Antivibration mount

based on NR

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Abstract

Neuburg Siliceous Earth offers benefits with respect to:

- Mooney viscosity
- Compression Set, especially with Aktisil PF 216
- Electrical insulation properties
- Temperature dependence of the dynamic properties
- Dynamic stiffening

Optimization potential is seen with regard to:

- Reversion
- Tear resistance

As a cost-saving grade, Sillitin Z 86 is the material of choice.
Technically, the best results are obtained with Aktisil MM und PF 216.

1 Introduction

Resilient engine mounts represent an important component for vibration insulation in the machinery and automotive industry. In most cases, because of its outstanding mechanical and dynamic properties, natural rubber is used as the polymer base. The service temperature is mostly limited to less than 70 °C, in exceptional cases up to 100 °C, as natural rubber at higher temperatures does not offer the required stability.

The typical filler for mount compounds is carbon black, while mineral fillers so far do hardly find use in this field.

The aim of the present study was to evaluate if material properties could be positively modified by blends of carbon black with Neuburg Siliceous Earth, also with regard to dynamic properties and electrical insulation characteristics.

2 Experimental

2.1 Compound formulations

The starting point was an engine mount formulation based on NR, with a hardness around 50 Shore A (Tab. 1).
In order to adjust as far as possible the same hardness, half of the carbon black was replaced by Neuburg Siliceous Earth at a ratio of 1:2. This way, basic effects of the Neuburg Siliceous Earth should already be evident and the basic properties largely maintained, so that the results of this fundamental study could be used in detail for further development work.

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Base Formulation

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NR – 50 Shore A

	phr	
NR SMR 20	100.0	100.0
Stearic acid	1.0	1.0
Zinkoxyd aktiv	3.0	3.0
Sunthene 4240	5.0	5.0
Carbon black N 774	50.0	25.0
Neuburg Siliceous Earth	-	50.0
Vulkanox 4010 NA/LG	1.0	1.0
Vulkanox HS/LG	0.5	0.5
Perkacit TMTD	0.5	0.5
Santocure CBS	3.0	3.0
Sulfur	0.3	0.3
Total	**164.3**	**189.3**

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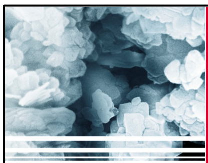
Table 1

The raw materials used were the following:

NR SMR 20:	Standardized natural cis- 1.4-Polyisoprene
Zinkoxyd aktiv:	Zink oxide
Stearic acid:	Processing aid
Carbon black N 774:	SRF black
Sillitin Z 86:	Neuburg Siliceous Earth
Aktisil MM:	Neuburg Siliceous Earth, surface treated
Aktisil PF 216:	Neuburg Siliceous Earth, surface treated
Sunthene 4240:	Naphthenic processing oil
Vulkanox 4010 NA/LG:	N-Isopropyl-N´-phenyl-p-phenyldiamine (IPPD)
Vulkanox HS/LG:	2.2.4-Trimethyl-1.2-dihydrochinoline (TMQ)
Perkacit TMTD:	Tetramethyl thiuramdisulfide
Santocure CBS:	N-Cyclohexyl-2-benzothiazole sulfenamide
Sulfur:	Curing agent



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Fillers Selected

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Characteristics

	Particle size [µm]		Oil absorption [g/100g]	Specitic Surface area BET [m²/g]	Functionali-zation
	d_{50}	d_{97}			
Sillitin Z 86	1.9	8	55	11	none
Aktisil MM	2.2	10	45	7	Mercapto
Aktisil PF 216	2.2	10	50	8	Tetrasulfane

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Table 2

The fillers were selected primarily with the objective of hopefully improving the dynamic properties in comparison with the black filled compound.

Although a priori the surface treated Aktisil grades could be expected to impart the best properties, Sillitin Z 86 as an untreated grade was included in order to bring out the effects of the surface treatment.

The grades selected as most appropriate were Aktisil MM, which is Sillitin Z 86 modified with a mercapto functional group, and Aktisil PF 216, a Sillitin Z 86 modified with a tetrasulfane functional group. (Tab. 2)

2.2 Compounding and curing

The compound batches were mixed on a laboratory mill (Schwabenthan Polymix 150 L).

At first, the natural rubber was peptized at a mill temperature of 50 °C down to a viscosity of about 50 Mooney units.
Then a uniform sheet was adjusted, and the other ingredients were added and dispersed in the sequence as listed in *Table 1*, again at a constant mill temperature of 50 °C.

Curing took place in a laboratory press at 170 °C, originally planned for a time t_{90} + 10 %. When this time was below 5 minutes, curing time was adjusted to five minutes.

3 Results

3.1 Mooney viscosity and Mooney scorch time

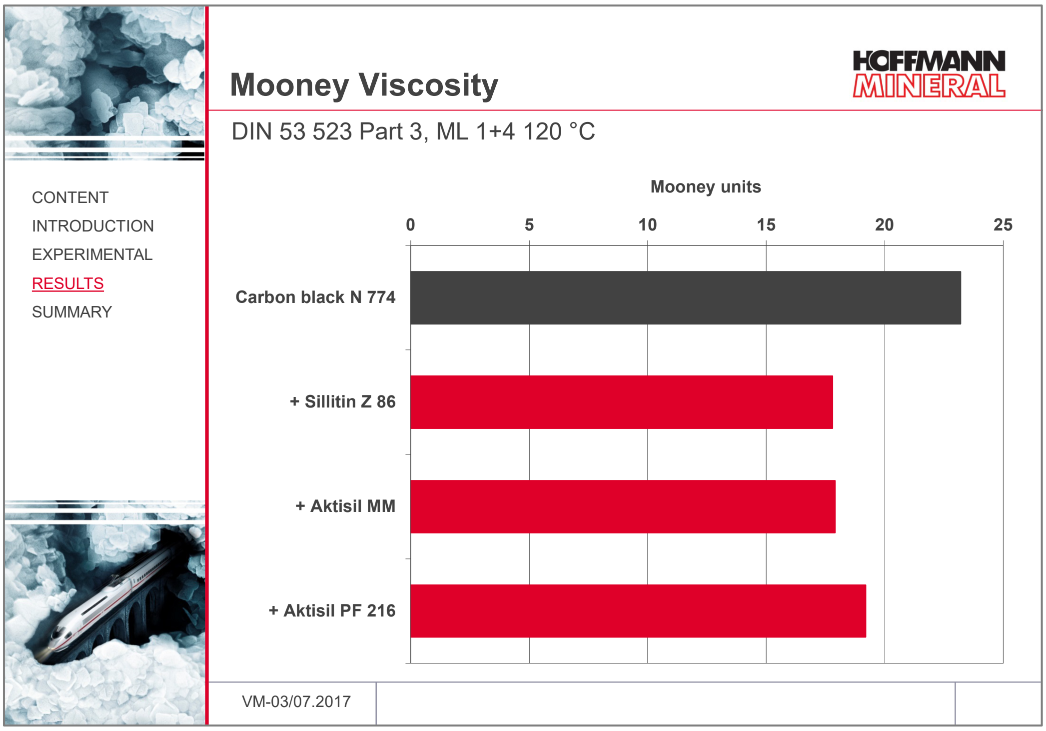

Fig. 1

The resulting viscosities with the filler blends were always lower than in the straight carbon black compound, and offered, therefore, improved flow properties. (Fig. 1)

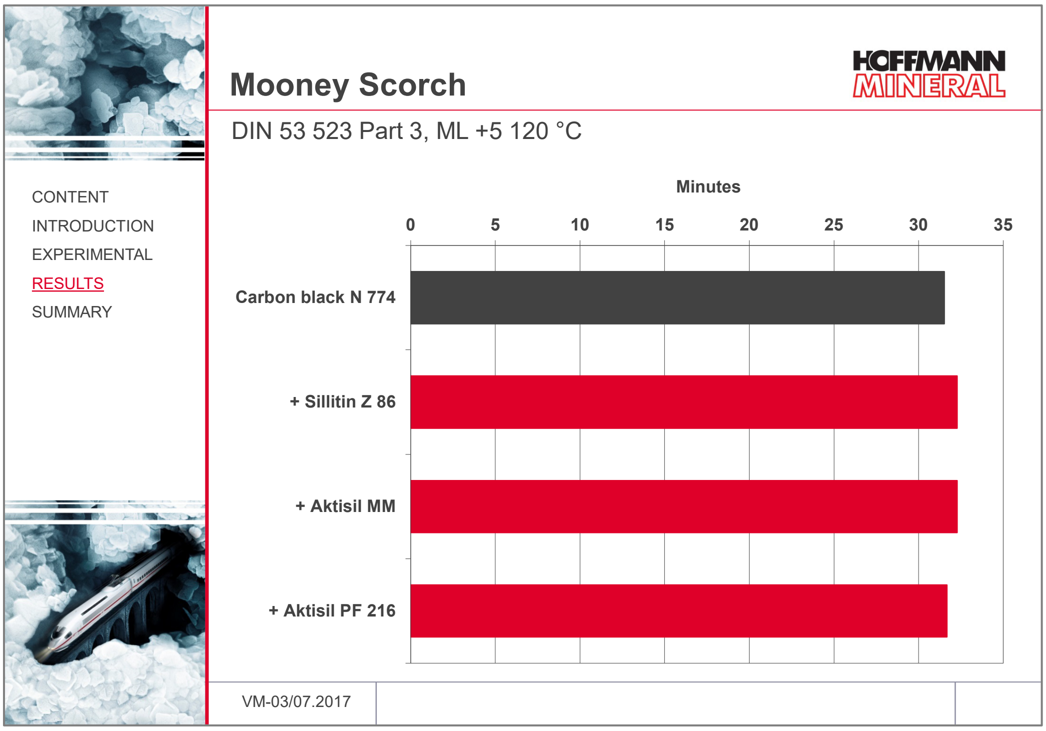

Fig. 2

By contrast, Mooney scorch time as a measure for the onset of premature cure, remained practically unaffected by the mineral fillers. (Fig.2)

3.2 Curing properties

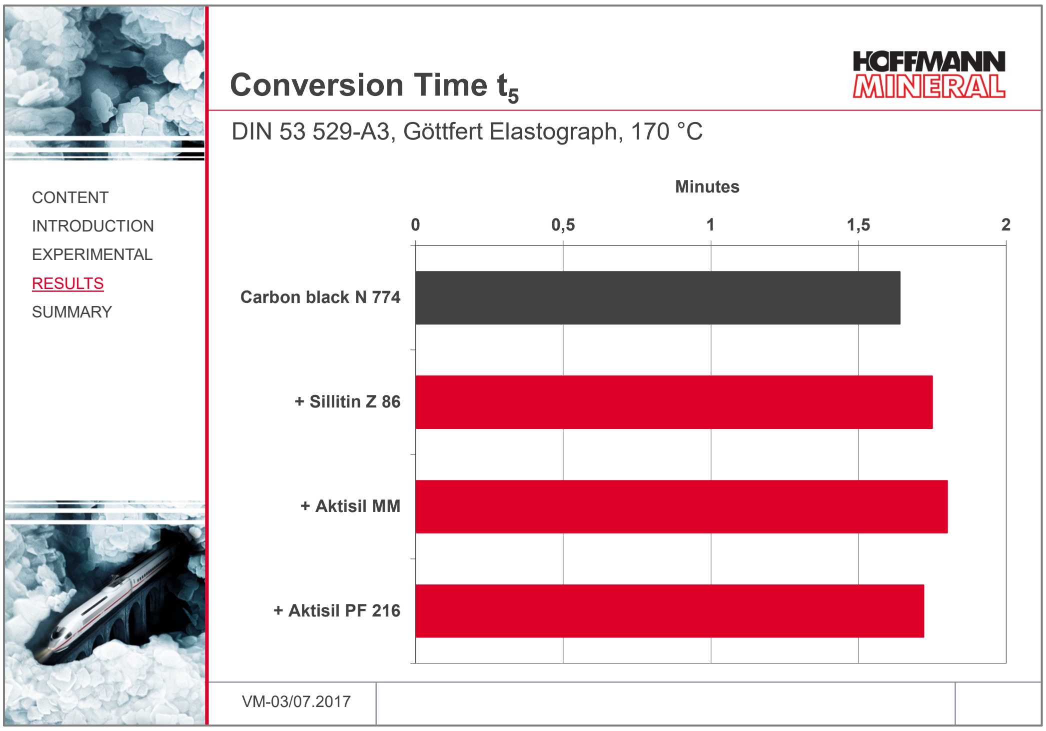

Fig. 3

The conversion time t_5, as a measure for the flow time, was slightly longer with the mineral fillers. (Fig. 3)

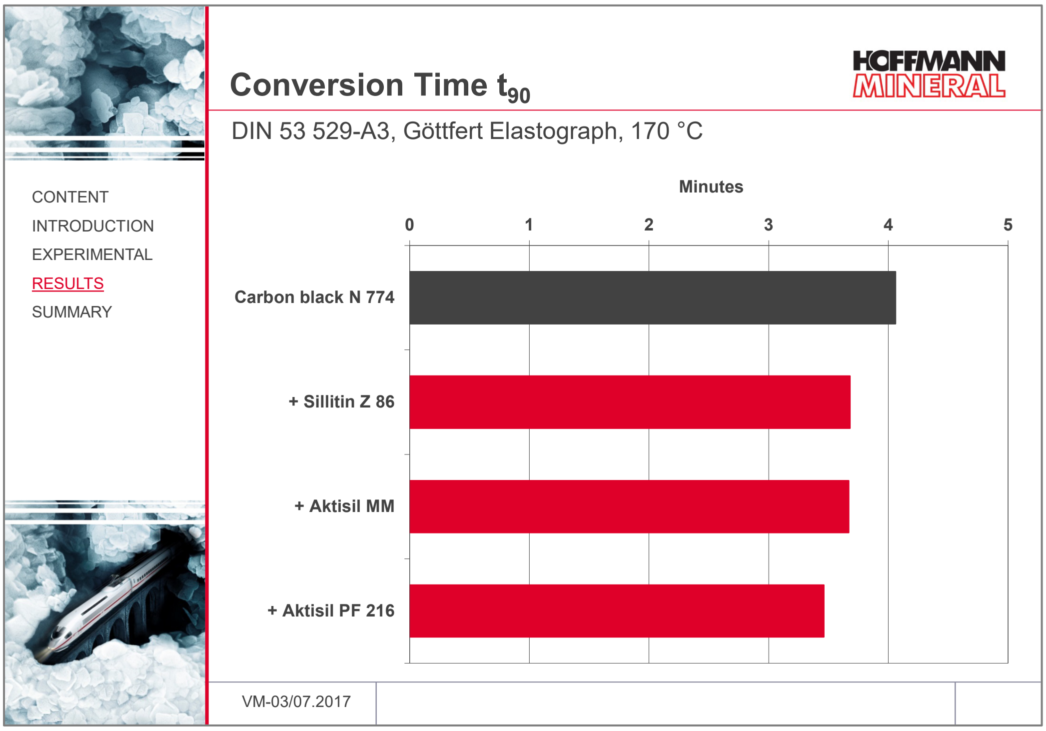

Fig. 4

By contrast, the time t_{90} which indicates the time to full cure, is tendentially shortened by the mineral fillers. This means for total process cycles there is a positive effect with the filler blends containing Neuburg Siliceous Earth. (Fig. 4)

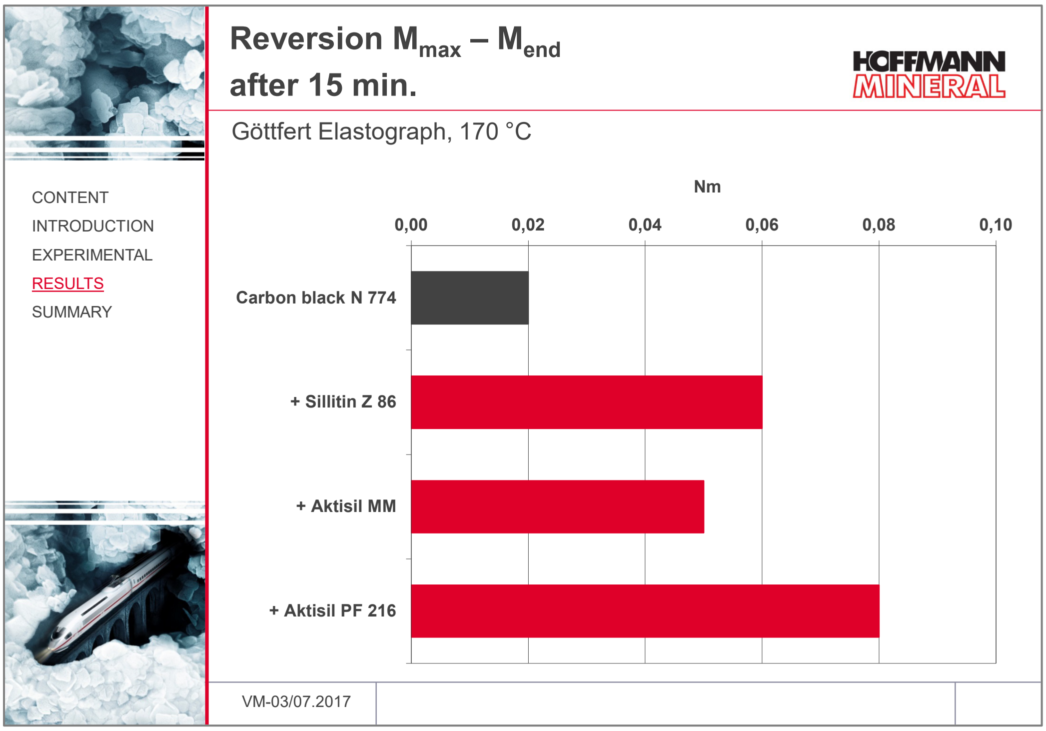

Fig. 5

The decrease of the torque after its maximum as caused by reversion is very little pronounced with the carbon black compound. With the filler blends, a stronger downturn is observed.
Consequently, for ongoing development work the curing system should be appropriately optimized, or the curing temperature lowered. (Fig. 5)

3.3 Mechanical properties

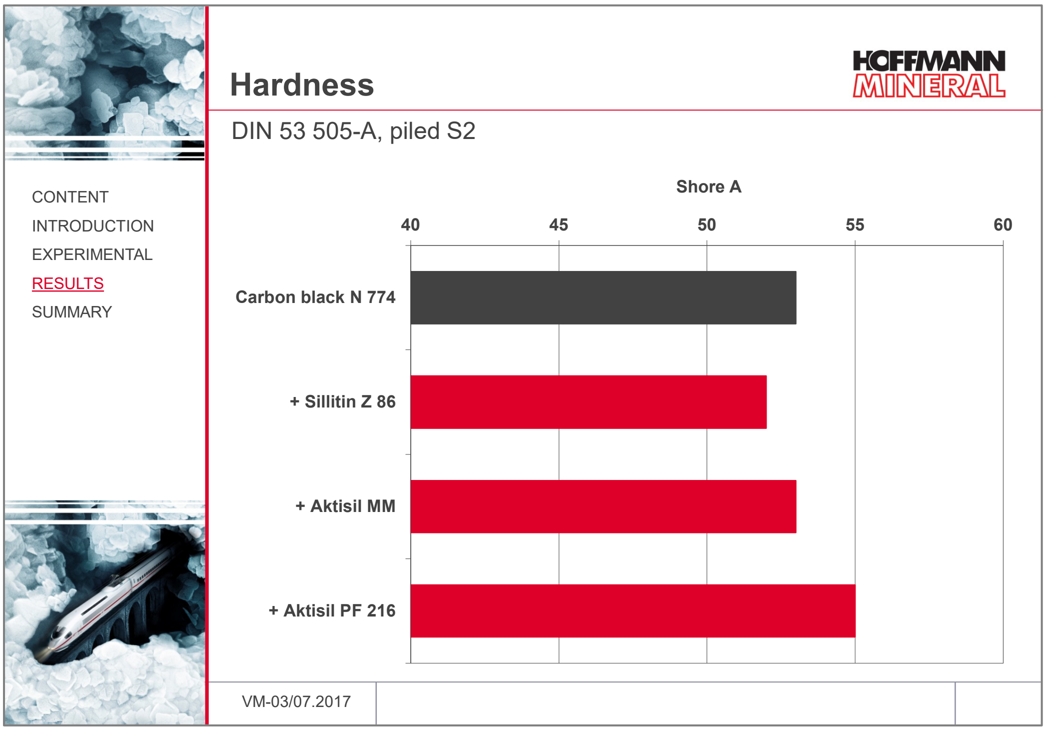

Fig. 6

With the selected replacement ratio 1:2 of carbon black to mineral filler, approximately equivalent hardness results are obtained, with the surface treatment of the Aktisil grades pointing to slightly higher figures. (Fig. 6)

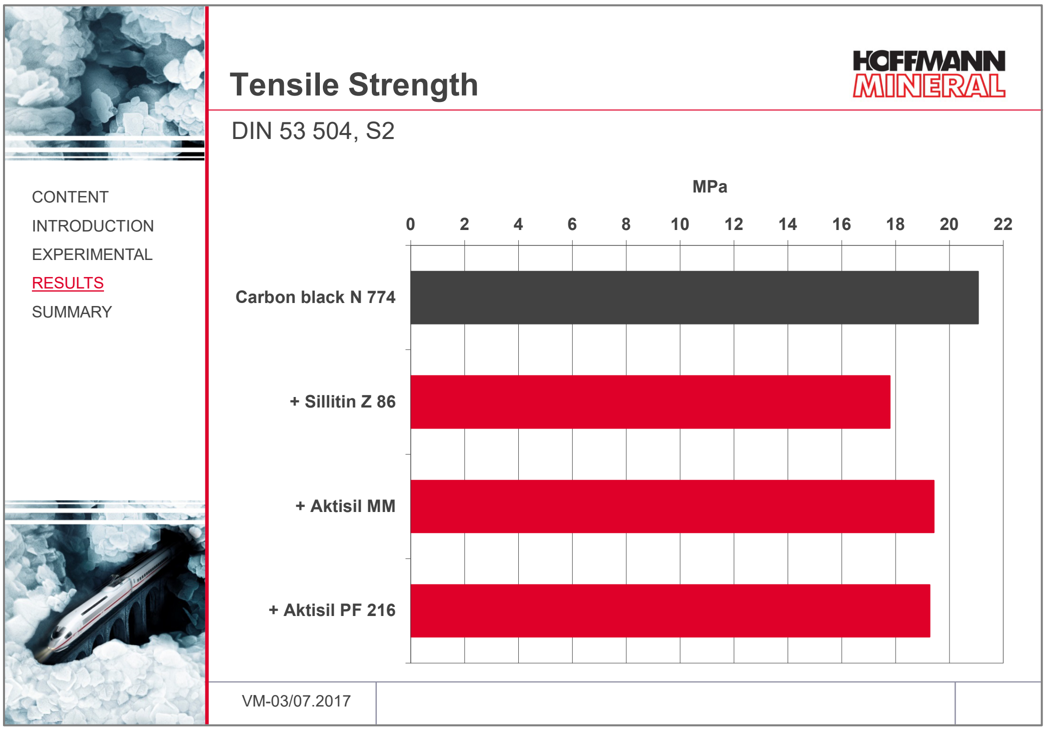

Fig. 7

The straight carbon black compound gives the highest tensile strength of the series. Sillitin Z 86 comes out lowest. Aktisil MM and Aktisil PF 216 almost match the straight black loading. (Fig. 7)

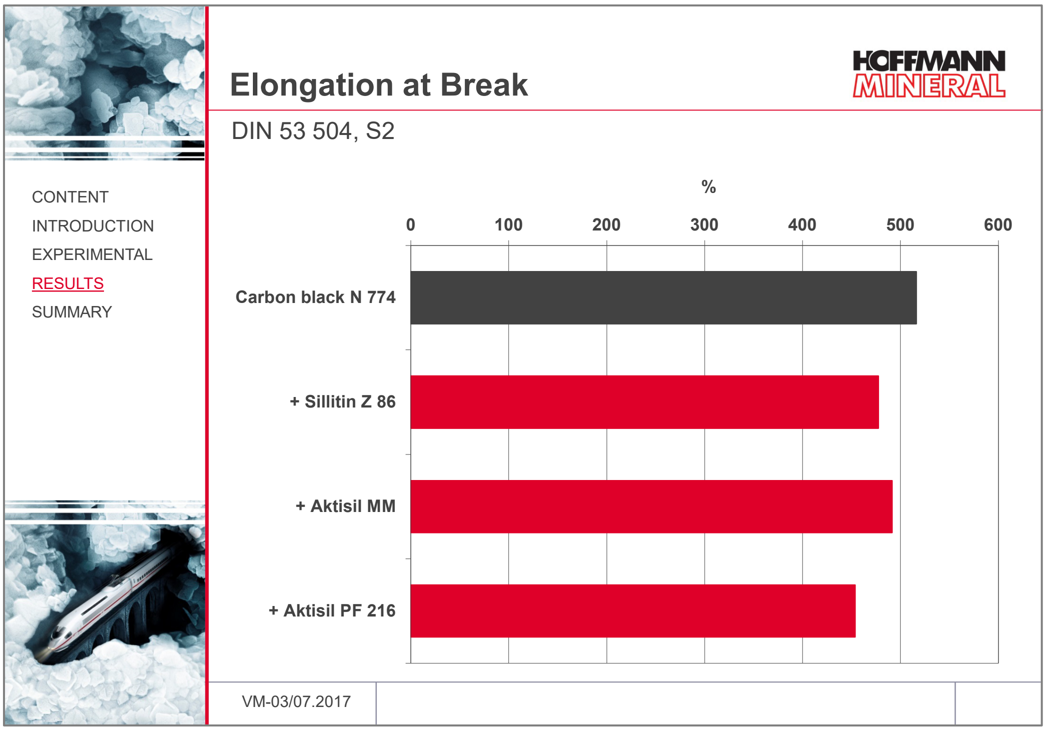

Fig. 8

On elongation at break, the filler blends exhibit hardly any effect at all. There is just a slightly reduced result with Aktisil PF 216. (Fig. 8)

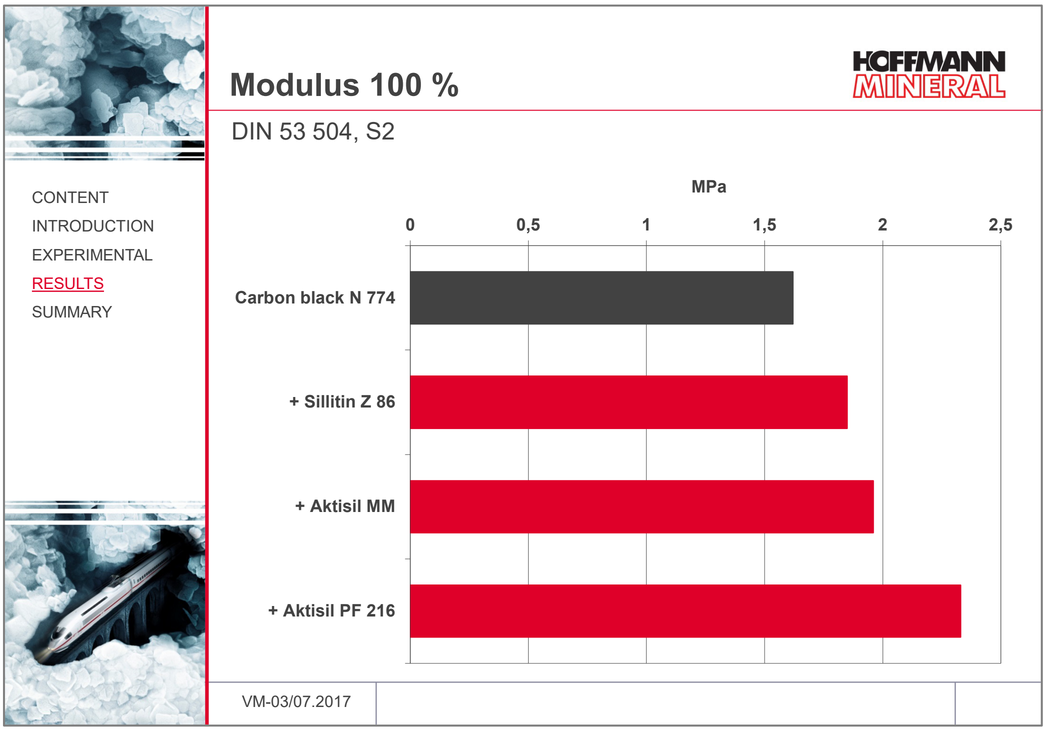

Fig. 9

The 100 % tensile modulus with Sillitin Z 86 is already higher than in the straight carbon black compound. The Aktisil grades lead to further increases. (Fig. 9)

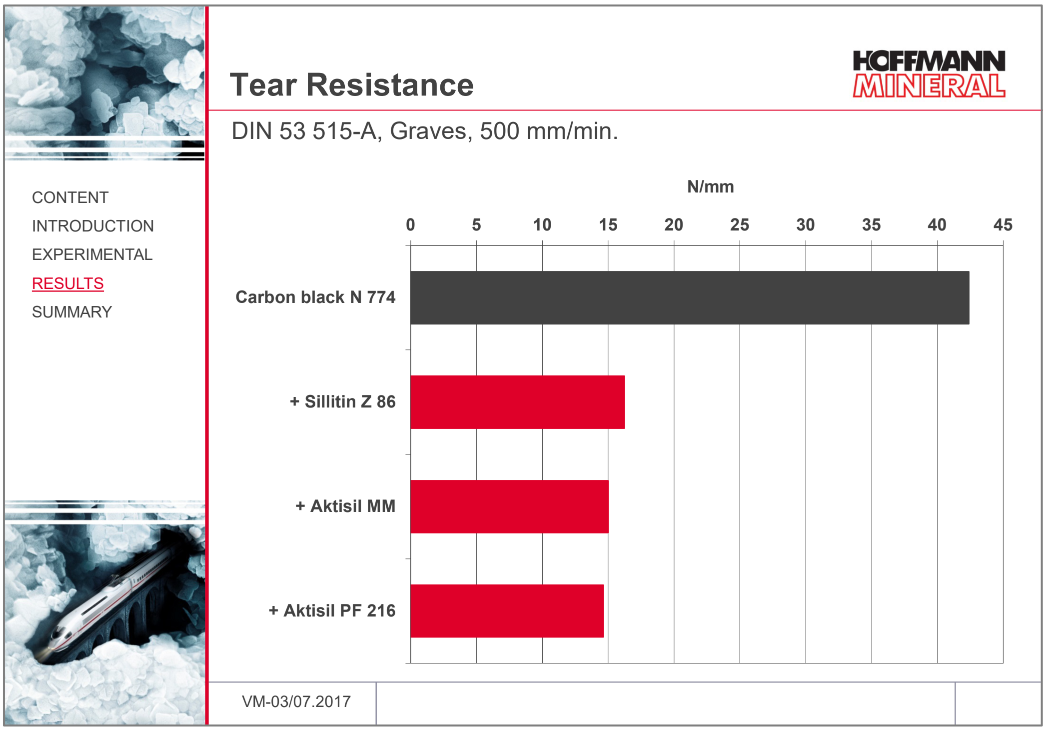

Fig. 10

For tear resistance, the filler blends come out with markedly lower figures. This difference, however, should be remedied by optimizing the curing system and temperature, as well as possibly by adding some precipitated silica. (Fig. 10)

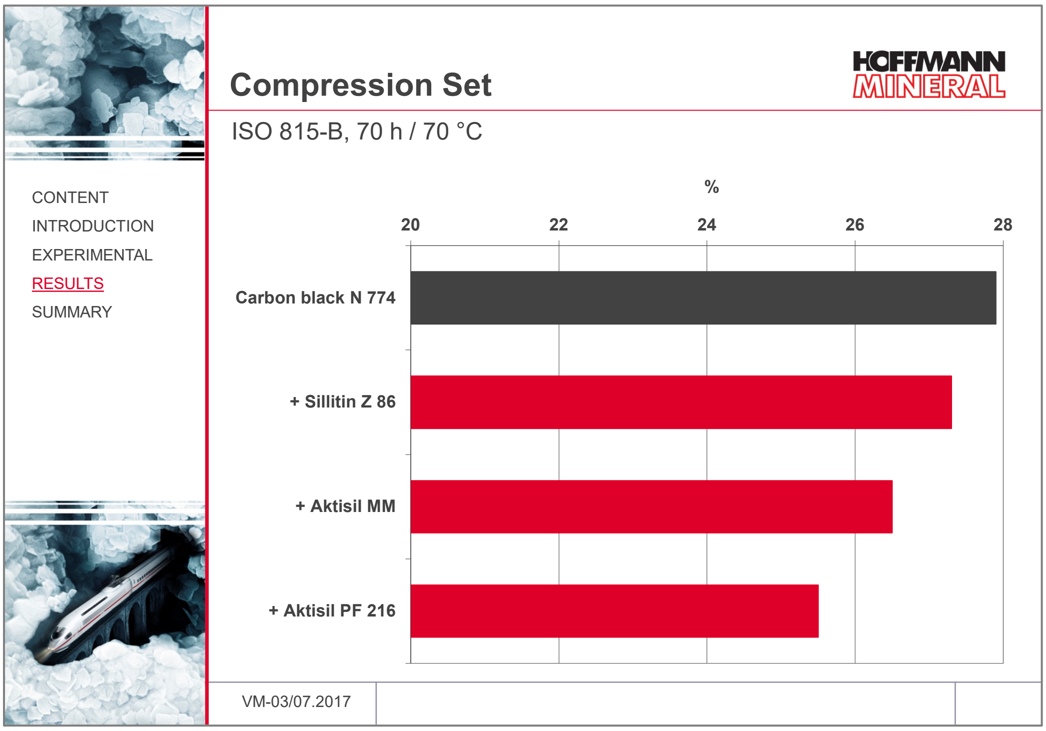

Fig. 11

Compression set at 70 °C is distinctly better with the filler blends, with Aktisil PF 216 leading to the lowest result. This should go along with improved, i.e. lower general set properties. (Fig. 11)

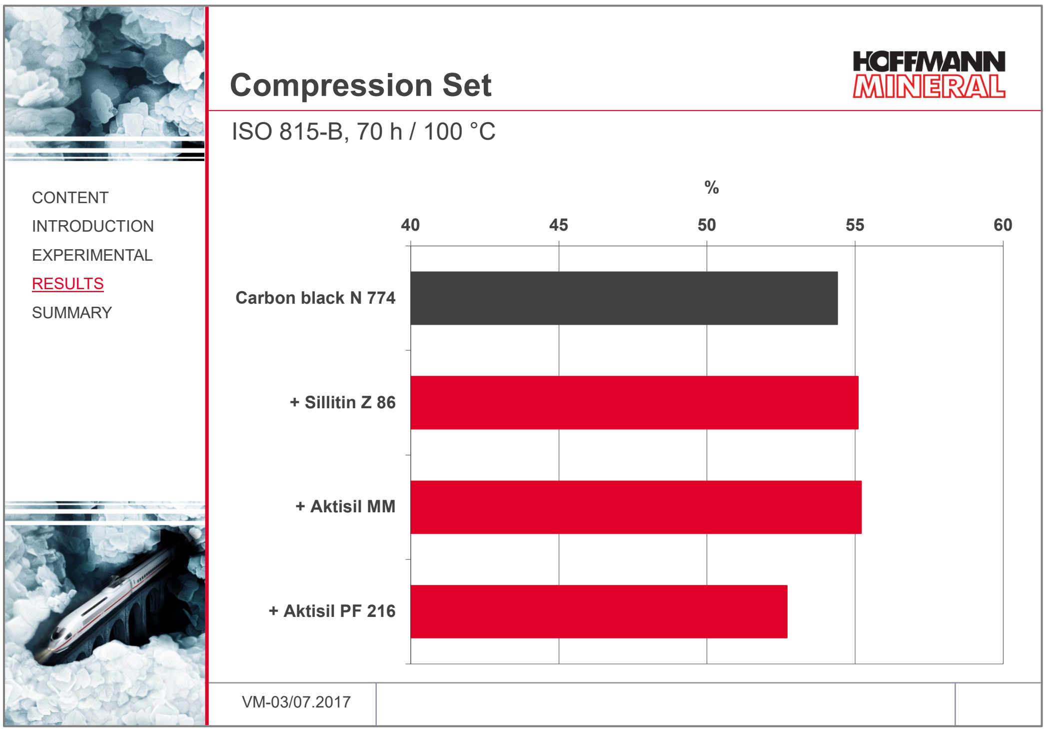

Fig. 12

At 100 °C, the compression figures come closer to each other; only Aktisil PF 216 remains somewhat better. (Fig. 12)

3.4 Hot air aging at 168 h / 70 °C

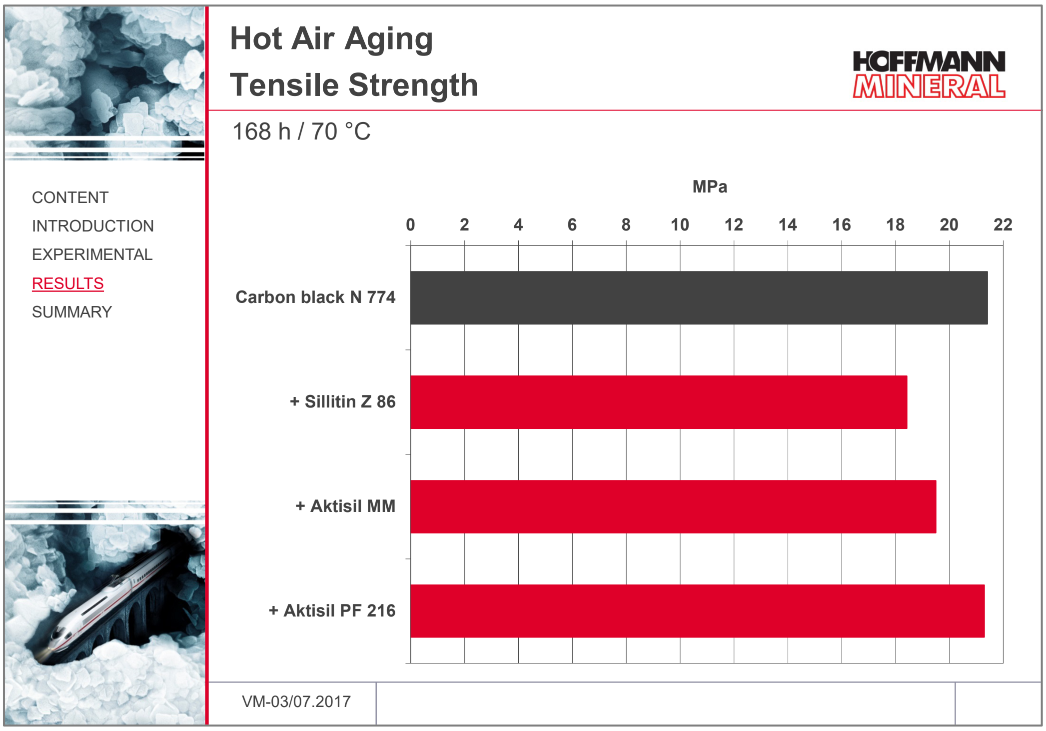

Fig. 13

After hot air aging, the tensile strength remains similar to the unaged relationships.
Aktisil PF 216 allows to attain the level of the carbon black compound. (Fig. 13)

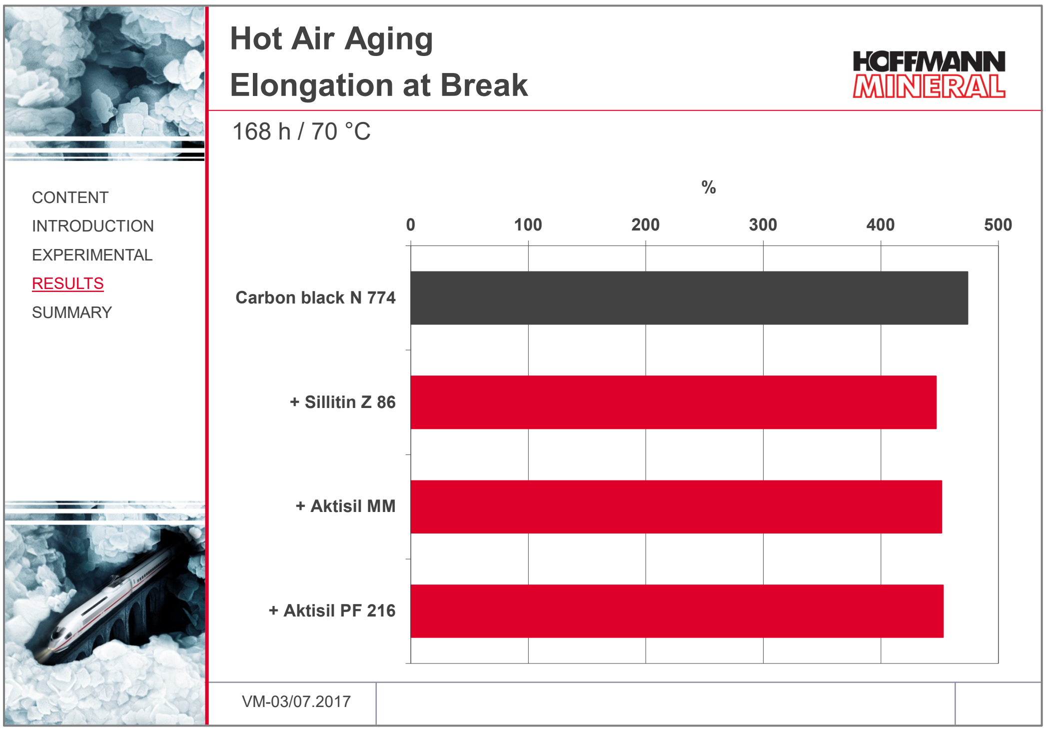

Fig. 14

For aged elongation at break, there are hardly any differences to be found. (Fig. 14)

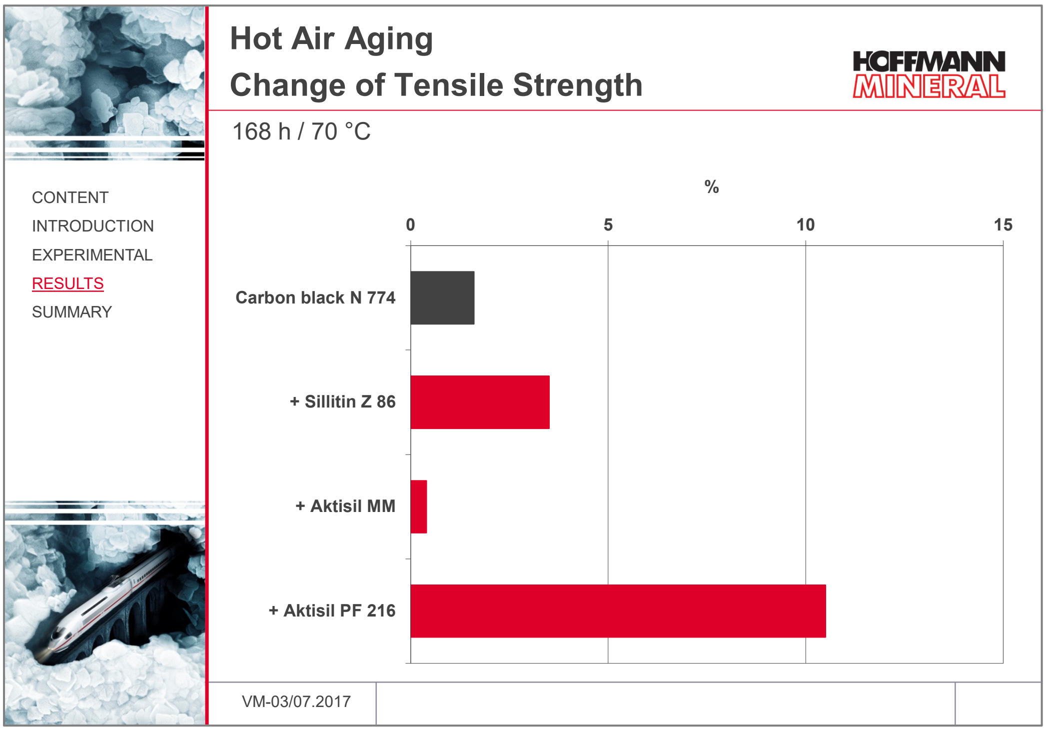

Fig. 15

Looking at the percent change of tensile strength during aging, a marked increase is evident with Aktisil PF 216. (Fig. 15)

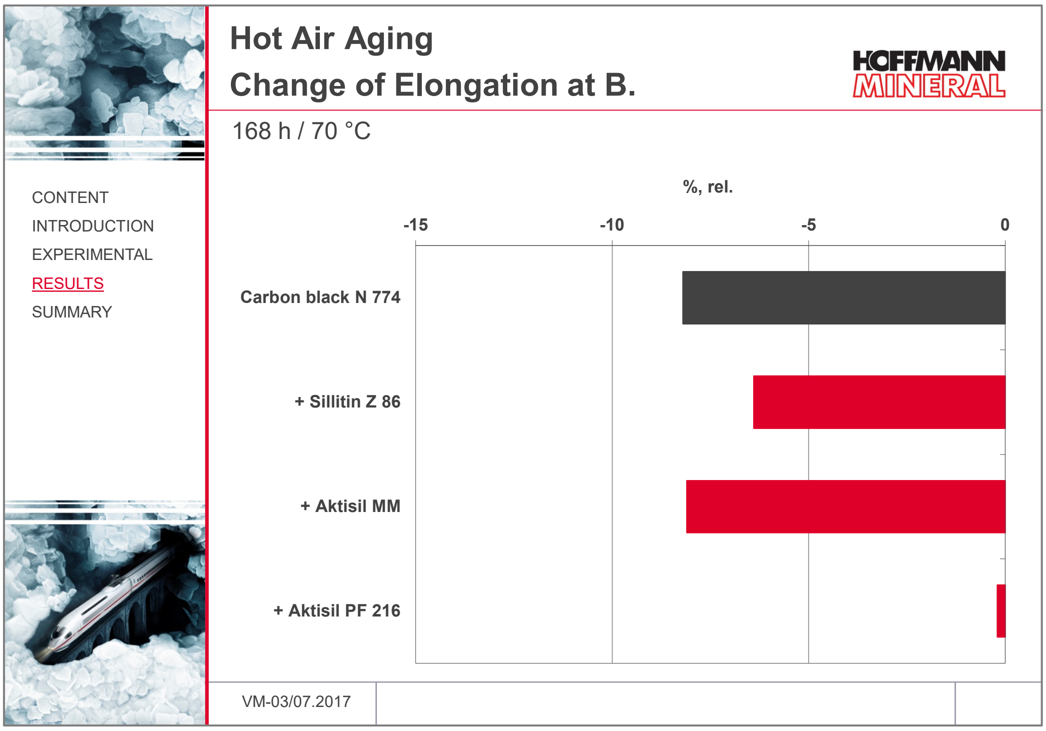

Fig. 16

Aktisil PF 216 does not show any change of elongation at break during aging, while the carbon black, the Sillitin Z 86 and the Aktisil MM compound decrease by 8 %. (Fig. 16)

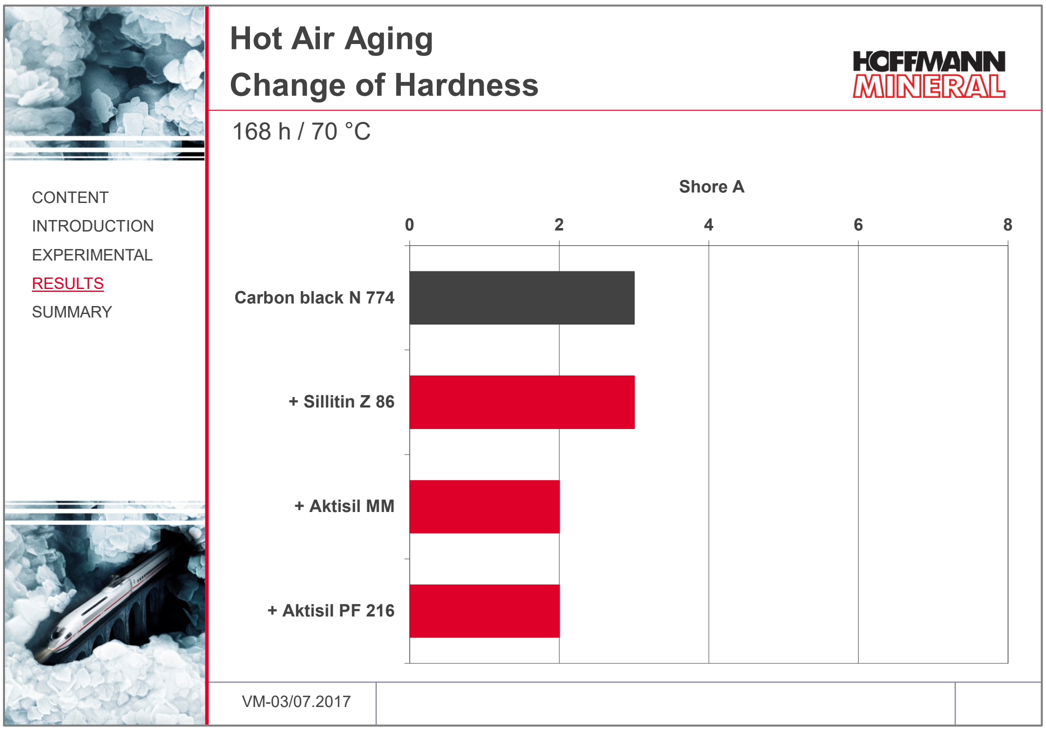

Fig. 17

There is hardly any change in hardness during the heat aging. (Fig. 17)

3.5 Volume resistivity

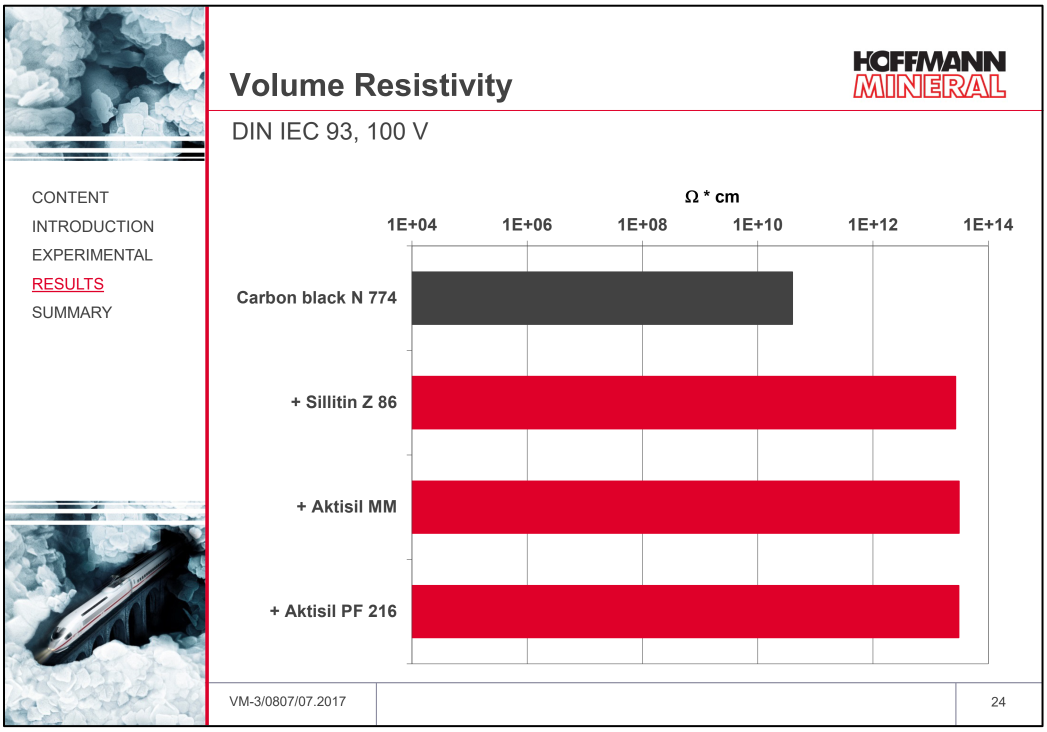

Fig. 18

As expected, the resistivity increases with the filler blends, by about 3 magnitudes. In branbury mixed compounds, the absolute level as well as the increases caused by the Neuburg Siliceous Earth could well come out somewhat lower because of poorer carbon black dispersion, but such effects will naturally depend on the carbon black grade and the loading level. (Fig. 18)

3.6 Dynamic properties

Description of the measurement and their execution: The testing was done on a circular disc, diameter 25 mm and thickness about 2 mm, punched out from a cured rubber sheet. The sample was introduced into a Rheometer MCR 300 (from *Paar*) with a contoured plate/plate system. After tempering for 5 minutes, a normal force of 20 Newton (0.04 MPa) was loaded in order to ensure a good force closure between the measuring plate and the sample. A gap width of about 1.8 mm resulted under these conditions. First of all, a frequency sweep was carried out with the shear deformation defined in the preliminary tests, i.e. 0.3 %. Ideally, a still smaller deformation would have been preferable, because closer to the real linear viscoelastic region. An amplitude sweep with the same sample was done next. This basically simple test design, in particular at high deformations, can cause a certain variation by sliding effects on the sample surface, which, however, would not change much with regard to the fundamental effects observed.

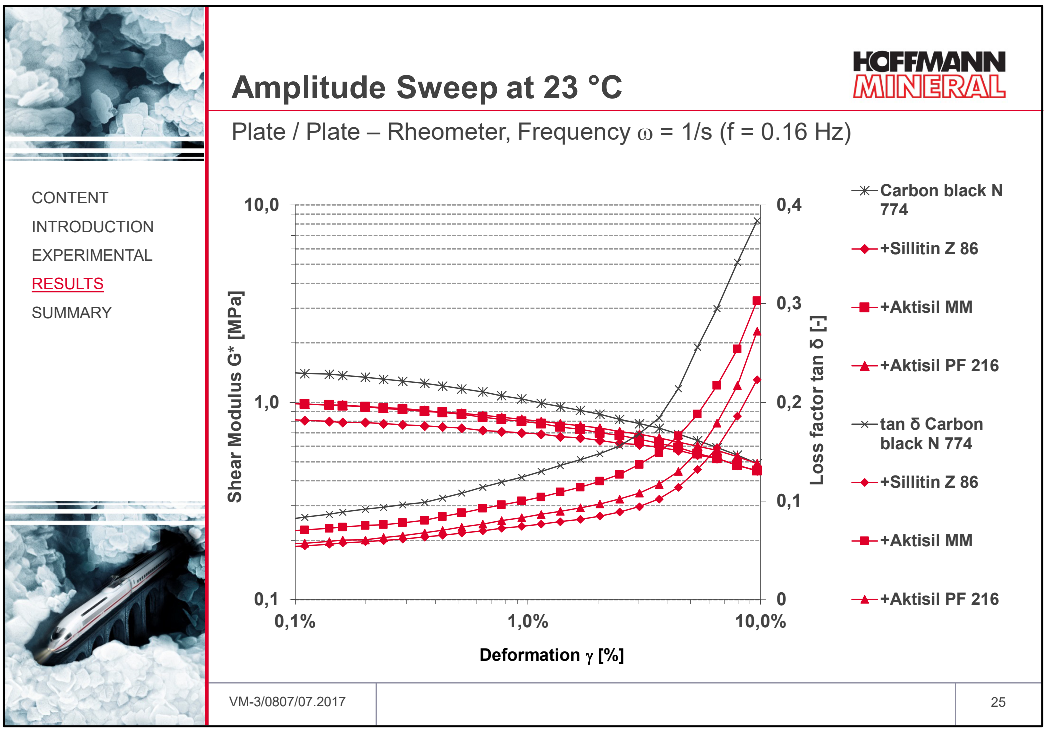

Fig. 19

The complex shear modulus in the amplitude sweep only shows for the carbon black loaded compound a higher figure with very low deformation, but comes closer to the results of the filler blends when the deformation is increased. The reason for this behavior is the stronger amplitude dependence of the compound with straight carbon black loa-ding. Sillitin Z 86 in the blend comes out at the lowest level, while the two Aktisil grades approach the results of the black compound but do not show the same strong amplitude effects.

With regard to the dynamic loss factor, the always highest figures of the straight carbon black reference compound look impressive. The blend with Sillitin Z 86, by contrast, reachest the lowest levels, narrowly followed by Aktisil PF 216. Aktisil MM places itself approximately in the middle between the filler blends and the carbon black control. The sharp bend in the loss factor graphs indicating a marked change of the viscoelastic properties, shows up in the range of 3 to 4 % shear deformation, without a clear differentiation between the compounds tested. Overall, the results with Aktisil PF 216 appear of high interest, as a high shear modulus with only low amplitude dependence is obtained along with a low loss factor. The consequence should lie in a lower dynamic heat-buildup with the blend compared to the straight carbon black compound – which in fact was confirmed on the industrial level for another formulation. (Fig. 19)

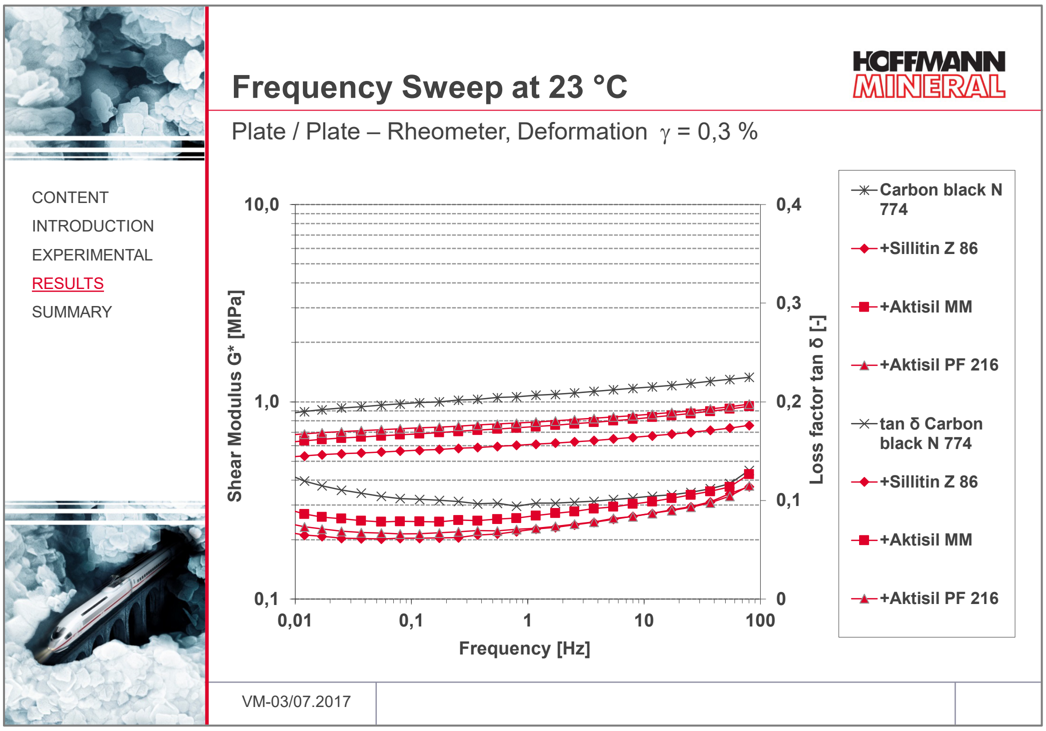

Fig. 20

For the frequency sweep at 23 °C, the same ranking of the complex shear modulus is found as for the amplitude sweep: straight carbon black followed by blends with the Aktisil grades, and on the lowest level Sillitin Z 86. Again, only the control compound loaded alone with carbon black demonstrates a higher increase than the filler blends with increasing frequency.
The loss factor of the filler blends is lower compared with the reference compound, in particular at very low frequencies. In summary, the low frequency dependence of the filler blends appears as an interesting effect. (Fig. 20)

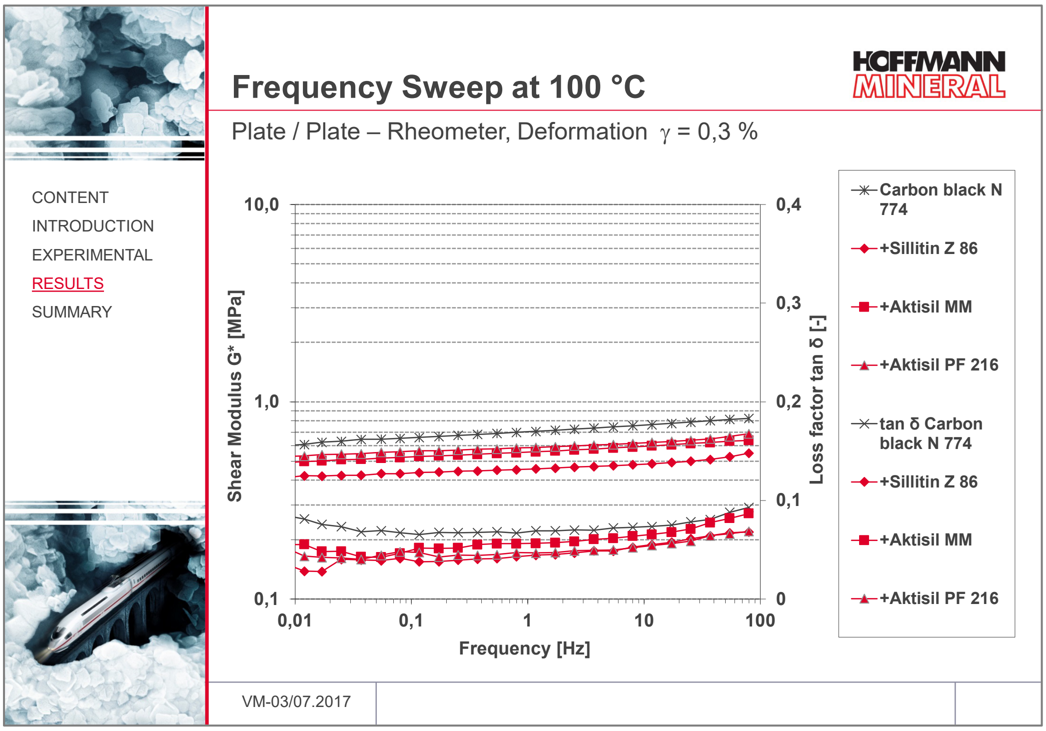

Fig. 21

The results at 100 °C deliver the same ranking as at 23 °C, but on a lower level and with smaller differences. (Fig. 21)

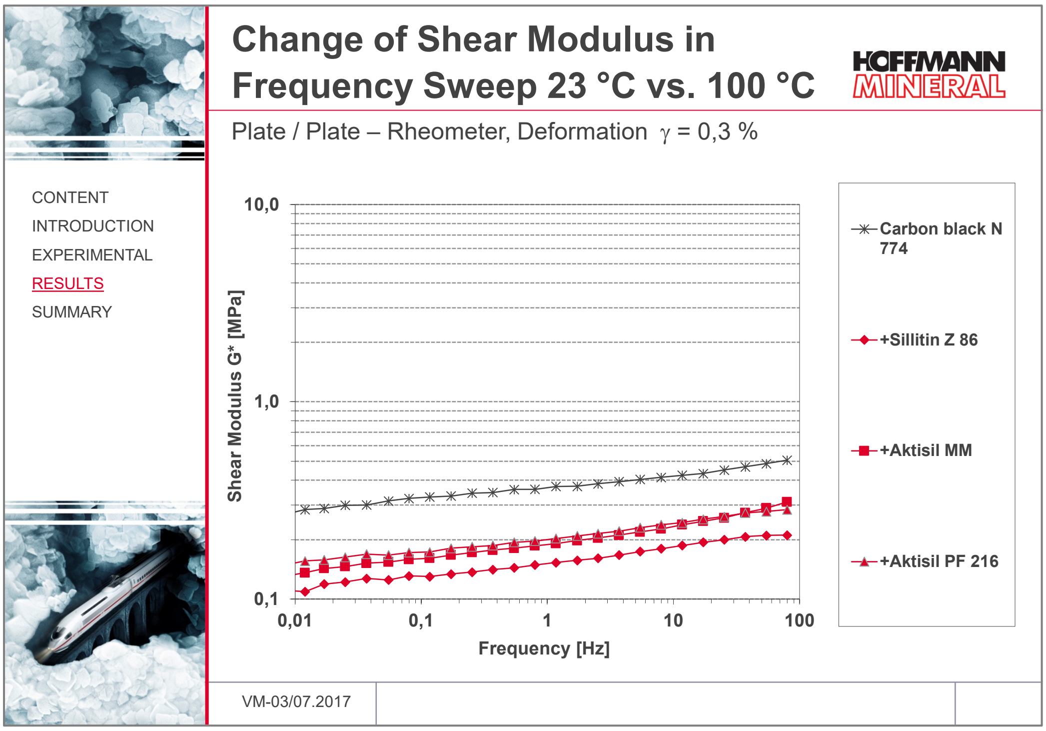

Fig. 22

Looking, however, at the shear modulus differences between 23 and 100 °C, the filler blends with only about half the latitude of changes offer clearly better results. (Fig. 22)

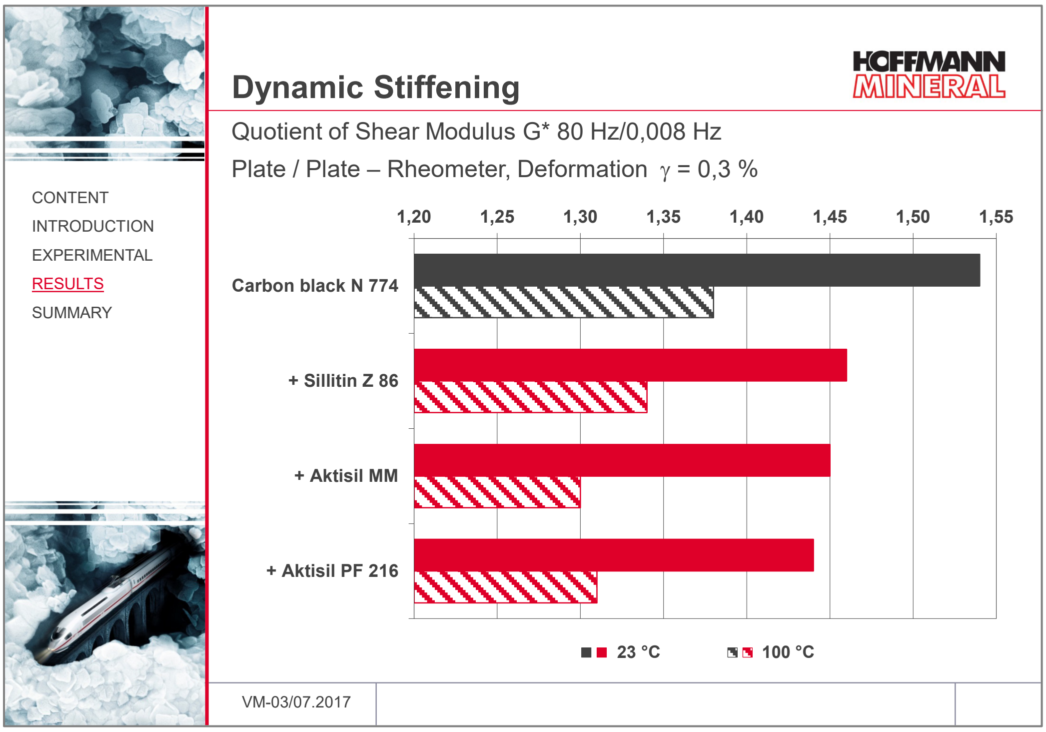

Fig. 23

The dynamic stiffening is improved with the Siliceous Earth blends. The effect is more distinct at 23 °C as at 100 °C.
In total, Aktisil PF 216 offers very good results in the dynamical tests, in particular high shear modulus with low loss factor and low dependence of frequency and temperature. (Fig. 23)

4 Summary

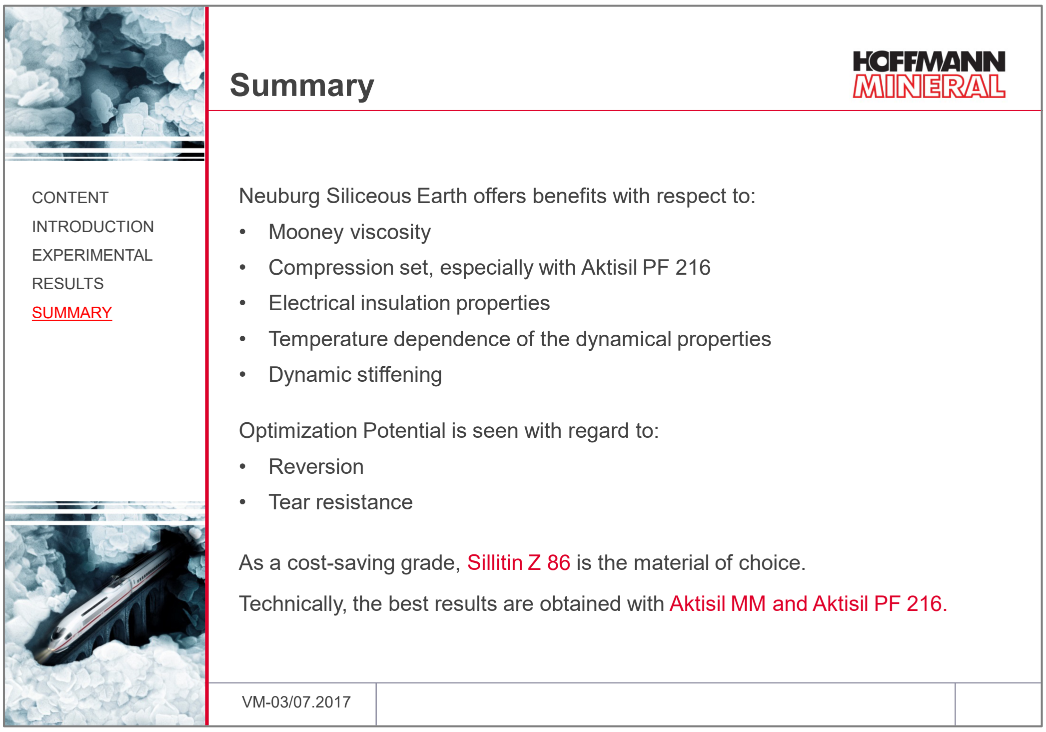

Fig. 25

5 Conclusions and outlook

Neuburg Siliceous Earth allows to obtain definitely positive results.

The especially important dynamic properties are improved with Neuburg Siliceous Earth with regard to loss factor, frequency dependence and temperature dependence.

How far these observed property improvements can be transferred to practical experience should be verified on actual industrial components. This can only be made by a manufacturer of parts supplied to the industry.

There certainly remains a potential for optimization regarding curing conditions with appropriate curing systems as well as with respect to tear resistance.