
engl. calc. Clay, vinyl functio.	7	0.0	-27.1	63.3	-2.41
americ. calc. Clay, vinyl functio. (B)	6	-8.2	-17.0	32.9	-2.46
americ. Talc*	8	36.2	-25.0	64.8	-2.82
americ. coated Talc, amino functio.	6	6.9	-44.7	58.5	-2.70

Immersion in reference oil IRM 903 168 h / 150 °C – Neuburg Siliceous Earth

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]	Change of volume [%]
Sillitin V 85*	-6	-1.3	-10.0	1.4	7.7	12.3
Sillitin V 88*	-6	-2.0	-15.8	1.0	7.8	12.0
Sillitin N 75*	-6	4.9	-11.4	1.8	7.7	12.1
Sillitin N 85*	-7	5.7	-11.1	13.0	7.7	11.9
Sillitin Z 86*	-6	9.9	-8.7	0.9	7.7	12.0
Sillitin Z 89*	-7	7.3	-12.1	-3.8	7.8	12.1
Sillikolloid P 87*	-5	21.3	-14.5	15.6	7.6	12.1
Aktisil AM	-6	8.4	-9.4	-1.5	7.8	12.4
Aktisil VM 56	-5	7.0	-4.9	-3.6	7.8	12.0
Aktisil VM 56/89	-6	3.0	-3.1	-2.9	8.1	12.1
Aktisil MAM-R	-6	3.1	-6.0	10.9	7.9	11.7
Aktisil Q	-5	1.3	-5.7	-8.7	7.9	12.0
Aktisil PF 777	-9	8.1	-2.4	-8.7	8.7	13.0

Immersion in reference oil IRM 903 168 h / 150 °C – Competitors

* with silane addition

	Change of hardness S2 specimen [Shore A]	Change of tensile strength [%]	Change of elongation at break [rel.%]	Change of modulus 100 % [%]	Change of weight [%]	Change of volume [%]
Carbon Black N 550/30 (50 phr)	-7	-7.0	-1.6	-9.3	10.0	13.3
Carbon Black N 990 (100 phr)	-7	3.0	18.1	-17.7	7.8	11.2
pptd. silica 180 m²/g (35 phr)*	-5	-23.4	-20.9	10.3	10.1	14.0
pptd. silica 130 m²/g (40 phr)*	-8	-9.2	-20.1	8.5	9.6	13.6
pptd. aluminum silicate (60 phr)*	-7	-4.1	-7.8	-2.4	8.5	12.7
pptd calcium silicate (70 phr)*	-7	-5.1	-8.2	0.3	7.9	12.2
pptd. sodium alum. silicate (60 phr)*	-7	-8.9	-7.5	-4.0	8.4	12.3
engl. Clay*	-5	19.2	-9.5	8.7	7.5	11.8
engl. calc. Clay*	-6	16.4	-9.2	-2.6	7.6	11.9
americ. calc. Clay*	-5	11.1	-13.5	4.5	7.9	12.5
americ. calc. Clay, amino functio.	-6	7.5	-21.1	-3.0	8.0	12.4
americ. calc. Clay, vinyl functio. (T)	-5	5.6	-10.2	-0.9	7.7	12.2
engl. calc. Clay, vinyl functio.	-6	2.9	-12.7	4.7	8.1	12.3
americ. calc. Clay, vinyl functio. (B)	-5	-1.5	-2.3	-1.9	7.5	12.1
americ. Talc*	-3	4.3	-20.7	12.4	7.5	12.1
americ. coated Talc, amino functio.	-5	4.9	-11.2	12.5	8.0	12.8