

# **Neuburg Siliceous Earth**

**versus**

**wollastonite and barium sulfate**

**in peroxide cured FKM**

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## **1      Introduction**

Fluoropolymers are generally known for their good resistance to temperature and media. They are therefore the preferred choice in sealant and media-routing applications where the properties of other polymers are no longer sufficient.

The use of fillers can improve the property profile of a fluoropolymer.

Light mineral fillers are used alongside carbon black N990. Wollastonite and barium sulfate are typical examples of the same.

This paper compares the various types of Neuburg Siliceous Earth (NSE) with these typical examples.

## 2 Experimental

### 2.1 Fillers, formulations and compounding

| Fillers, Characteristics |   | HOFFMANN<br>MINERAL |
|--------------------------|---|---------------------|
| Filler                   | Description                                       | Functionalization   |
| Wollastonite AST         | Calcium silicate, $d_{50}$ : 3,5 µm               | Amino silane        |
| Wollastonite EST         | Calcium silicate, $d_{50}$ : 3,5 µm               | Epoxy silane        |
| Barium sulfate           | ppt. barium sulfate, $d_{50}$ : 3 µm              | -                   |
| Silfit Z 91              | Calcined Neuburg Siliceous Earth, $d_{50}$ : 2 µm | -                   |
| Aktifit VM               | Calcined Neuburg Siliceous Earth, $d_{50}$ : 2 µm | Vinyl               |
| Aktifit PF 111           | Calcined Neuburg Siliceous Earth, $d_{50}$ : 2 µm | Alkyl               |
| Aktifit AM               | Calcined Neuburg Siliceous Earth, $d_{50}$ : 2 µm | Amino               |
| Aktifit PF 115           | Calcined Neuburg Siliceous Earth, $d_{50}$ : 2 µm | Special amino       |
| Aktisil AM               | Neuburg Siliceous Earth, $d_{50}$ : 2 µm          | Amino               |
| Aktisil Q                | Neuburg Siliceous Earth, $d_{50}$ : 4 µm          | Methacrylic         |
| VM-01/0718/04.2019       |   |                     |

Fig. 1

Silfit Z 91 was chosen as a calcined variant of Neuburg Siliceous Earth without surface treatment.

The grades Aktifit VM, Aktifit PF 111, Aktifit AM and Aktifit PF 115 are based on Calcined Neuburg Siliceous Earth and have been surface treated with the functional group listed in Fig. 1.

Aktisil AM and Aktisil Q are derivatives of conventional NSE types, although the latter is based on a somewhat coarser Neuburg Siliceous Earth.

The NSE grades are compared with wollastonite types AST – treated with aminosilane – and EST – treated with epoxysilane.

A comparison is also shown with precipitated barium sulfate.

The formulation (Fig. 2) shows the typical structure of a peroxide-cured FKM compound with zinc oxide, coagent and peroxide.

The same loading – 30 phr – was used for both wollastonite and the NSE grades, while 49 phr was chosen for the barium sulfate (to achieve equal dosage by volume of the barium sulfate which has a higher density). This produced vulcanizates with the same hardness ranging between 65 and 70 Shore A.

Compounding was performed on a laboratory mill (Schwabenthan Polymix 150 L). The polymer was applied to the mill at 50°C and rolled into even sheets. After incorporation of the zinc oxide, the filler was added. To ensure the even distribution of the compound ingredients, the compound was rolled 10 times. Given the stickiness on the roller surface, the rollers were cooled down to 30°C for this process. The compounds were typically mixed for 15 minutes.

Vulcanization in the press was performed at 177 °C for 7 minutes. Post-cure was conducted 2 hours at 232 °C.

**Fig. 2**

## 2.2 Tests

The results shown here relate to post-cured test specimens unless otherwise indicated.

Along with measuring the hardness, tensile tests were performed and the compression set examined.

Media resistance was examined as follows:

- |                          |                   |
|--------------------------|-------------------|
| • Hot air                | 94 hours / 230°C  |
|                          | 504 hours / 210°C |
| • Engine oil OS206304    | 168 hours / 150°C |
| • Fuel FAM B (DIN 51604) | 70 hours / 23°C   |
| • Acetic acid (1M, pH 3) | 168 hours / 100°C |

Aging in acetic acid was aimed at simulating blow-by resistance.

The results of all examined compounds and all tests can be found in tabular form at the end of this report.

### 3 Results

#### 3.1 Neuburg Siliceous Earth versus Wollastonite AST

##### 3.1.1 Rheological properties

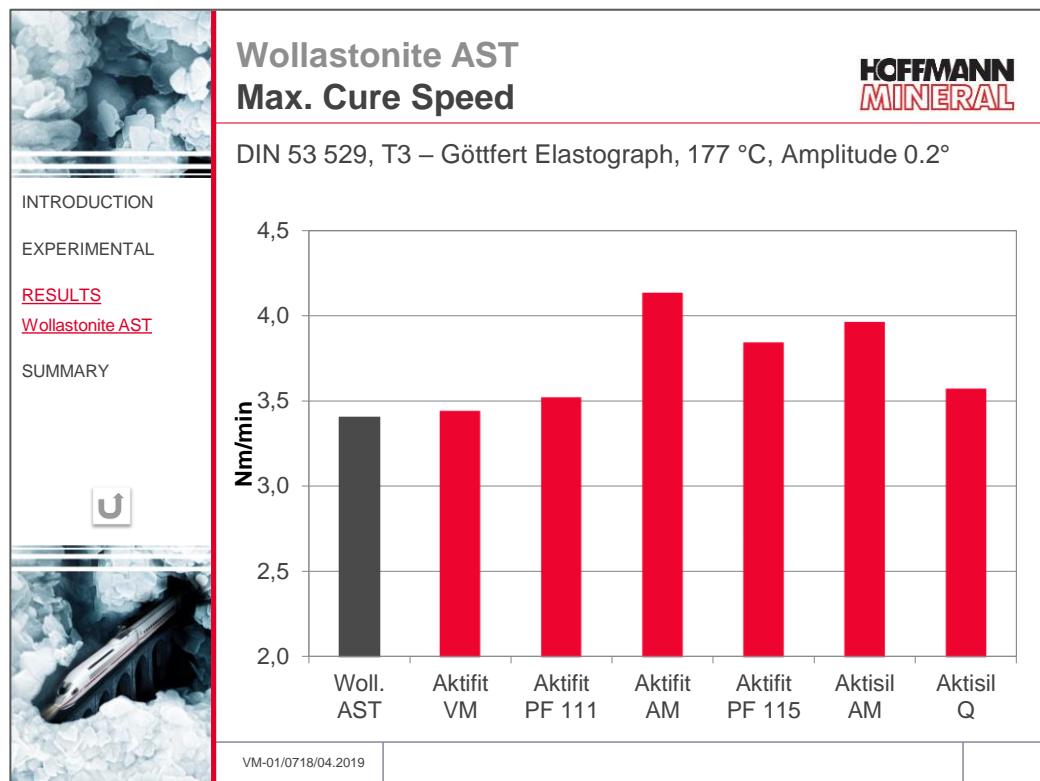


Fig. 3

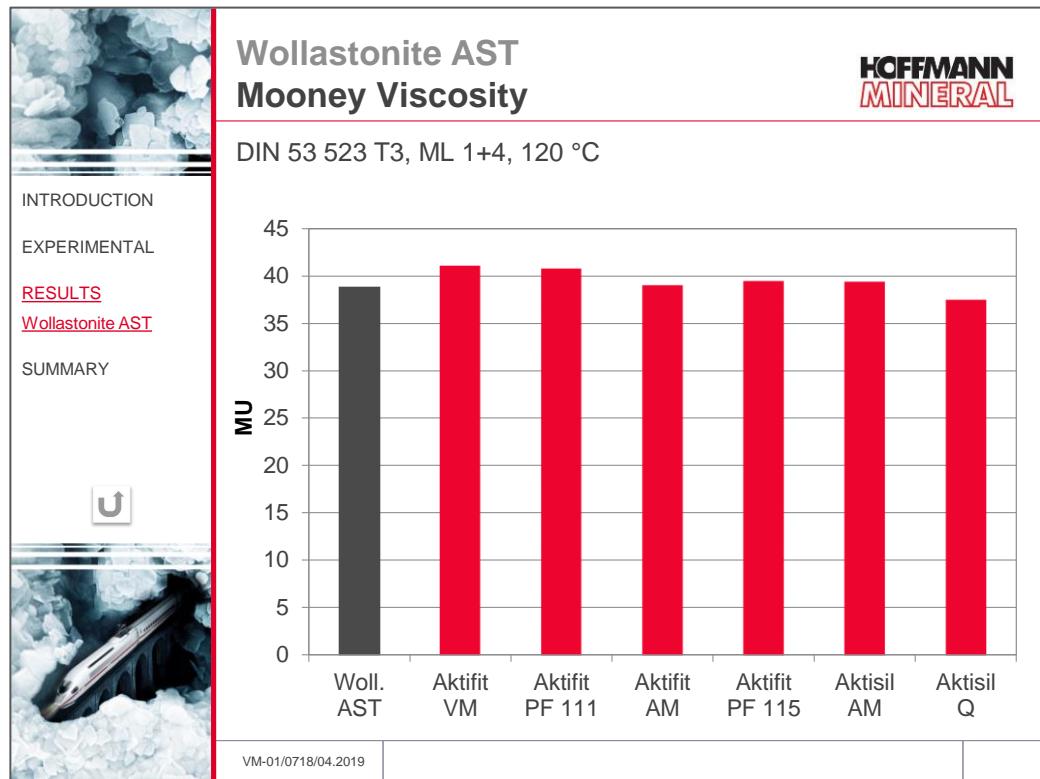


Fig. 4

The amino functional NSE grades Aktifit AM, Aktifit PF 115 and Aktisil AM enable a faster curing speed than the aminosilane-treated wollastonite (Fig. 3). The viscosity of the compounds is comparable across the board (Fig. 4).

### 3.1.2 Mechanical properties

All NSE grades raise tensile strength compared to the aminosilane-treated wollastonite (Fig. 5). At the same time, the good elongation at break performance is maintained, e.g. with Aktifit PF 111, Aktifit AM and Aktifit PF 115 (Fig. 6). The resulting moduli at 100 % elongation are shown in Fig. 7.

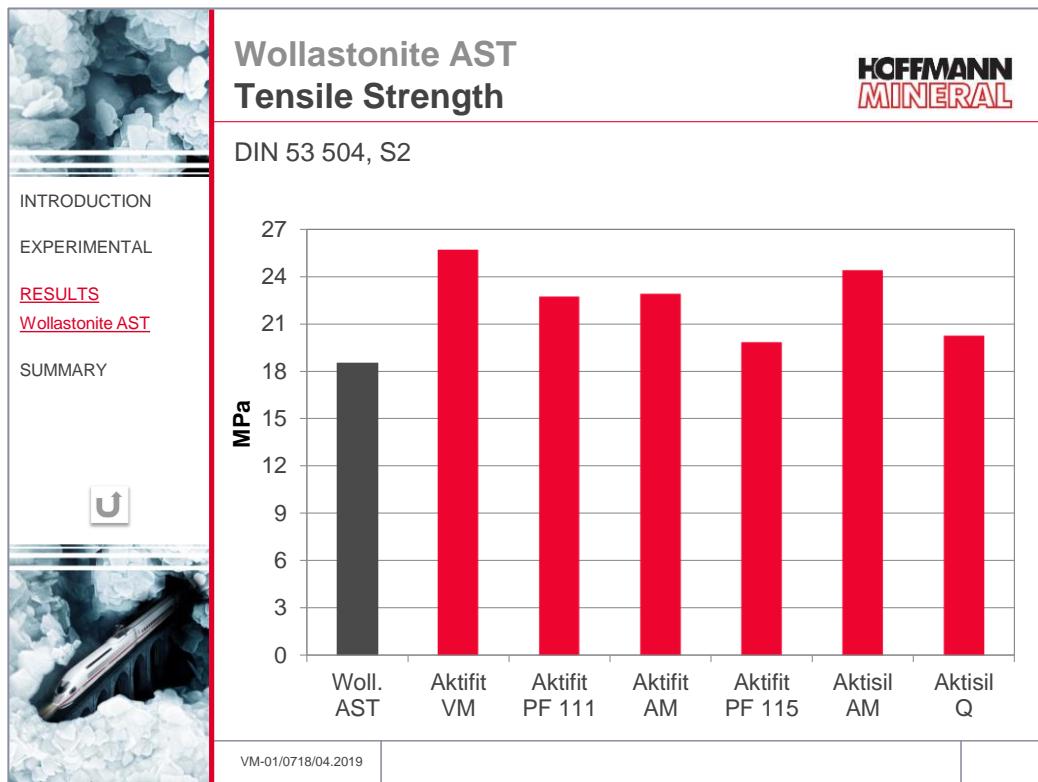


Fig. 5

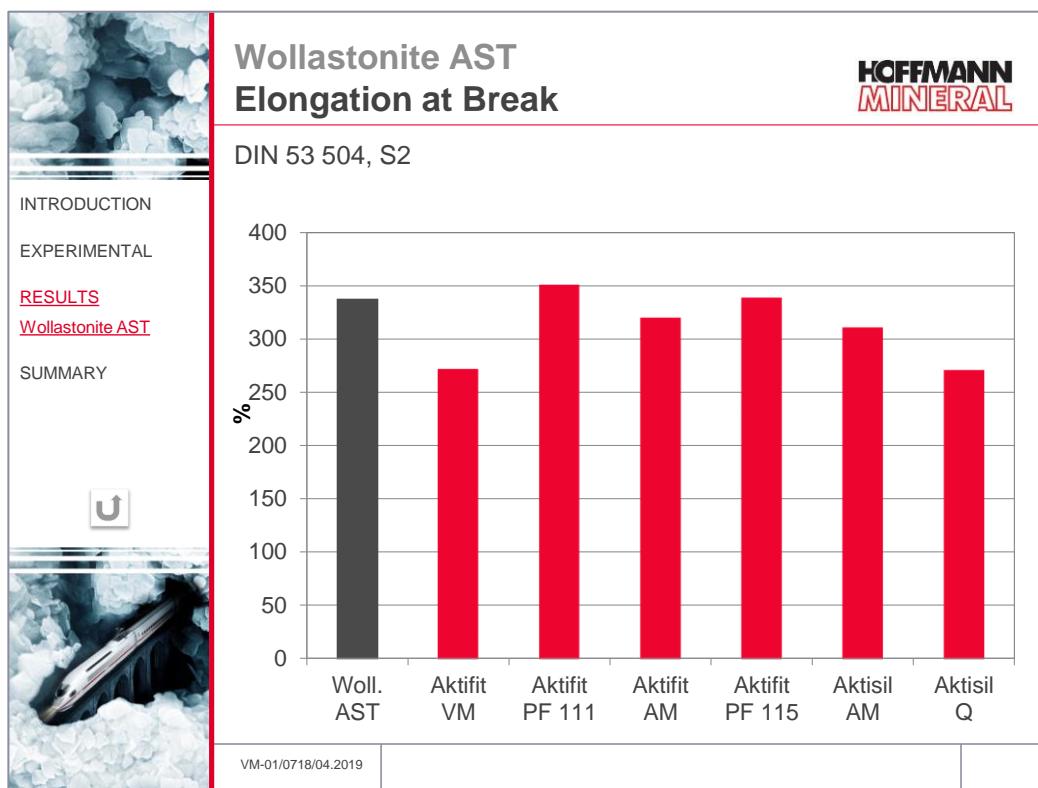
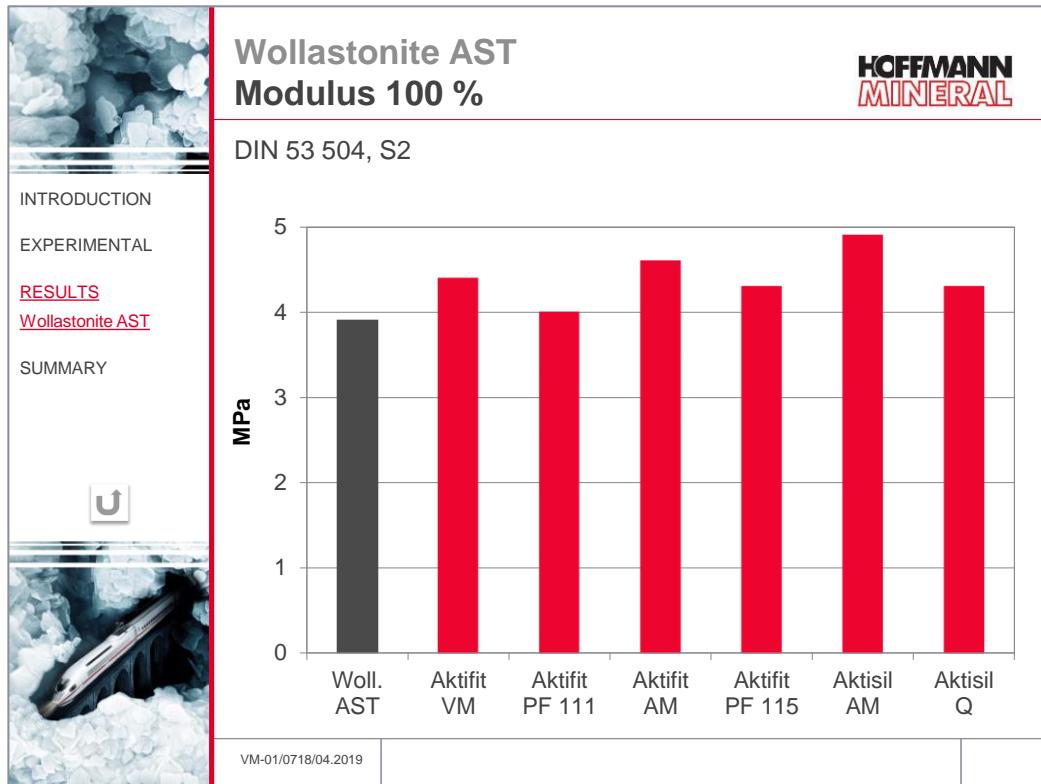


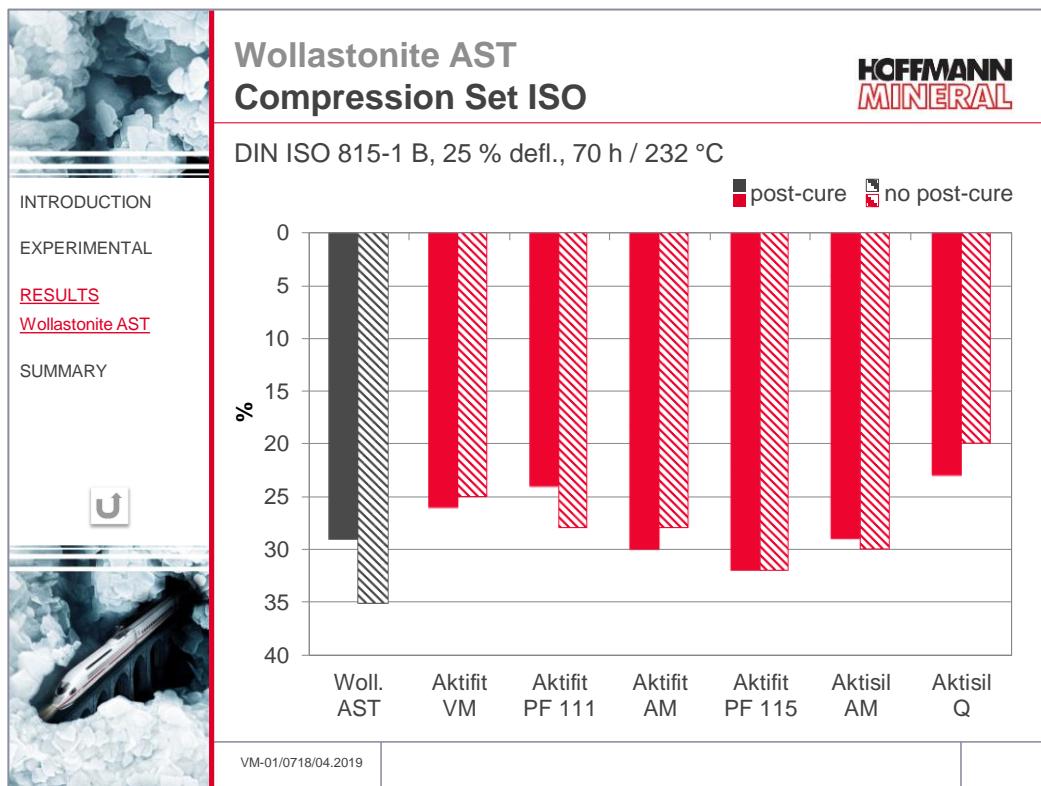
Fig. 6



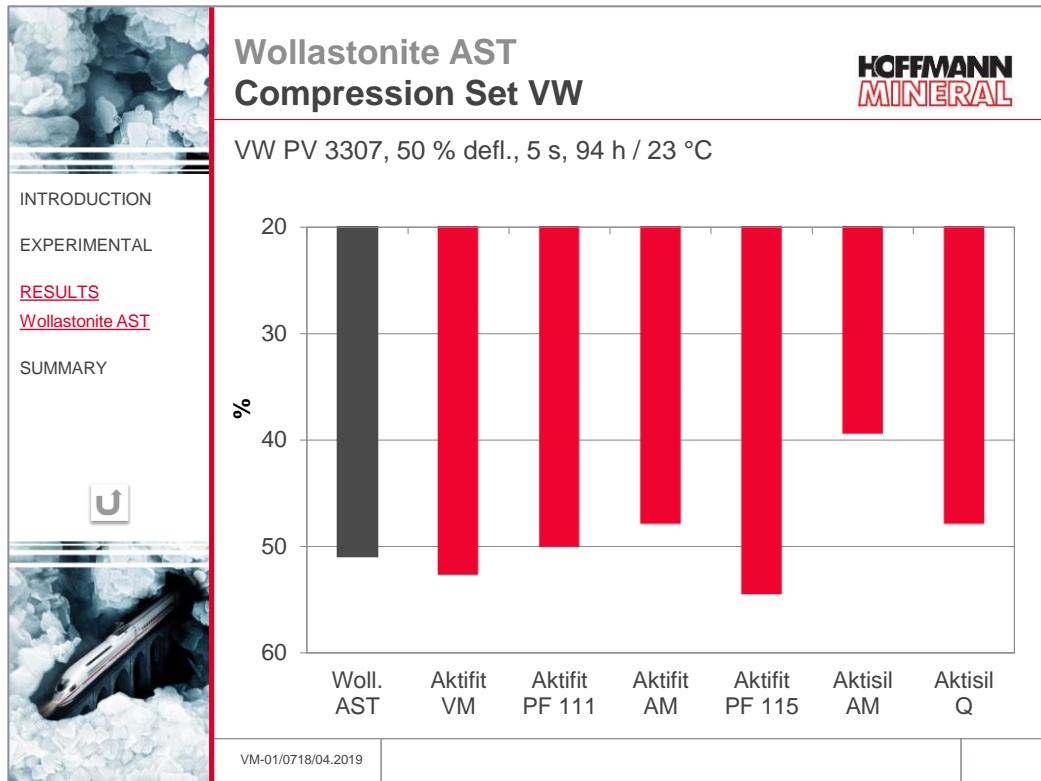
**Fig. 7**

By replacing the aminosilane-treated wollastonite with Neuburg Siliceous Earth, it proves to be possible to reduce the compression set. Fig. 8 shows the compression set as per DIN ISO 815-1 B after 70 hours at 232 °C. The marked improvement with Aktifit VM, Aktifit PF 111 and especially Aktisil Q is clearly apparent. Aktisil Q, in particular, offers the benefit of significantly reducing compression set even on test specimens, that have not been post-cured.

If VW's compression set as per PV 3307 is important, the use of Aktisil AM is recommended as it results in the best value at room temperature (Fig. 9).

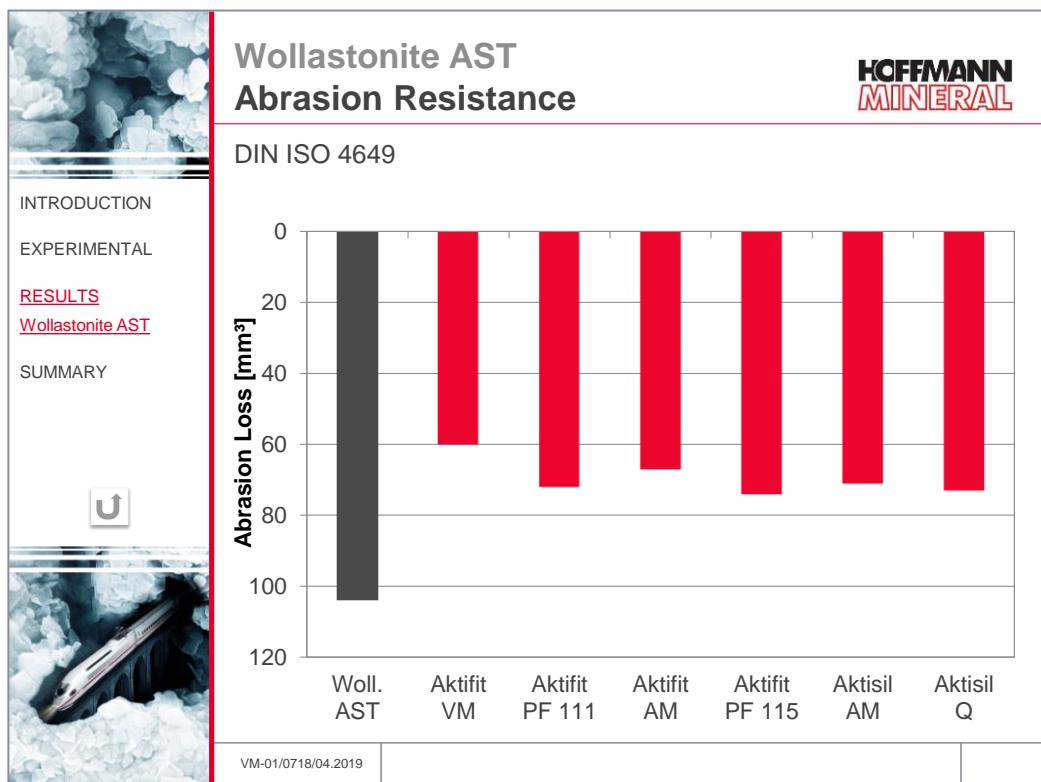


**Fig. 8**



**Fig. 9**

If abrasion resistance of the component is important, replacing the aminosilane-treated wollastonite with any of the tested NSE types produces a significant improvement (Fig. 10)



**Fig. 10**

### 3.1.3 Media resistance

#### 3.1.3.1 Resistance to hot air and fuel

The changes in mechanical properties after aging in hot air or fuel are comparable across the board. The higher tensile strength and comparable elongation at break of the vulcanizates filled with Neuburg Siliceous Earth are maintained versus the aminosilane-treated wollastonite.

#### 3.1.3.2 Resistance to oil

An analysis of the changes in tensile strength and elongation at break after aging in engine oil (Fig. 11) clearly shows the benefits of using Aktifit AM or Aktisil Q. Compared to the wollastonite, they demonstrate the least reduction in mechanical properties and sustain unchanged high tensile strength (Fig. 12).

The influence of oil immersion on hardness is also virtually non-existent when using Neuburg Siliceous Earth, as clearly shown in Fig. 13.

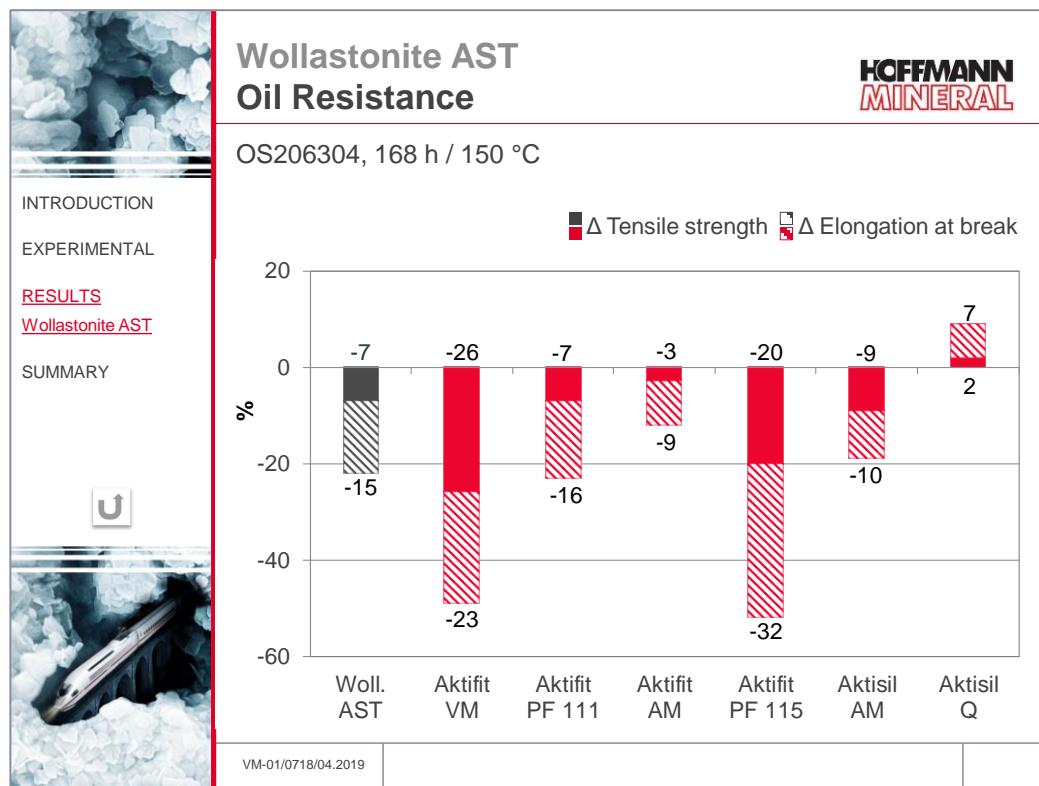
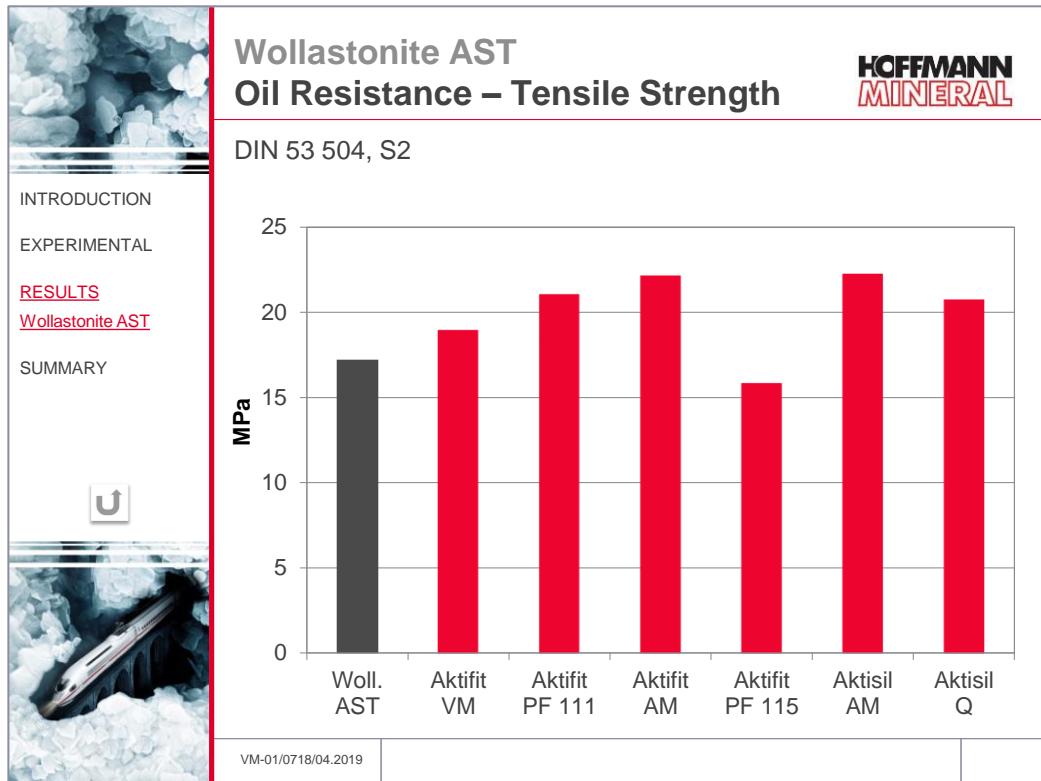
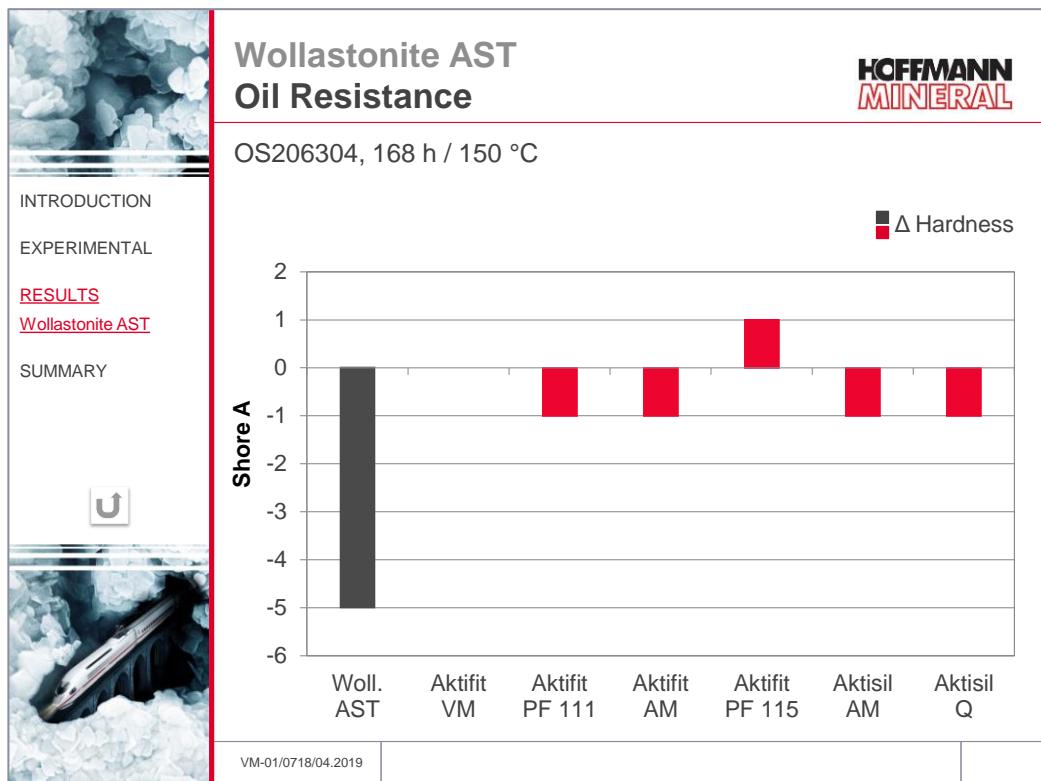


Fig. 11



**Fig. 12**



**Fig. 13**

### 3.1.3.3 Resistance to acid

Replacing the aminosilane-treated wollastonite with Neuburg Siliceous Earth makes the vulcanizates resistant to acetic acid. This is verified both by the changes in tensile strength, elongation at break (Fig. 14) and hardness (Fig. 15), and by the increase in volume of the test specimen (Fig. 16 + Fig. 17).

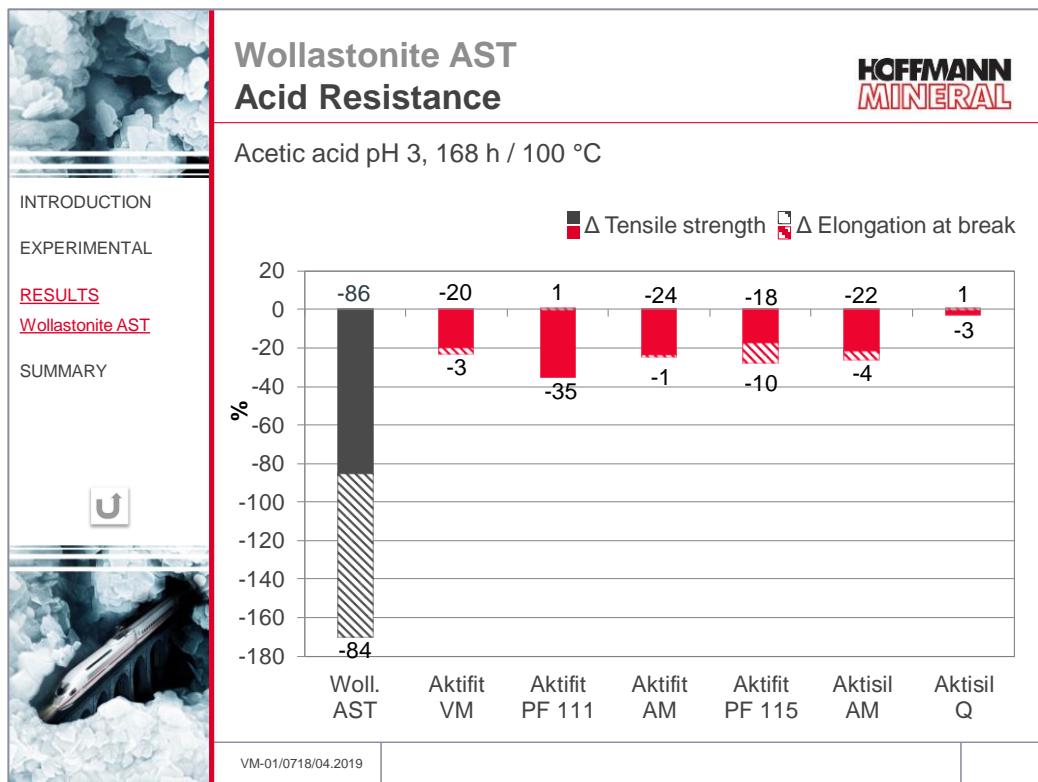


Fig. 14

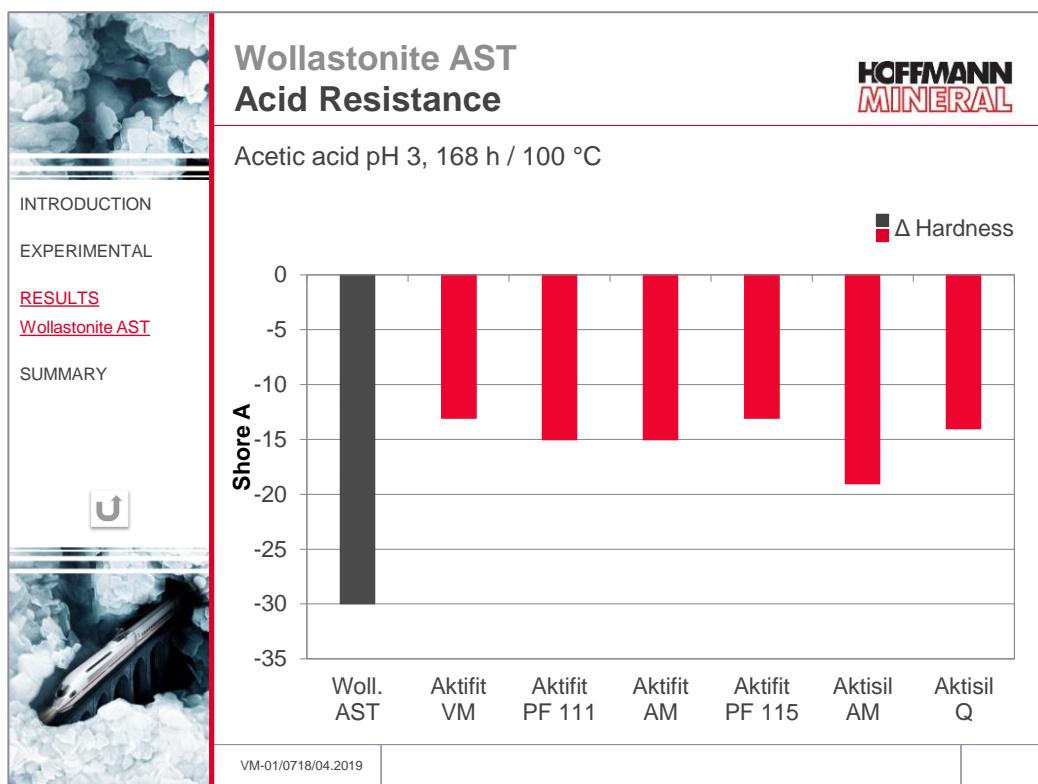


Fig. 15

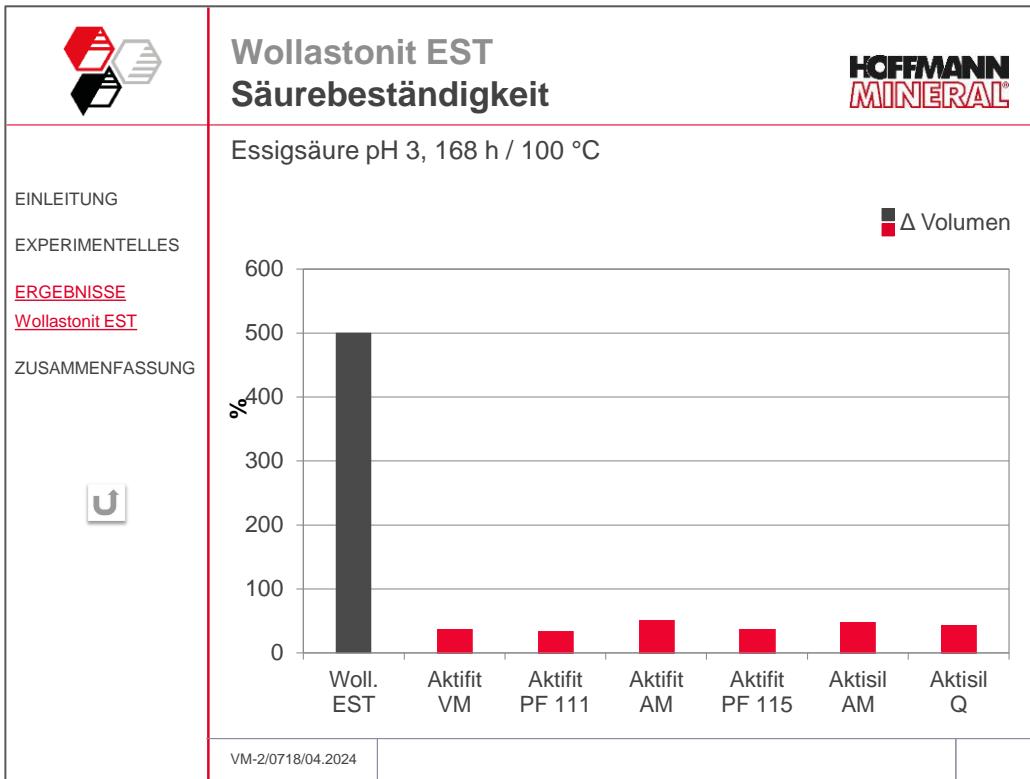


Fig. 16

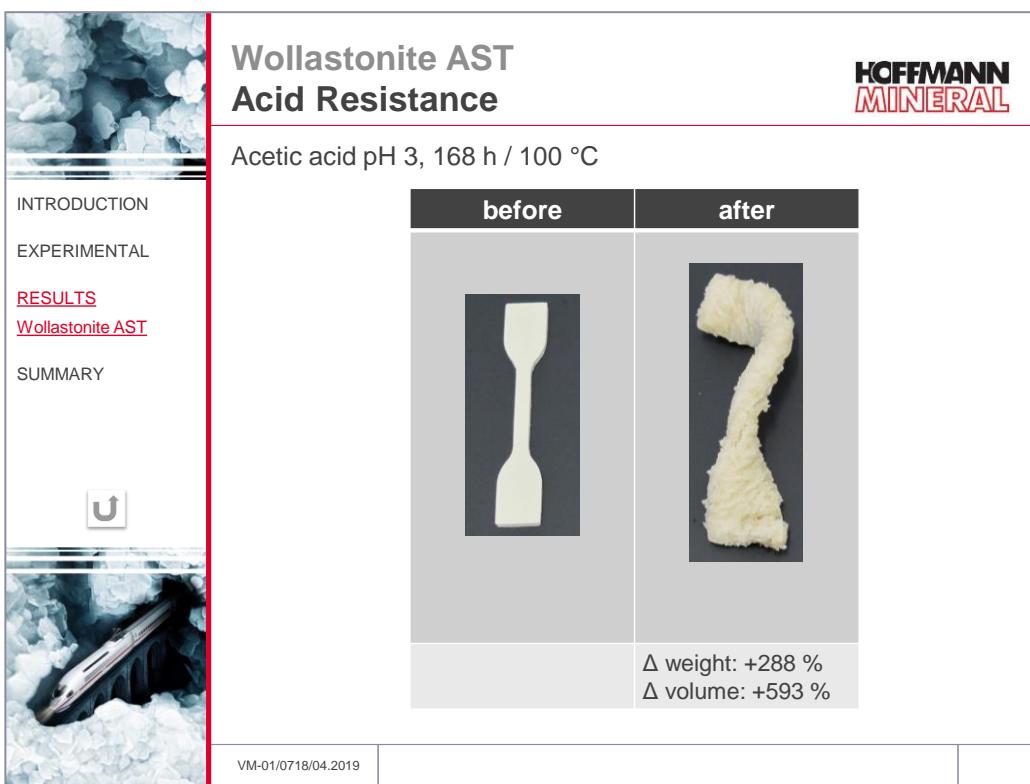


Fig. 17

### 3.1.4 Evaluation of the results

Various properties and combinations of properties – often even contradicting properties – are positively influenced by the Neuburg Siliceous Earth products. This is verified in the following summary analysis.



**Evaluation**
**NSE vs. Wollastonite AST**
**HOFFMANN  
MINERAL**

| Wollastonite AST<br>65 Shore A |                                    | Aktifit<br>VM | Aktifit<br>PF 111 | Aktifit<br>AM | Aktifit<br>PF 115 | Aktisil<br>AM | Aktisil<br>Q |
|--------------------------------|------------------------------------|---------------|-------------------|---------------|-------------------|---------------|--------------|
| INTRODUCTION                   |                                    | =             | =                 | +             | +                 | +             | =            |
| EXPERIMENTAL                   |                                    | =             | =                 | =             | =                 | =             | =            |
| RESULTS                        |                                    | +             | +                 | +             | =                 | +             | =            |
| SUMMARY                        |                                    |               |                   |               |                   |               |              |
|                                | Cure speed                         | =             | =                 | +             | +                 | +             | =            |
|                                | Viscosity                          | =             | =                 | =             | =                 | =             | =            |
|                                | Tensile strength (TS)              | +             | +                 | +             | =                 | +             | =            |
|                                | Elongation at break                |               | =                 | =             | =                 | =             | =            |
|                                | Modulus 100 %                      | +             | =                 | +             | +                 | +             | +            |
|                                | CS ISO 200 °C                      | =             | =                 | =             | =                 | =             | =            |
|                                | CS ISO 200 °C, no post-cure        | +             | =                 | +             | =                 | =             | +            |
|                                | CS ISO 232 °C                      | =             | +                 | =             | =                 | =             | +            |
|                                | CS ISO 232 °C, no post-cure        | +             | +                 | +             | =                 | +             | +            |
|                                | CS VW 23 °C                        | =             | =                 | =             | =                 | +             | =            |
|                                | CS VW 150 °C                       | =             | =                 | =             | =                 | =             | =            |
|                                | Abrasion resistance                | +             | +                 | +             | +                 | +             | +            |
|                                | Hot air resistance 210 °C          | =             | =                 | =             | =                 | =             | =            |
|                                | TS after storage in hot air 210 °C | +             | +                 | +             | =                 | +             | +            |
|                                | Hot air resistance 230 °C          | =             | =                 | =             | =                 | =             | =            |
|                                | TS after storage in hot air 230 °C | +             | +                 | +             | =                 | +             | =            |
|                                | Fuel resistance                    | =             | =                 | =             | =                 | =             | =            |
|                                | TS after storage in fuel           | +             | +                 | +             | =                 | +             | +            |
|                                | Oil resistance                     |               | =                 | +             |                   | =             | +            |
|                                | TS after storage in oil            | =             | +                 | +             | =                 | +             | +            |
|                                | Resistance to acetic acid          | +             | +                 | +             | +                 | +             | +            |

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**Fig. 18**

Fig. 18 shows which NSE grades either improve (+) or match (=) the relevant property performance versus the aminosilane-treated wollastonite. Red + signs indicate the NSE product that achieves the best result for the appropriate property among NSE grades.

## 3.2 Neuburg Siliceous Earth versus Wollastonite EST

### 3.2.1 Rheological properties

Compared to the epoxysilane-treated wollastonite, all of the listed NSE types are able to achieve faster curing speeds, as shown in Fig. 19. The variants with amino functional group achieve the highest levels. Viscosity (Fig. 20) is comparable across the board.

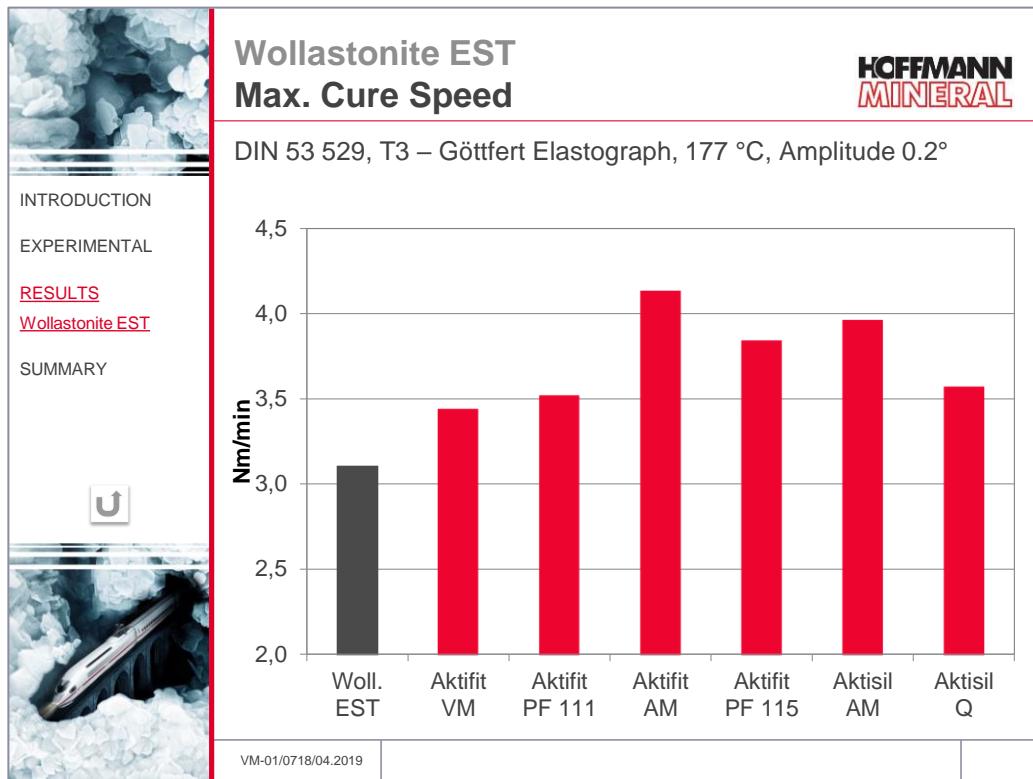


Fig. 19

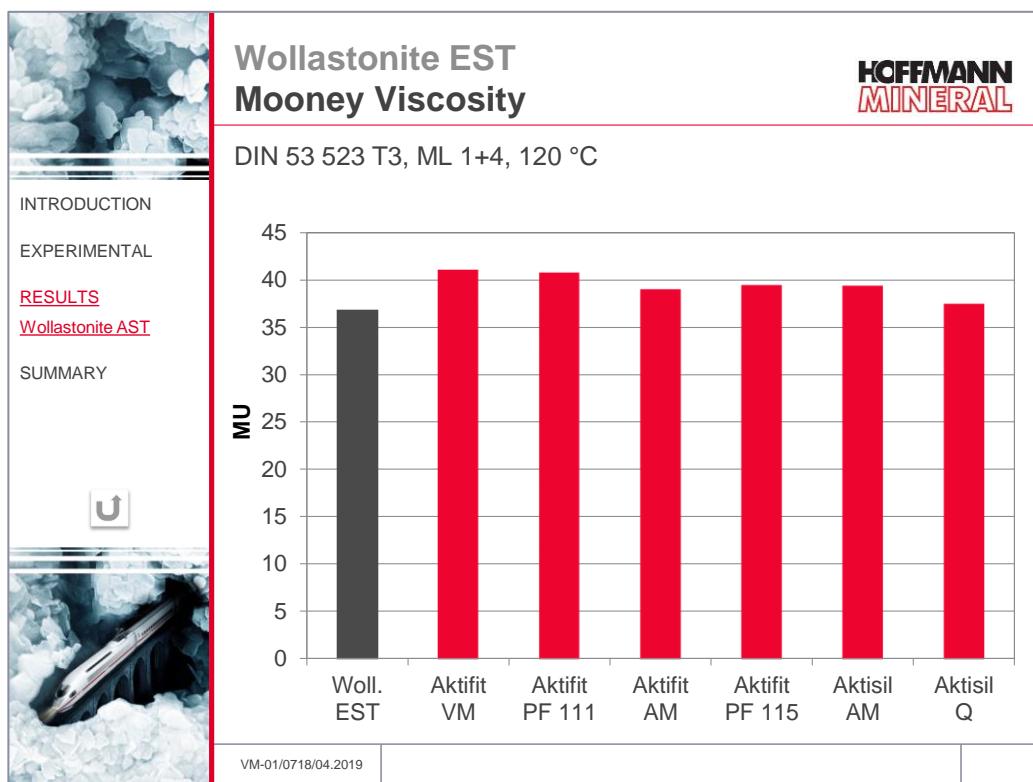


Fig. 20

### 3.2.2 Mechanical properties

The tensile strength with Aktifit PF 115 and Aktisil Q is comparable to that of the epoxysilane-treated wollastonite (Fig. 21). The other NSE grades all result in higher tensile strength. Equally, the NSE variants are able to raise moduli at 100 % elongation compared to the wollastonite (Fig. 22).

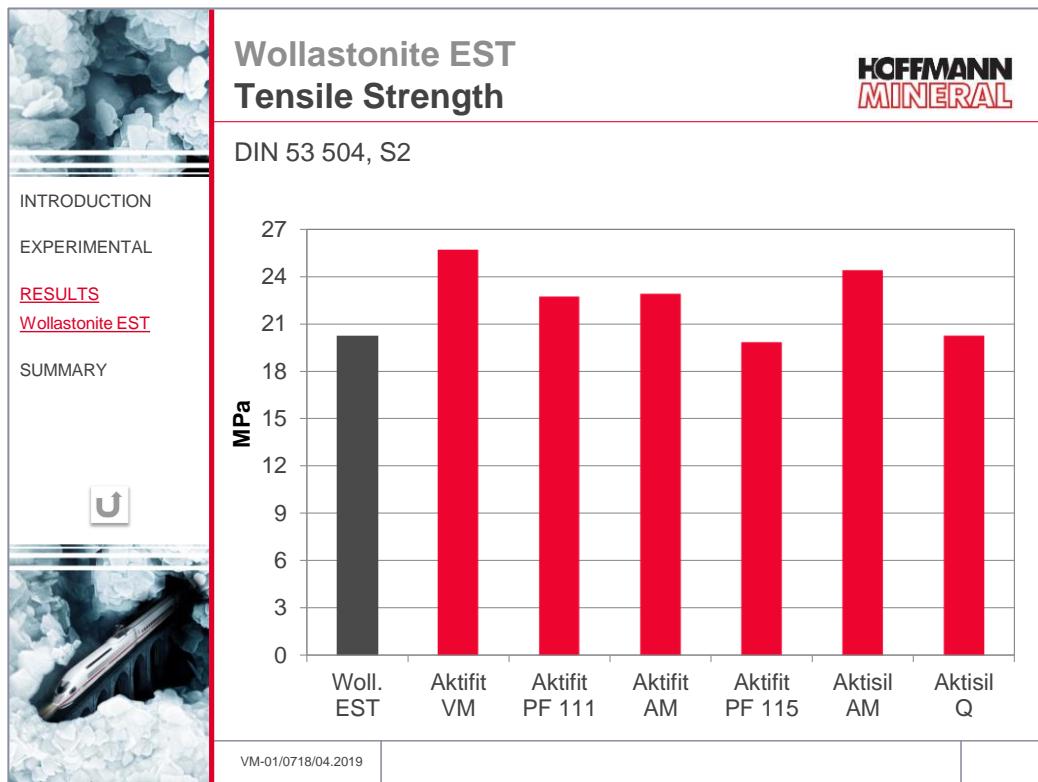


Fig. 21

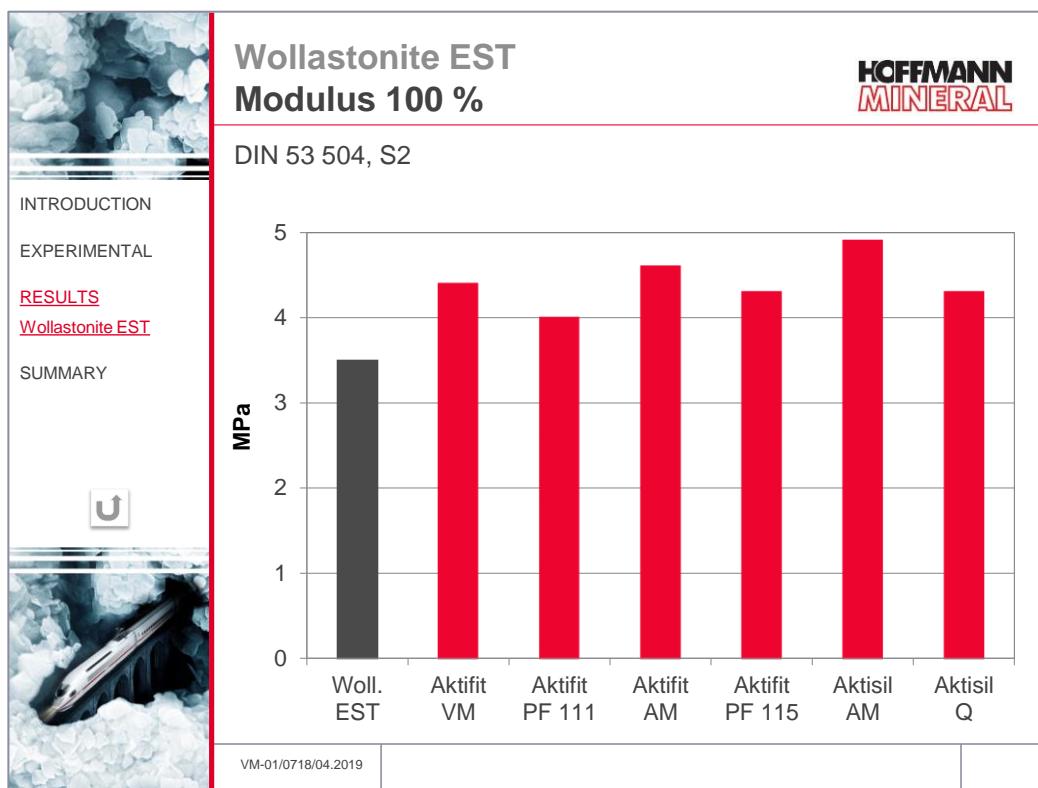
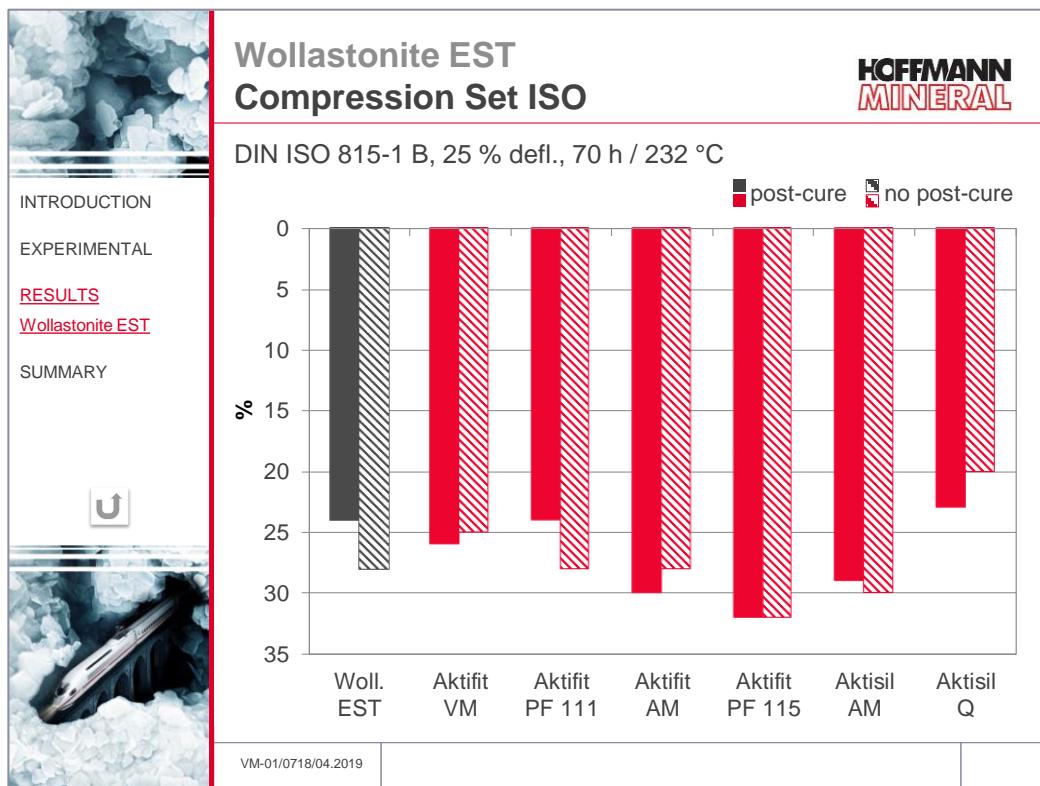


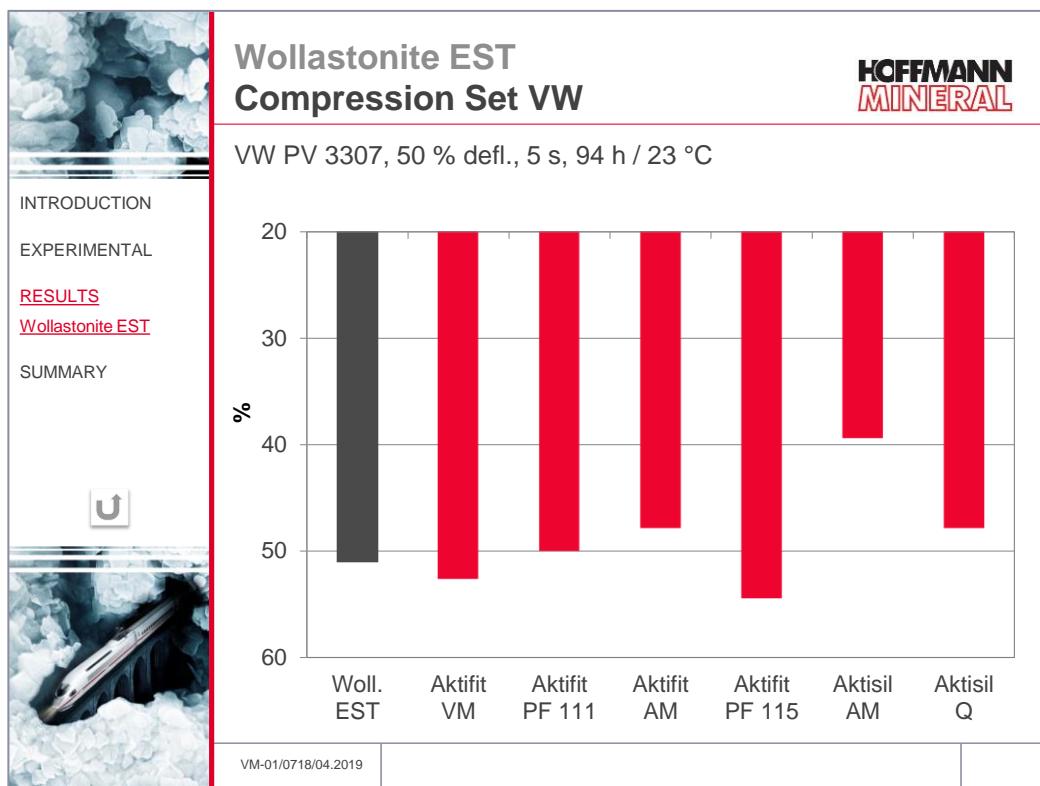
Fig. 22

As far as the compression set is concerned, the performance of the epoxysilane-treated wollastonite is already good (Fig. 23). Aktifit VM, Aktifit PF 111 and Aktisil Q are able to match it. The latter's performance is better than wollastonite if the specimens are not post-cured.

Replacing the wollastonite with Aktisil AM results in a significant reduction in the compression set as measured according to VW test specification PV 3307, as shown in Fig. 24.



**Fig. 23**



**Fig. 24**

If applications require improved abrasion resistance, the epoxysilane-treated wollastonite can be replaced with any of the NSE variants addressed in this paper (Fig. 25).

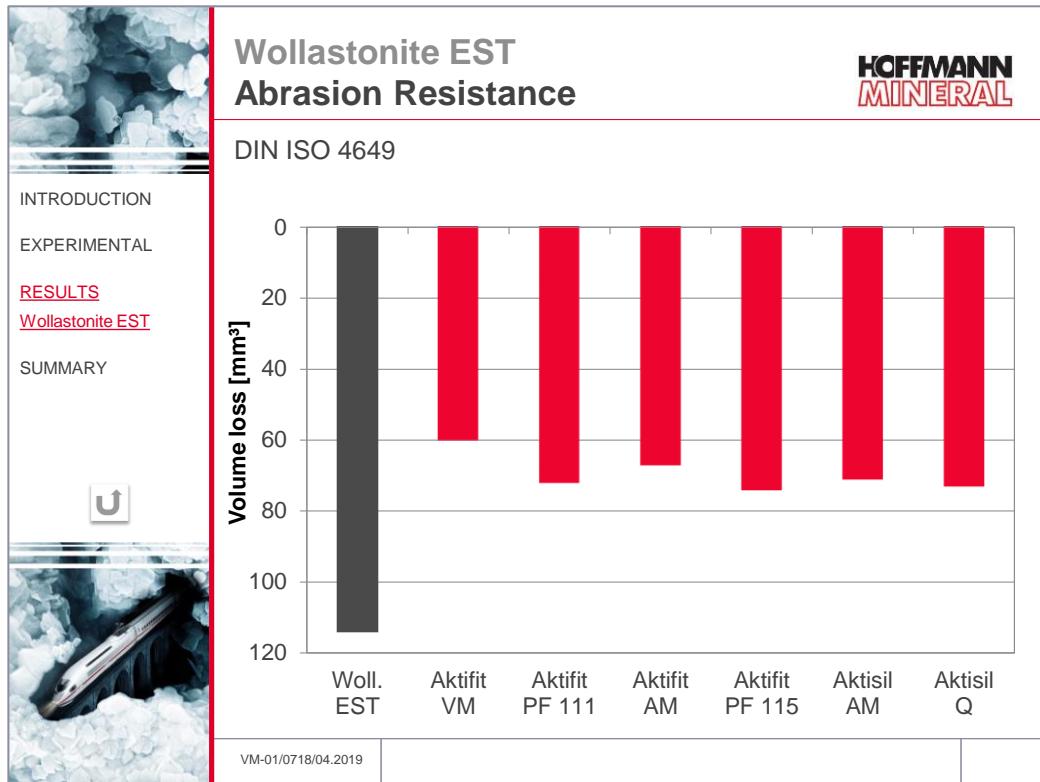


Fig. 25

### 3.2.3 Media resistance

#### 3.2.3.1 Resistance to hot air and fuel

The changes in mechanical properties after aging in hot air or fuel are comparable across the board. The higher tensile strength of the vulcanizates filled with Neuburg Siliceous Earth are maintained versus the epoxysilane-treated wollastonite.

#### 3.2.3.2 Resistance to oil

With regard to resistance to oil (OS206304), Aktifit PF 111, Aktifit AM, Aktisil AM and Aktisil Q score better than the epoxysilane-treated wollastonite. They lead to much lesser changes in tensile strength and elongation at break after storing the vulcanizates in oil (Fig. 26). As a result, the tensile strength of these NSE variants is nearly 10 MPa better than that of the wollastonite (Fig. 27).

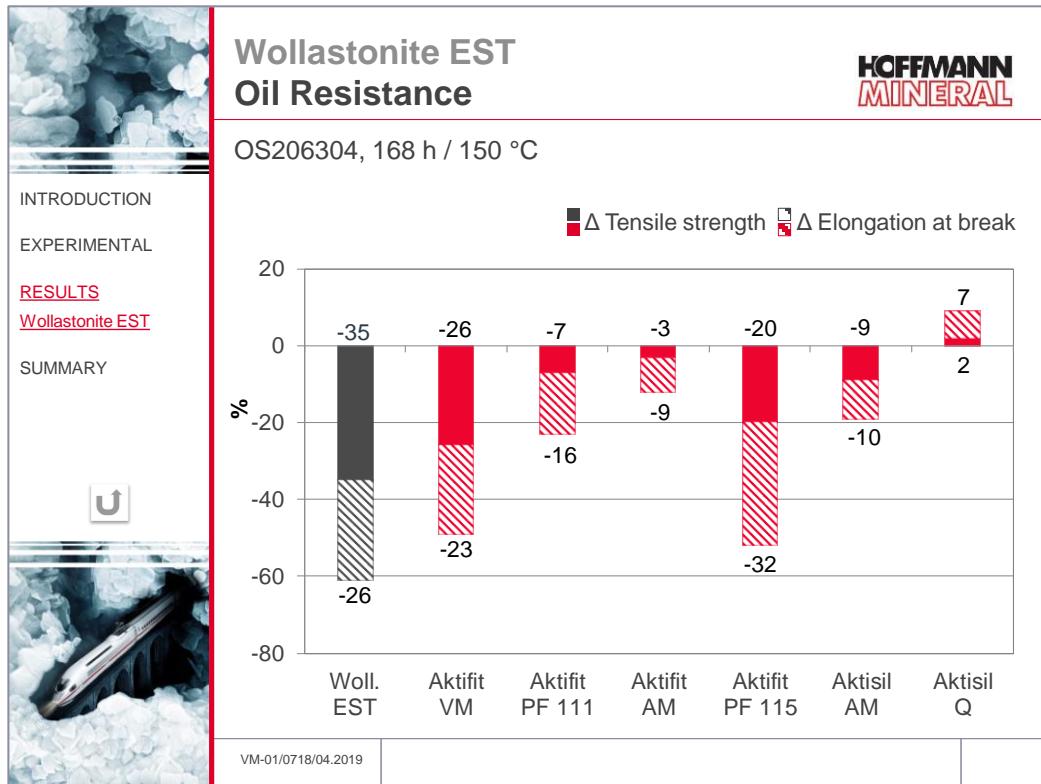


Fig. 26

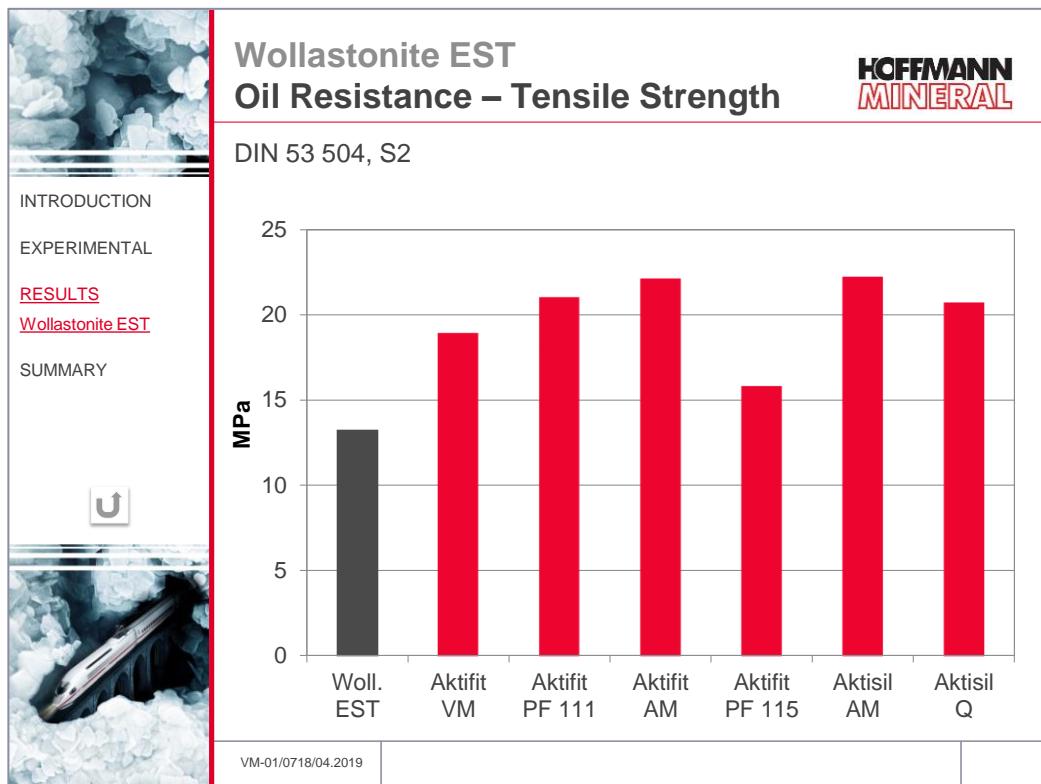


Fig. 27

### 3.2.3.3 Resistance to acid

Replacing the epoxysilane-treated wollastonite with Neuburg Siliceous Earth makes the vulcanizates resistant to acetic acid. This is verified both by the changes in tensile strength, elongation at break and hardness, which is no longer measurable because the test specimen is destroyed during testing (Fig. 29), and by the increase in volume of the test specimen (Fig. 30 + Fig. 31).

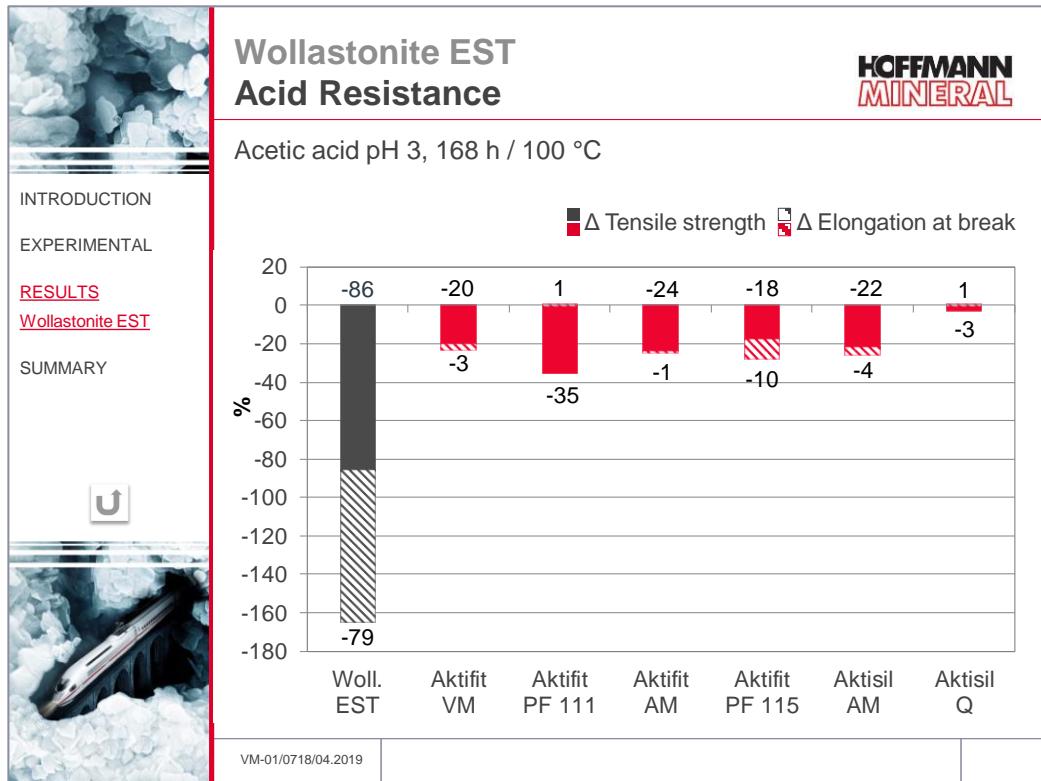


Fig. 28

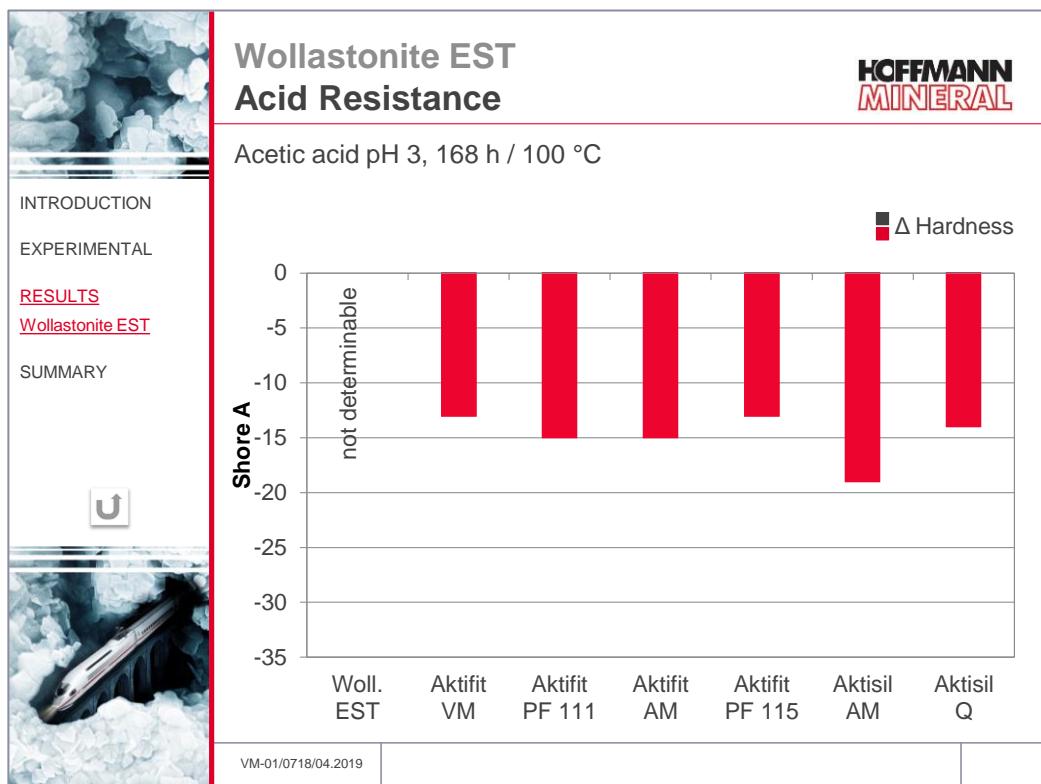
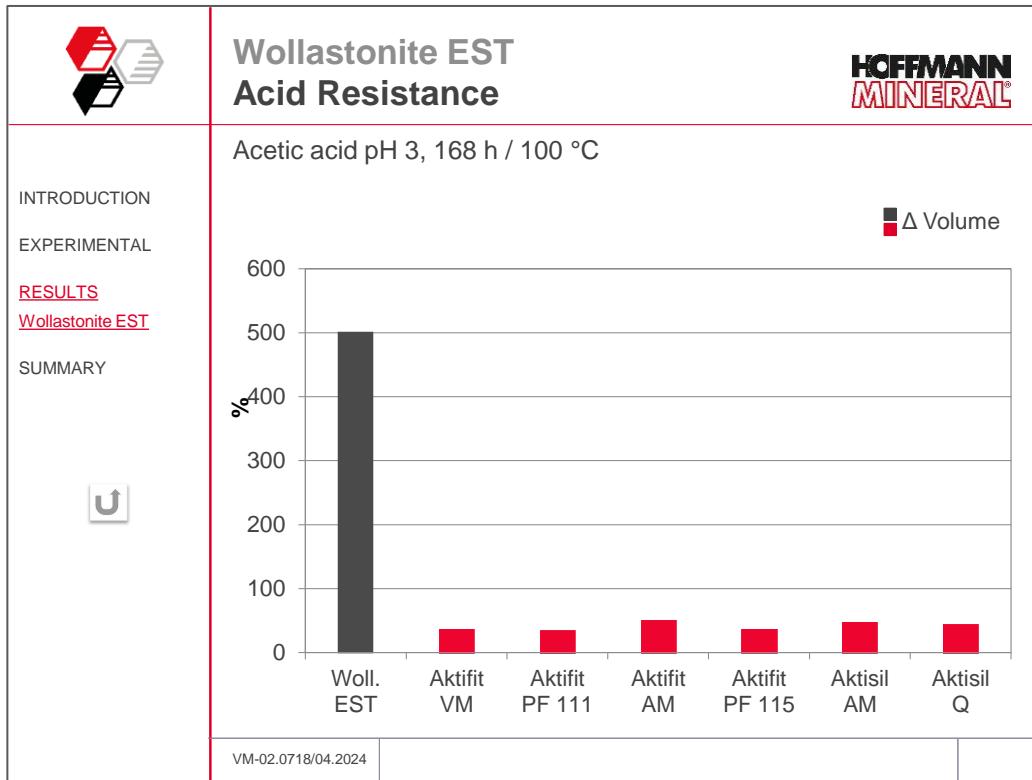


Fig. 29



**Fig. 30**



**Fig. 31**

### 3.2.4 Evaluation of the results

Various properties and combinations of properties – often even contradicting properties – are positively influenced by the Neuburg Siliceous Earth products. This is verified in the following summary analysis.



**Evaluation**  
**NSE vs. Wollastonite EST**

**HOFFMANN  
MINERAL**

| Wollastonite EST<br>65 Shore A | Aktifit<br>VM | Aktifit<br>PF 111 | Aktifit<br>AM | Aktifit<br>PF 115 | Aktisil<br>AM | Aktisil<br>Q |
|--------------------------------|---------------|-------------------|---------------|-------------------|---------------|--------------|
| Cure speed                     | +             | +                 | +             | +                 | +             | +            |
| Viscosity                      | =             | =                 | =             | =                 | =             | =            |
| Tensile strength (TS)          | +             | +                 | +             | =                 | +             | =            |
| Modulus100 %                   | +             | +                 | +             | +                 | +             | +            |
| CS ISO 200 °C                  | =             | =                 | =             | =                 | =             | =            |
| CS ISO 200 °C, no post-cure    | =             | =                 | =             | =                 | =             | =            |
| CS ISO 232 °C                  | =             | =                 |               |                   |               | =            |
| CS ISO 232 °C, no post-cure    | =             | =                 | =             |                   | =             | +            |
| CS VW 23 °C                    | =             | =                 | =             | =                 | +             | =            |
| CS VW 150 °C                   | =             | =                 | =             | =                 | =             | =            |
| Abrasion resistance            | +             | +                 | +             | +                 | +             | +            |
| Hot air resistance 210 °C      | =             | =                 | =             |                   |               | =            |
| TS after hot air 210 °C        | +             | +                 | +             | =                 | +             | =            |
| Hot air resistance 230 °C      | =             | =                 | =             |                   |               | =            |
| TS after hot air 230 °C        | +             | +                 | +             | =                 | +             | =            |
| Fuel resistance                | =             | =                 | =             | =                 | =             | =            |
| TS after storage in fuel       | +             | +                 | +             | +                 | +             | +            |
| Oil resistance                 | =             | +                 | +             | =                 | +             | +            |
| TS after storage in oil        | +             | +                 | +             | +                 | +             | +            |
| Resistance to acetic acid      | +             | +                 | +             | +                 | +             | +            |

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**Fig. 32**

Fig. 32 shows which NSE grades either improve (+) or match (=) the relevant property performance versus the aminosilane-treated wollastonite. Red + signs indicate the NSE product that achieves the best result for the appropriate property among NSE grades.

### 3.3 Neuburg Siliceous Earth versus Barium Sulfate

#### 3.3.1 Rheological properties

Replacing barium sulfate with Silfit Z 91 and the aminosilane-treated grades of Neuburg Siliceous Earth Aktifit AM, Aktifit PF 115 and Aktisil AM results in faster curing (Fig. 33). These grades also tend to reduce viscosity somewhat (Fig. 34). Aktisil Q seems to have a slightly greater impact in this respect.

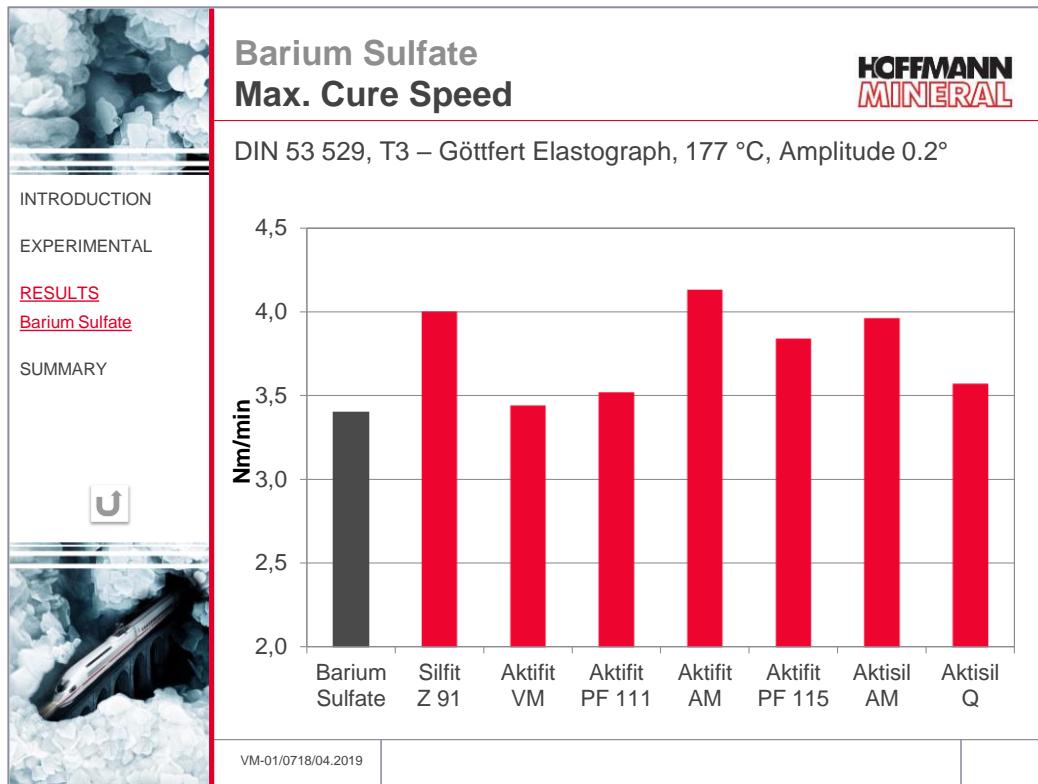


Fig. 33

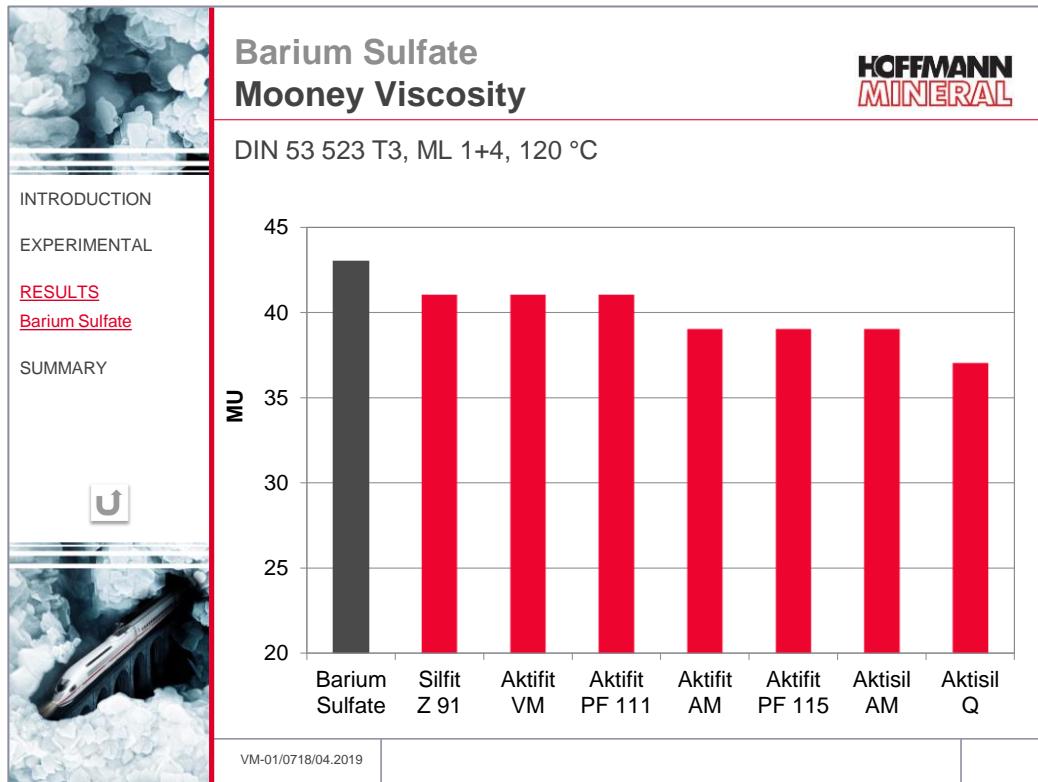


Fig. 34

### 3.3.2 Mechanical properties

All NSE grades significantly raise tensile strength compared to barium sulfate (Fig. 35). Remarkably, even Silfit Z 91 – a non-functional filler – is able to raise tensile strength by about 5 MPa. Accordingly, Silfit Z 91 can improve tensile strength without compromising elongation at break (Fig. 36). Most of the surface-treated grades of Neuburg Siliceous Earth also demonstrate acceptable elongation at break, however. At the same, they are able to nearly double moduli at 100 % elongation (Fig. 37).

Further, replacing barium sulfate with Silfit Z 91 or Aktifit PF 115 results in comparable tear resistance, as shown in Fig. 38. As far as tensile performance is concerned, therefore, Silfit Z 91, represents an excellent alternative to barium sulfate.

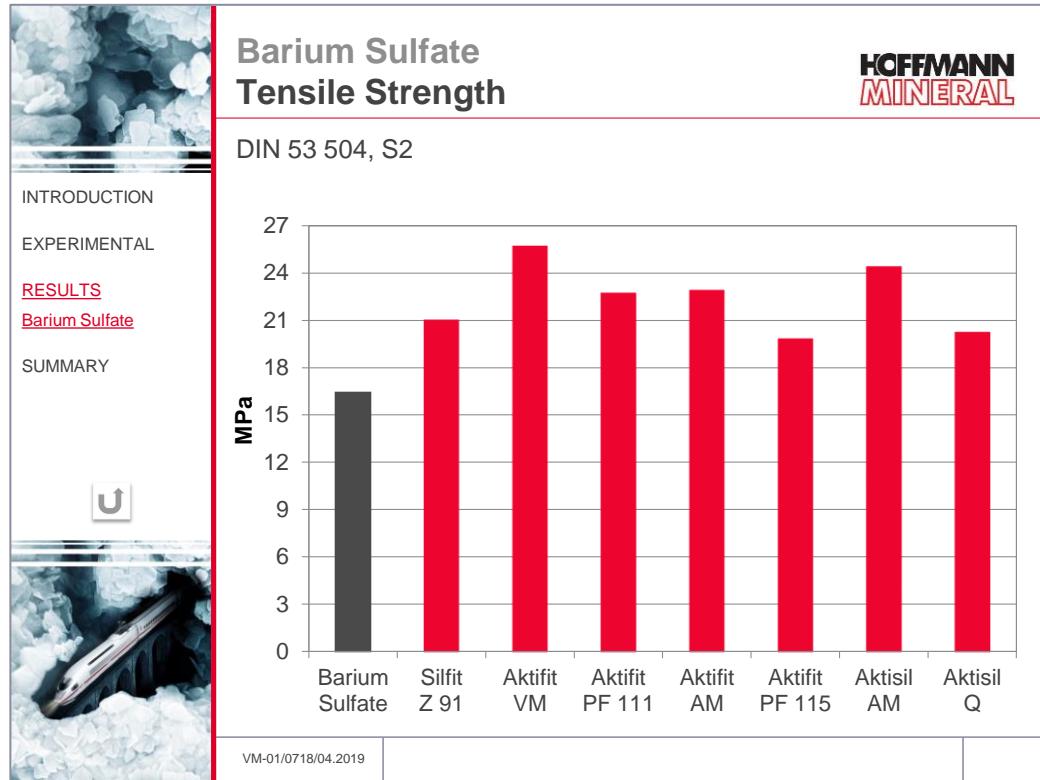
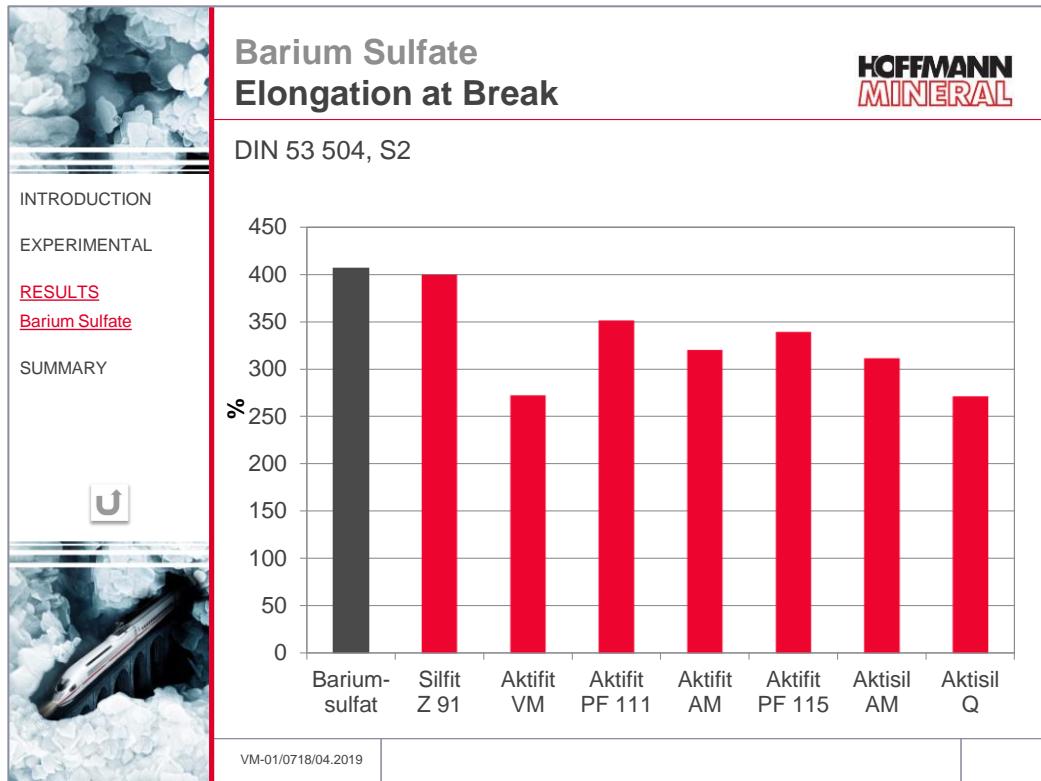
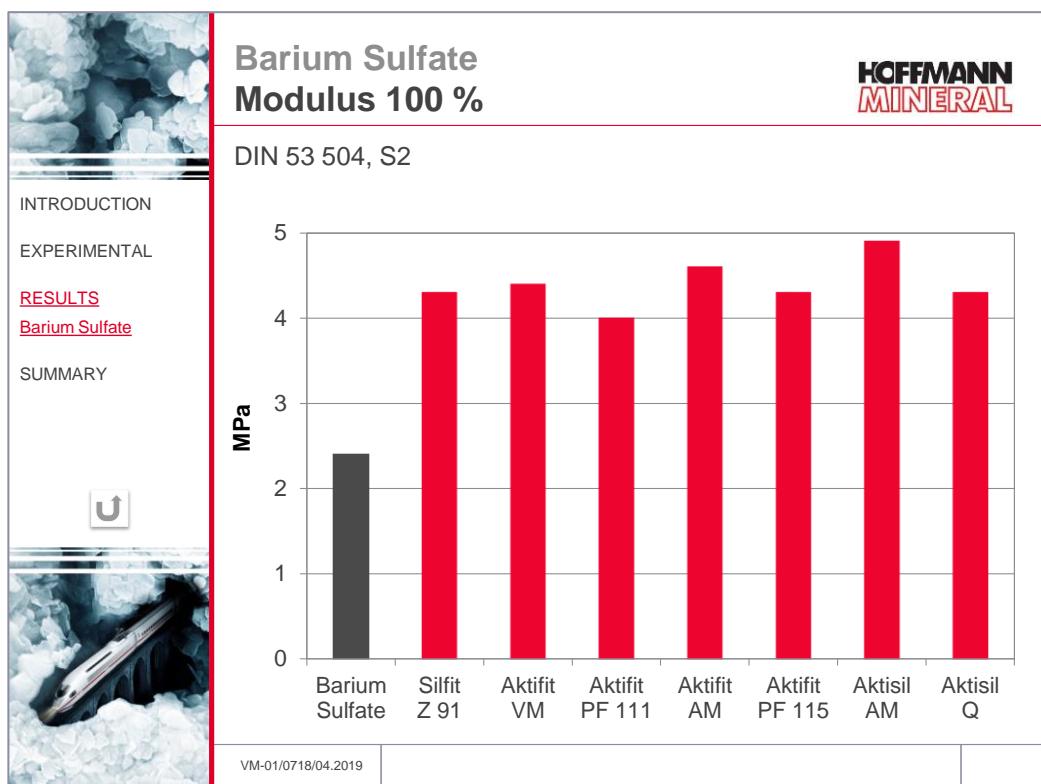


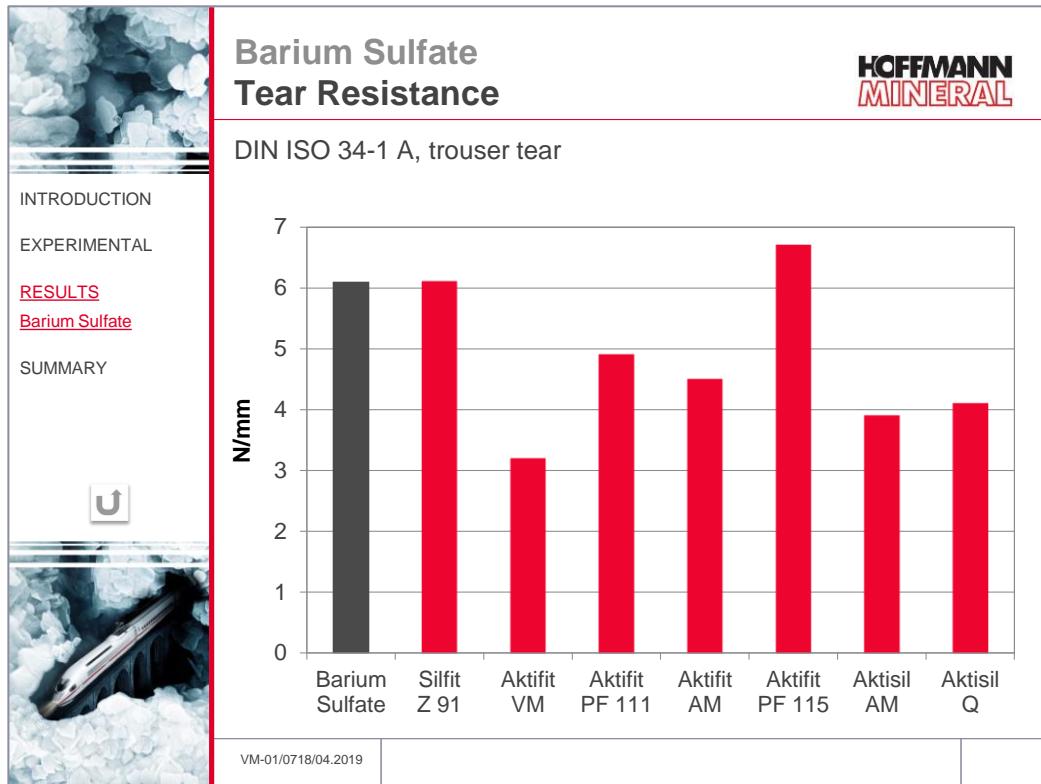
Fig. 35



**Fig. 36**



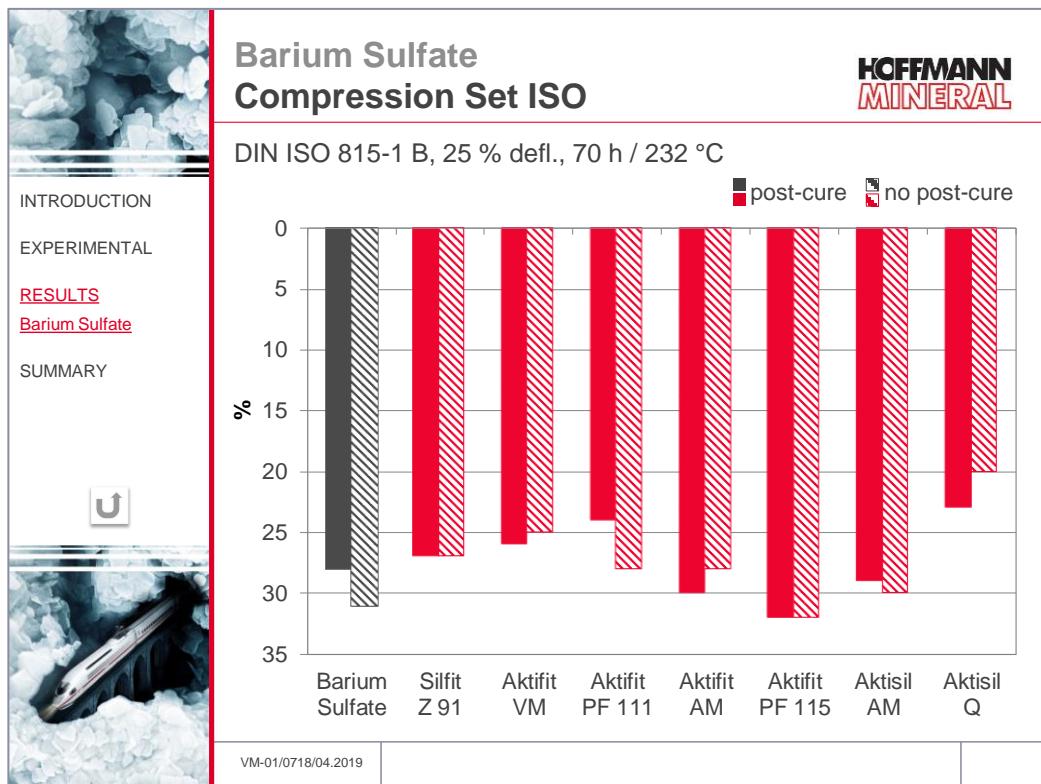
**Fig. 37**



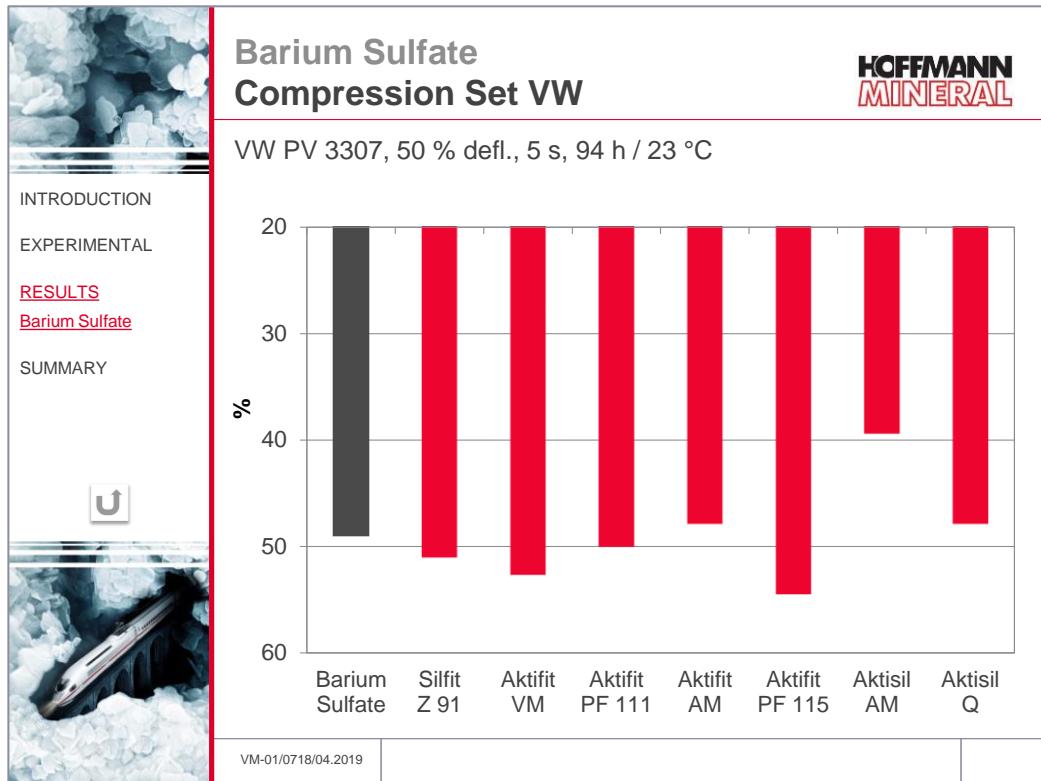
**Fig. 38**

Replacing the barium sulfate with Neuburg Siliceous Earth results in a reduction of the compression set. Fig. 39 shows the compression set as per DIN ISO 815-1 B after 70 hours at 232 °C. The improvement with Aktifit VM, Aktifit PF 111 and especially Aktisil Q is clearly apparent. Aktisil Q, in particular, offers the benefit of significantly reducing compression set even on test specimens, that have not been post-cured.

If VW's compression set as per PV 3307 is important, the use of Aktisil AM is recommended as it results in the best value at room temperature (Fig. 40).

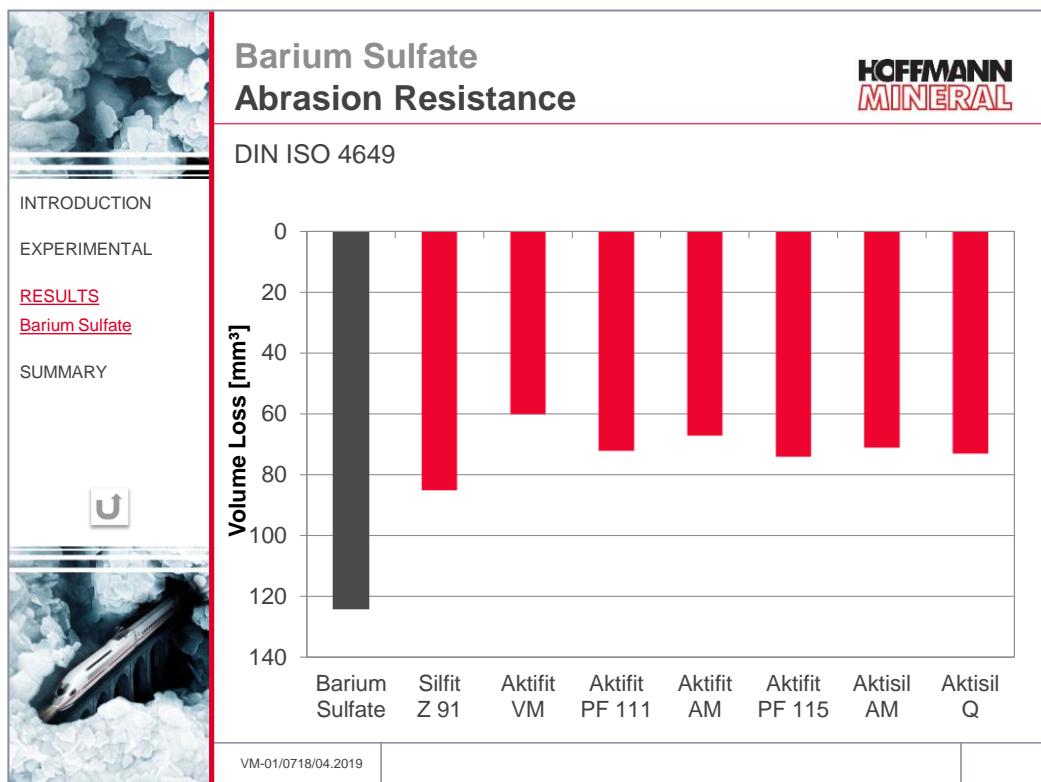


**Fig. 39**



**Fig. 40**

If applications require improved abrasion resistance, the barium sulfate can be replaced with any of the NSE variants addressed in this paper (Fig. 41).



**Fig. 41**

### 3.3.3 Media resistance

#### 3.3.3.1 Resistance to hot air

As the changes in tensile strength and elongation at break after aging in hot air show, NSE achieves comparable, and in most cases even better resistance to hot air than barium sulfate (Fig. 42 and Fig. 43).

Aktifit VM is particularly resistant at a short-term aging temperature of 230 °C. If the temperature remains at 210 °C for longer periods, the use of Aktifit PF 111, Aktifit AM or Aktisil AM is recommended.

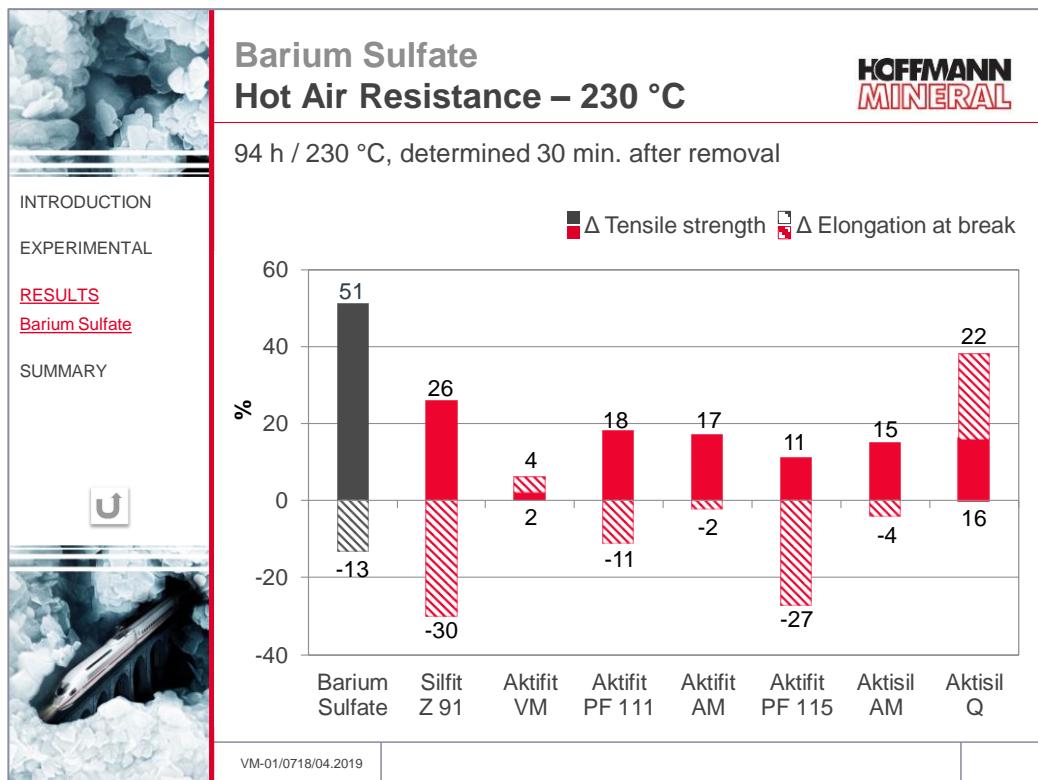


Fig. 42

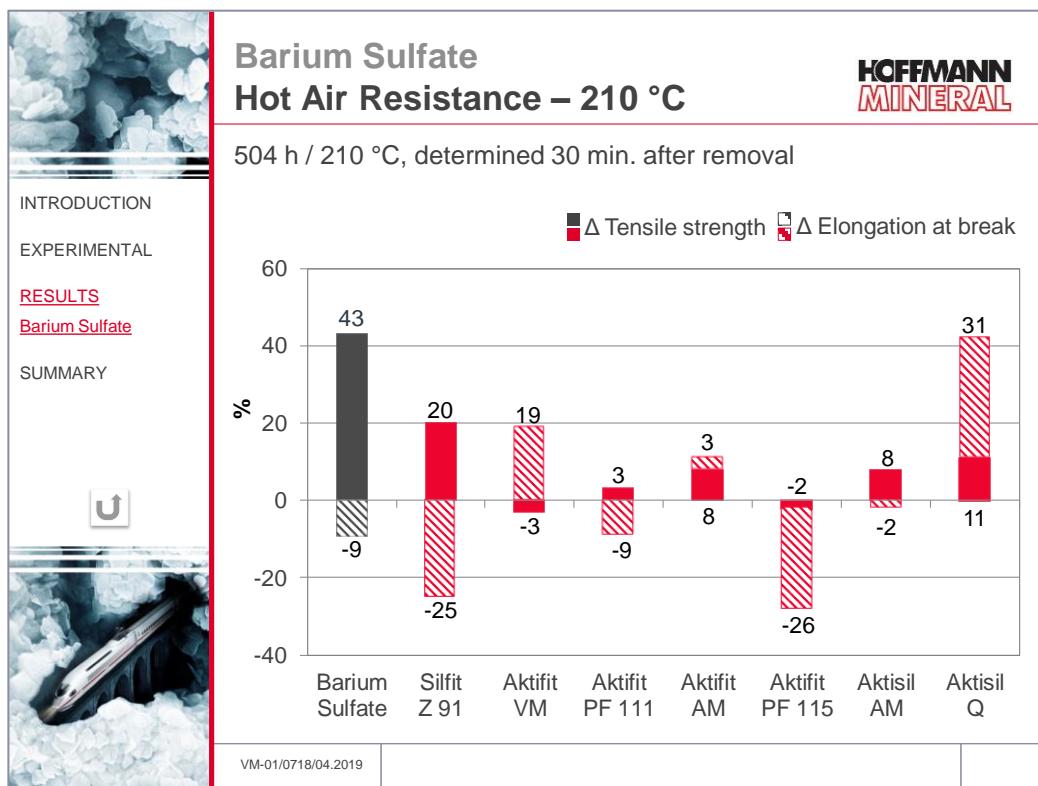


Fig. 43

### 3.3.3.2 Resistance to fuel

After immersion in fuel, the hardness of the vulcanizate filled with barium sulfate decreases to a greater degree than that of the vulcanizates made with Neuburg Siliceous Earth (Fig. 44).

The changes in tensile strength and elongation at break are comparable. As such, the greater strength of the NSE types is maintained when the vulcanizates were exposed to fuel (Fig. 45).

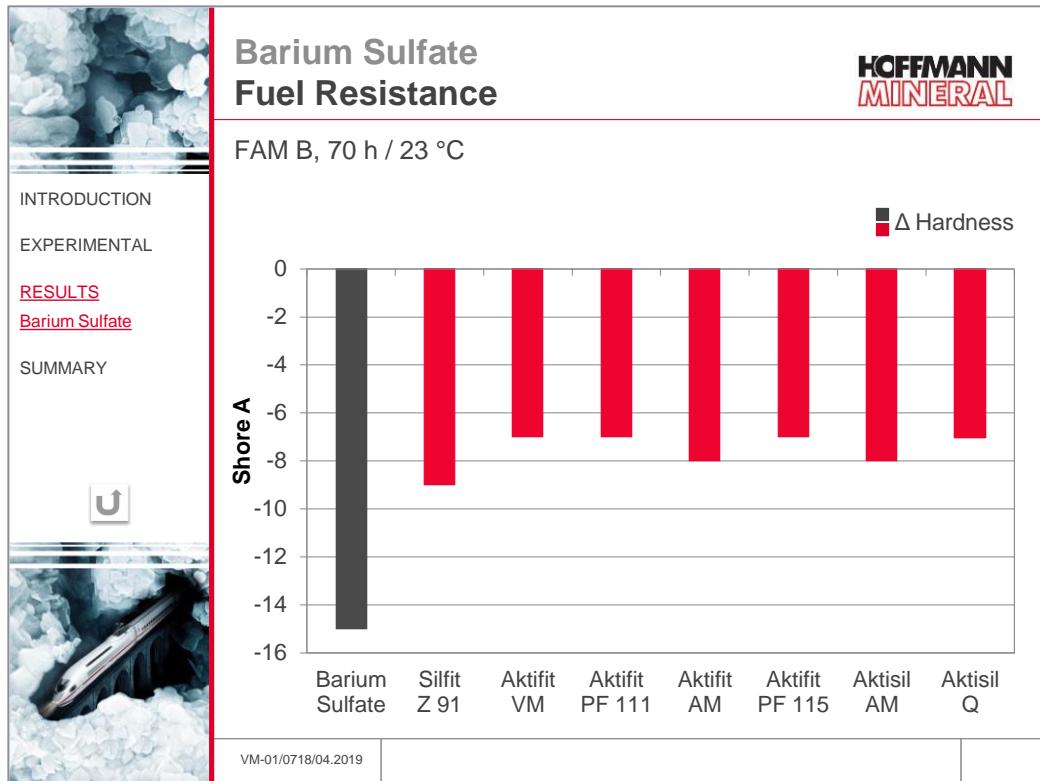


Fig. 44

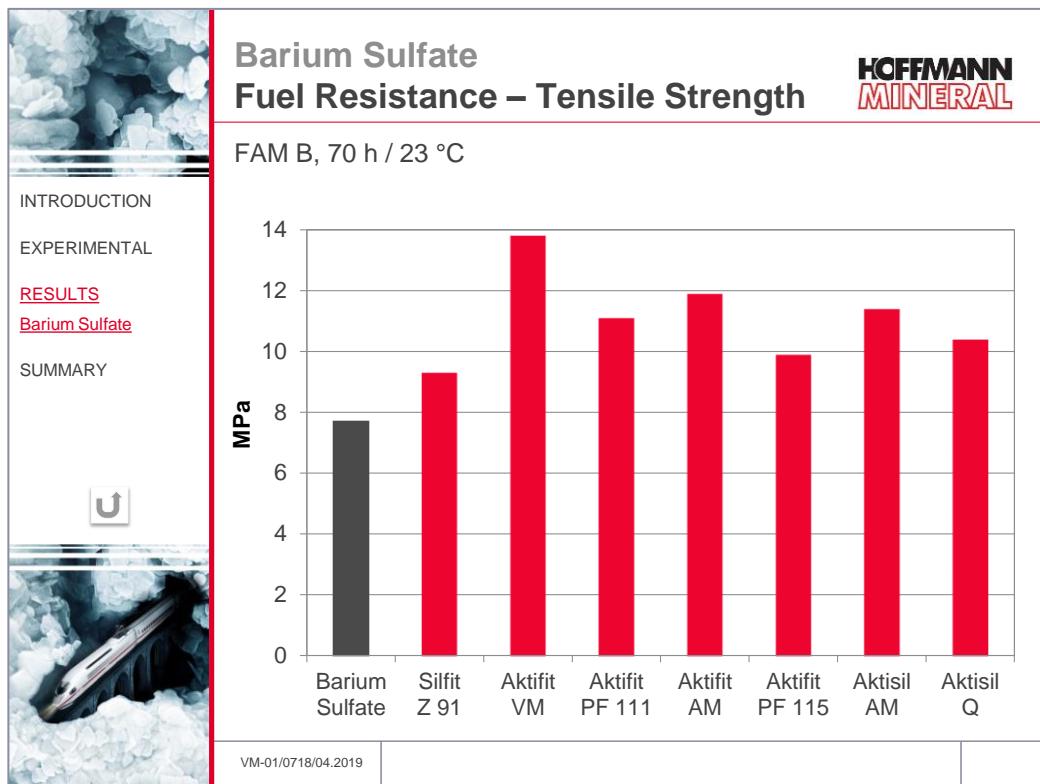


Fig. 45

### 3.3.3.3 Resistance to oil

Replacing barium sulfate with Neuburg Siliceous Earth results, in most cases, in vulcanizates with lesser changes in tensile strength and elongation at break (Fig. 46) and in all cases in less loss of hardness (Fig. 48). Thus, hardness and tensile strength performance (Fig. 47) are virtually unchanged. The NSE variants addressed in this paper therefore clearly improve resistance to oil, compared to barium sulfate.

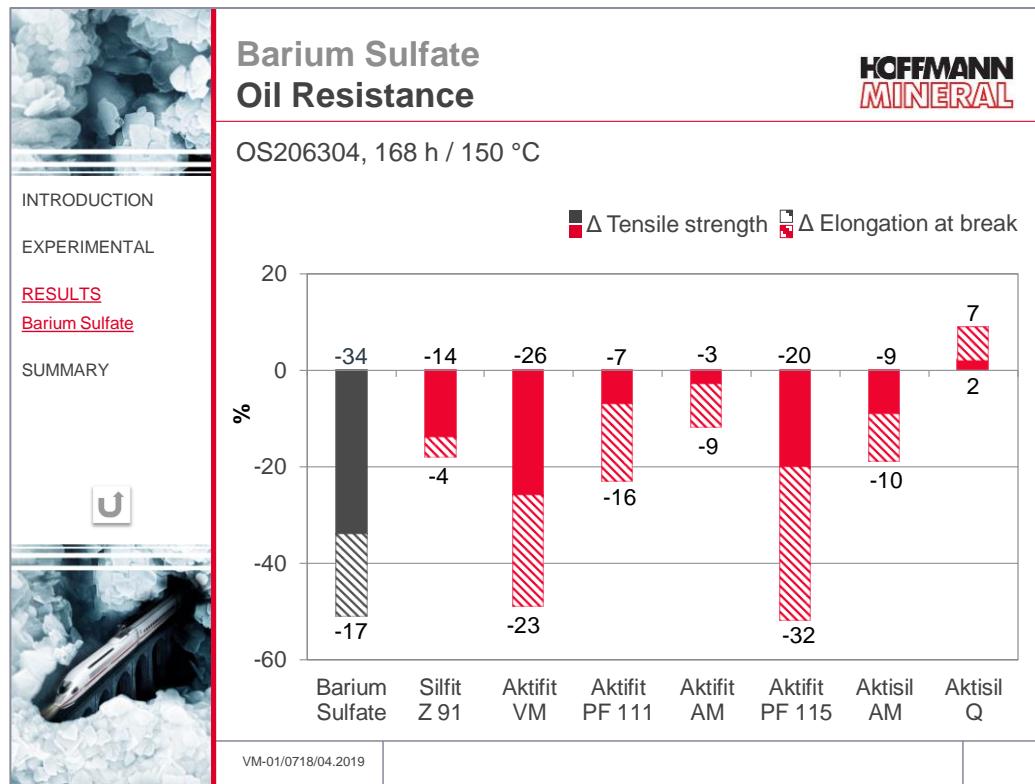


Fig. 46

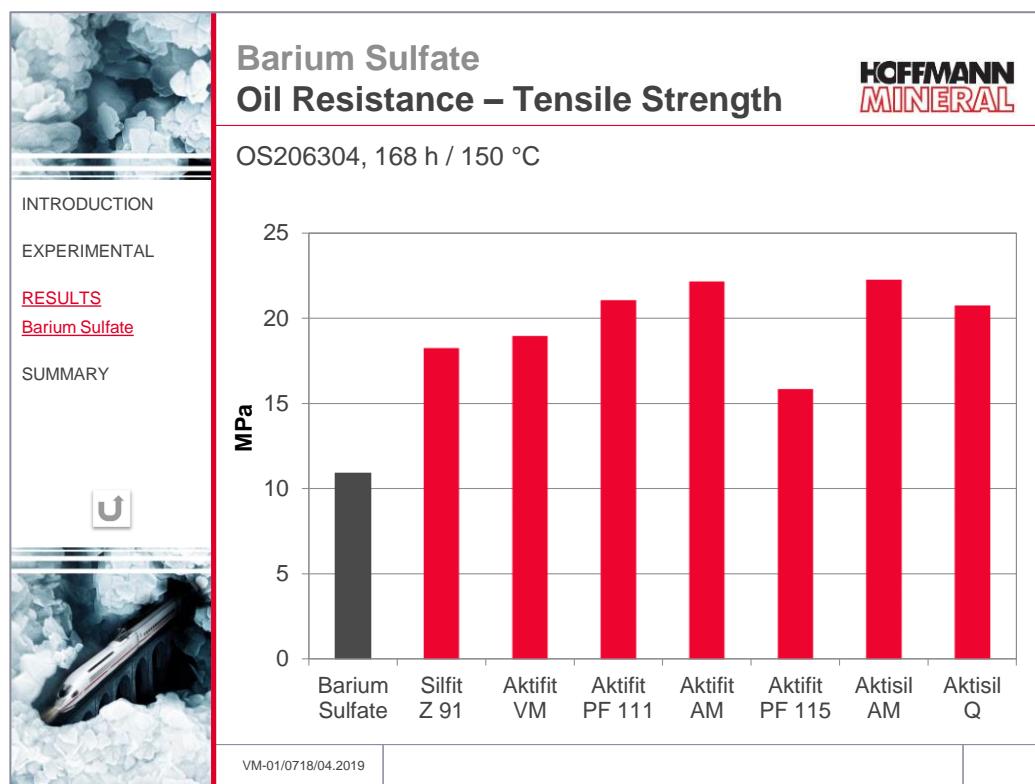


Fig. 47

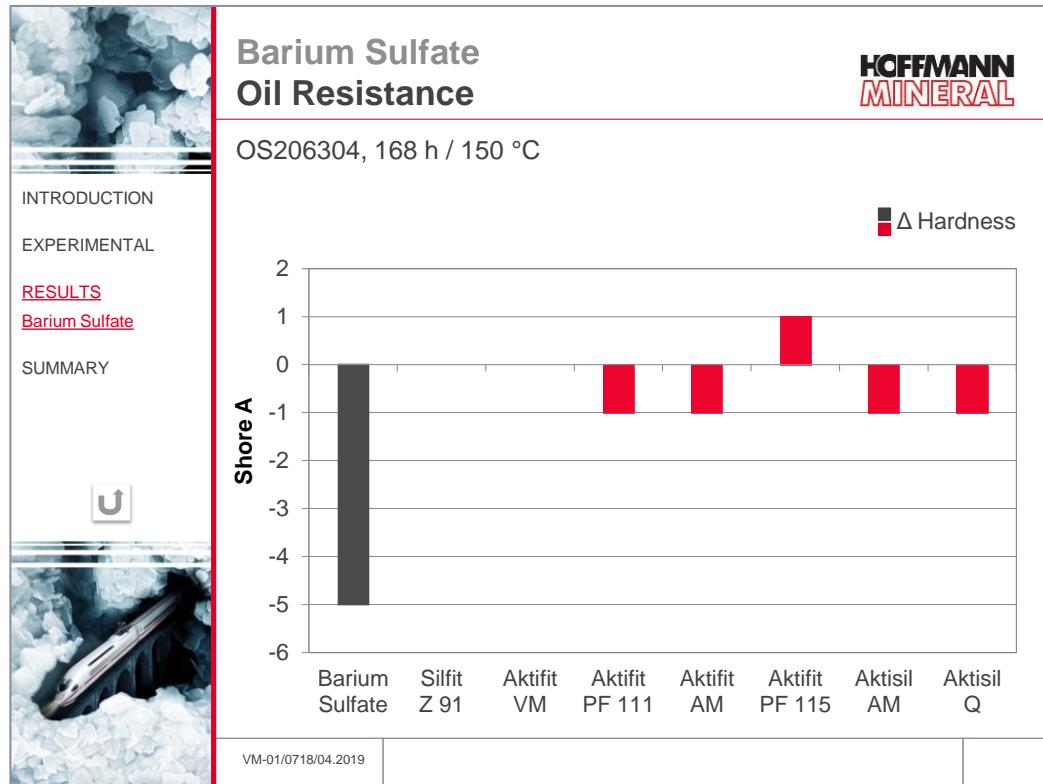


Fig. 48

### 3.3.3.4 Resistance to acid

Barium sulfate already achieves a significant improvement in resistance to acid versus wollastonite. Neuburg Siliceous Earth is, however, able to further improve the relatively good result achieved with barium sulfate. Especially the silanized NSE variants result in virtually no change in elongation at break (Fig. 49). Generally, Neuburg Siliceous Earth proves to result in less loss of hardness (Fig. 50), and the volume of the test specimens also increases to a much lesser degree than with barium sulfate. Even Silfit Z 91 – which is not surface-treated – manages to achieve a significant improvement (Fig. 51 and Fig. 52).

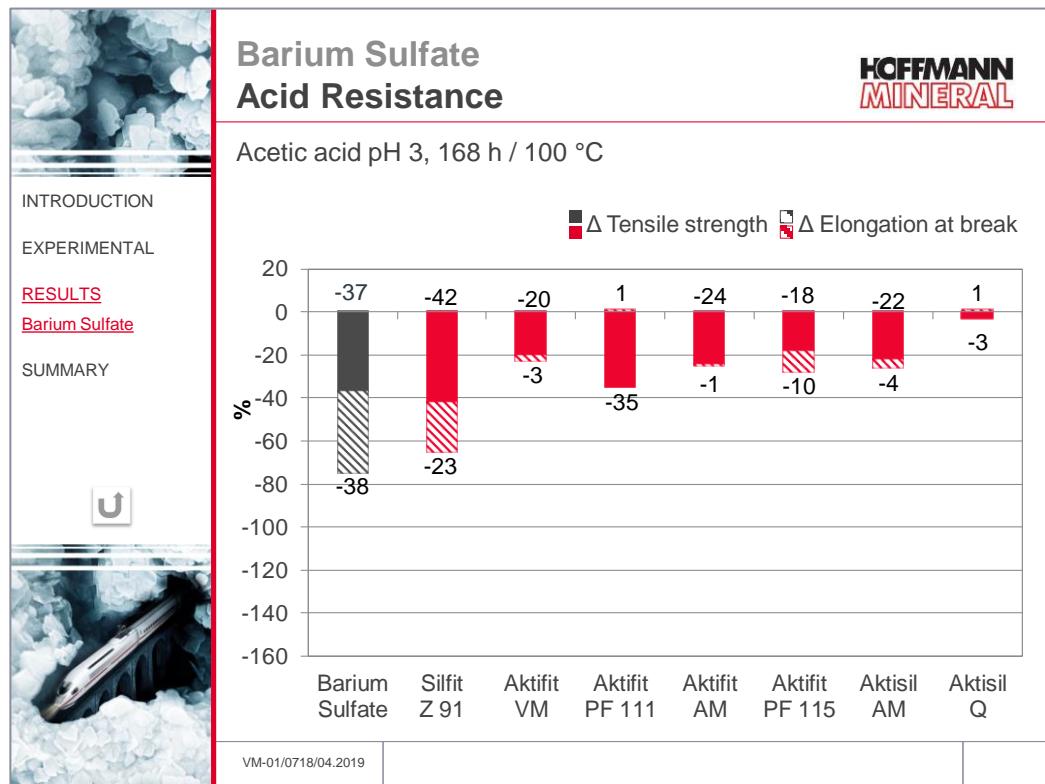
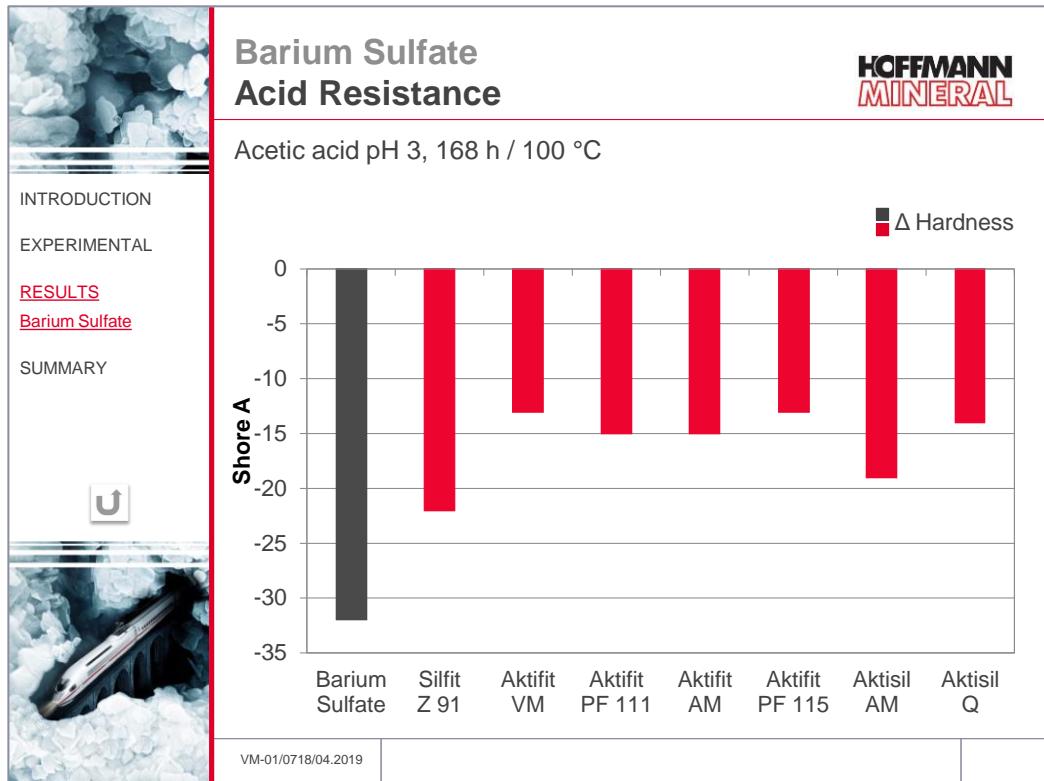
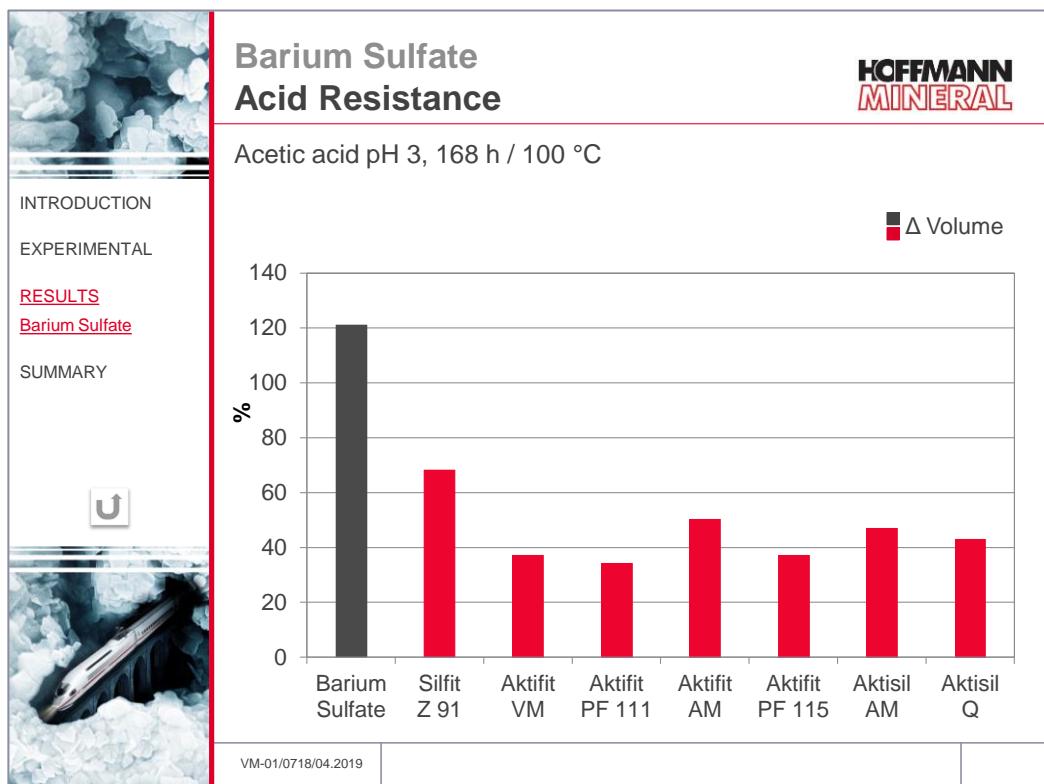


Fig. 49



**Fig. 50**



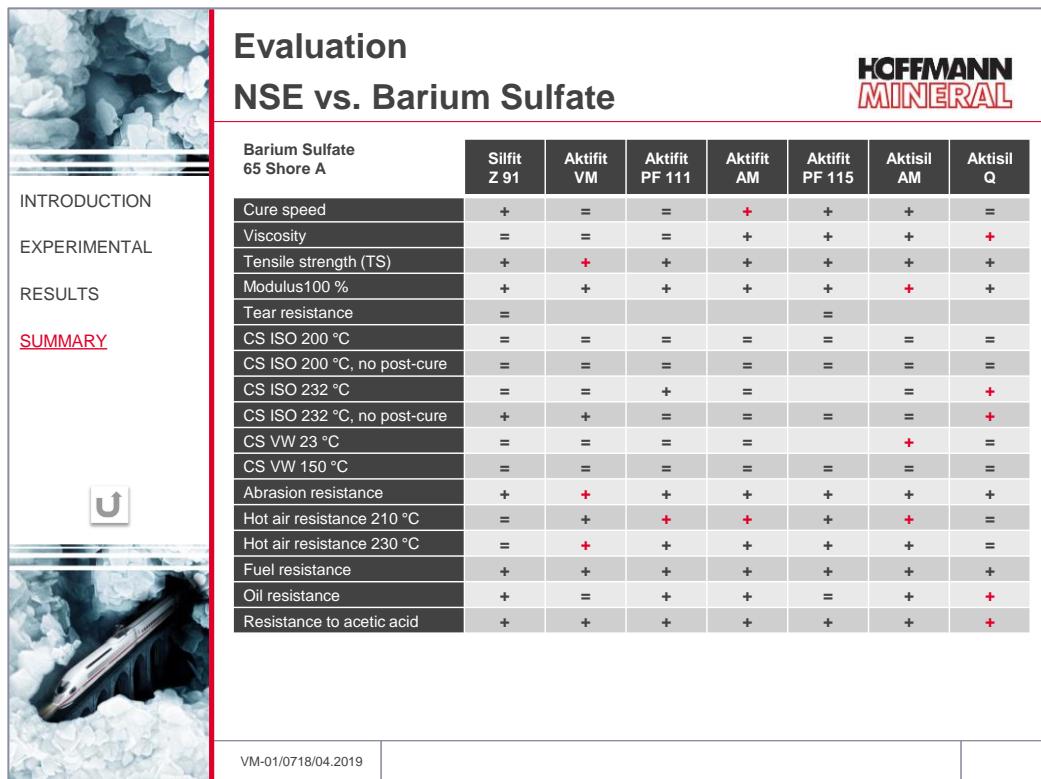
**Fig. 51**



**Fig. 52**

### 3.3.4 Evaluation of the results

Various properties and combinations of properties – often even contradicting properties – are positively influenced by the Neuburg Siliceous Earth products. This is verified in the following summary analysis.



**Fig. 53**

Fig. 53 shows which NSE grades either improve (+) or match (=) the relevant property performance versus the barium sulfate. Red + signs indicate the NSE product that achieves the best result for the appropriate property among NSE grades.

## 4 Summary

Several NSE grades raise cure speed compared to wollastonite or barium sulfate. By shortening the heating times, production costs could therefore be saved.

The somewhat lower viscosity resulting from replacing barium sulfate could indicate better flow properties in injection moulding (this would, however, require validation in tests of the appropriate shear rates).

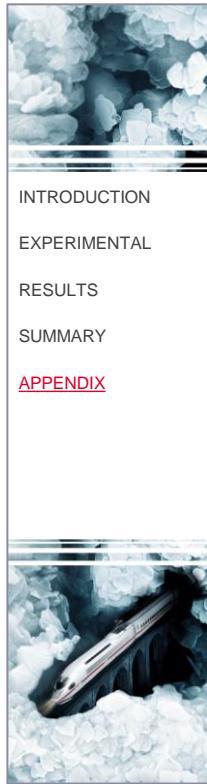
Generally, the Neuburg Siliceous Earth grades addressed in this paper produce better tensile strength performance than wollastonite or barium sulfate and improve abrasion resistance.

Resistance to hot air, oil or fuel can also be increased by using Neuburg Siliceous Earth instead of wollastonite or barium sulfate.

One particular advantage of this replacement is the significantly improved resistance of the vulcanizates filled with NSE to acetic acid, which can be used to simulate blow-by resistance. Thus, the possible applications of light-colored vulcanizates are significantly increased.

Neuburg Siliceous Earth therefore represents an alternative to wollastonite and barium sulfate in peroxide-cured FKM that can be used to generate various – improved – property profiles.

*Although our technical application advice and the information in this report are based on experience and provided to the best of our knowledge, they should only be construed as non-binding and are not in any way guaranteed. Claims cannot be derived from utilizing our data and recommendations, given that we have no influence over the working environment or conditions of use. Moreover, we can accept no liability whatsoever for any patent infringements that might result from utilization of the information we have provided.*

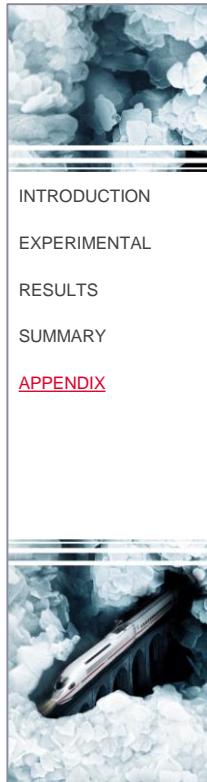


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| Loading 30 phr   |         | Silfit Z 91 | Aktifit VM | Aktifit PF 111 | Aktifit AM | Aktifit PF 115 | Aktisil AM | Aktisil Q |
|--|---------|-------------|------------|----------------|------------|----------------|------------|-----------|
| <b>Rheology</b>  |         |             |            |                |            |                |            |           |
| Mooney Viscosity,<br>ML Min., 120 °C   | MU      | 41          | 41         | 41             | 39         | 39             | 39         | 37        |
| Rotorless Curemeter<br>M <sub>min</sub> 177 °C                               | Nm      | 0.05        | 0.04       | 0.04           | 0.04       | 0.05           | 0.04       | 0.04      |
| Rotorless Curemeter<br>V <sub>max</sub> 177 °C                               | Nm/min. | 4.0         | 3.4        | 3.5            | 4.1        | 3.8            | 4.0        | 3.6       |
| Rotorless Curemeter<br>t <sub>90</sub> 177 °C                                | min.    | 0.8         | 0.8        | 0.9            | 0.8        | 0.8            | 0.8        | 0.8       |
| <b>Mechanical Properties – Cure Conditions 7 min. / 177 °C, no post-cure</b> |         |             |            |                |            |                |            |           |
| Hardness   | Sh. A   | 65          | 64         | 65             | 65         | 65             | 64         | 63        |
| Tensile Strength   | MPa     | 15          | 22         | 16             | 18         | 17             | 19         | 16        |
| Modulus 50 %   | MPa     | 1.74        | 1.70       | 1.68           | 1.68       | 1.72           | 1.83       | 1.60      |
| Modulus 100 %  | MPa     | 3.2         | 3.9        | 3.5            | 3.7        | 3.6            | 4.2        | 3.6       |
| Elongation at Break  | %       | 405         | 278        | 336            | 364        | 395            | 312        | 257       |
| Tear Resistance  | N/mm    | 6.2         | 3.1        | 5.4            | 4.7        | 6.0            | 4.5        | 4.0       |
| CS ISO,<br>70 h / 200 °C, 25 % defl.   | %       | 19          | 20         | 21             | 20         | 21             | 21         | 18        |
| CS ISO<br>70 h / 232 °C, 25 % defl.  | %       | 27          | 25         | 28             | 28         | 32             | 30         | 20        |
| VM-01/0718/04.2019   |         |             |            |                |            |                |            |           |

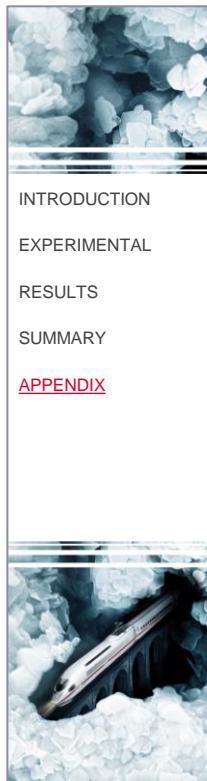


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| Loading 30 phr   |                 | Silfit Z 91 | Aktifit VM | Aktifit PF 111 | Aktifit AM | Aktifit PF 115 | Aktisil AM | Aktisil Q |
|--|-----------------|-------------|------------|----------------|------------|----------------|------------|-----------|
| <b>Mechanical Properties – Cure Conditions 7 min. / 177 °C, Post-cure 2 h / 232 °C</b> |                 |             |            |                |            |                |            |           |
| Hardness   | Sh. A           | 66          | 65         | 66             | 66         | 65             | 66         | 65        |
| Tensile Strength   | MPa             | 21          | 26         | 23             | 23         | 20             | 24         | 20        |
| Modulus 50 %   | MPa             | 1.91        | 1.75       | 1.76           | 1.83       | 1.84           | 1.92       | 1.72      |
| Modulus 100 %  | MPa             | 4.3         | 4.4        | 4.0            | 4.6        | 4.3            | 4.9        | 4.3       |
| Elongation at Break  | %               | 399         | 272        | 351            | 320        | 339            | 311        | 271       |
| Tear Resistance  | N/mm            | 6.1         | 3.2        | 4.9            | 4.5        | 6.7            | 3.9        | 4.1       |
| CS ISO,<br>70 h / 200 °C, 25 % def.  | %               | 21          | 21         | 19             | 20         | 20             | 21         | 20        |
| CS ISO<br>70 h / 232 °C, 25 % def.   | %               | 27          | 26         | 24             | 30         | 32             | 29         | 23        |
| CS VW PV3307<br>94 h / 23 °C, 50 % def.  | %               | 51          | 53         | 50             | 48         | 54             | 39         | 48        |
| CS VW PV3307<br>94 h / 150 °C, 50 % def.   | %               | 37          | 37         | 36             | 38         | 39             | 34         | 38        |
| Abrasion Loss  | mm <sup>3</sup> | 85          | 60         | 72             | 67         | 74             | 71         | 73        |
| VM-01/0718/04.2019   |                 |             |            |                |            |                |            |           |

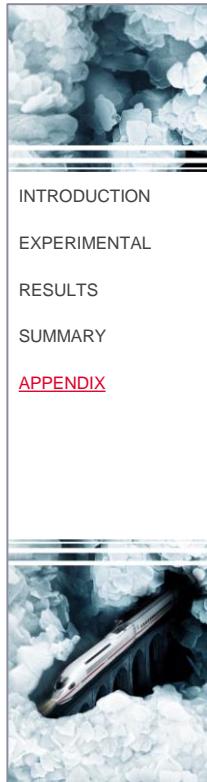


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| Loading 30 phr   |       | Silfit Z 91 | Aktifit VM | Aktifit PF 111 | Aktifit AM | Aktifit PF 115 | Aktisil AM | Aktisil Q |
|--|-------|-------------|------------|----------------|------------|----------------|------------|-----------|
| <b>Hot Air Aging, 504 h / 210 °C, determined after 30 min. after removal</b> |       |             |            |                |            |                |            |           |
| Hardness   | Sh. A | 69          | 68         | 68             | 68         | 69             | 69         | 67        |
| Tensile Strength   | MPa   | 25          | 25         | 23             | 25         | 19             | 26         | 22        |
| Elongation at Break  | %     | 301         | 323        | 320            | 330        | 252            | 304        | 356       |
| Δ Hardness   | Sh. A | +3          | +3         | +2             | +2         | +4             | +3         | +2        |
| Δ Tensile Strength   | %     | +20         | -3         | +3             | +8         | -2             | +8         | +11       |
| Δ Elongation at Break  | rel.% | -25         | +19        | -9             | +3         | -26            | -2         | +31       |
| <b>Hot Air Aging, 94 h / 230 °C, determined after 30 min. after removal</b>  |       |             |            |                |            |                |            |           |
| Hardness   | Sh. A | 67          | 67         | 68             | 67         | 68             | 68         | 65        |
| Tensile Strength   | MPa   | 26          | 26         | 27             | 27         | 22             | 28         | 23        |
| Elongation at Break  | %     | 280         | 283        | 313            | 314        | 247            | 299        | 331       |
| Δ Hardness   | Sh. A | +1          | +2         | +2             | +1         | +3             | +2         | 0         |
| Δ Tensile Strength   | %     | +26         | +2         | +18            | +17        | +11            | +15        | +16       |
| Δ Elongation at Break  | rel.% | -30         | +4         | -11            | -2         | -27            | -4         | +22       |
| VM-01/0718/04.2019   |       |             |            |                |            |                |            |           |

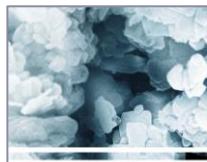


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| Loading 30 phr  |       | Silfit Z 91 | Aktifit VM | Aktifit PF 111 | Aktifit AM | Aktifit PF 115 | Aktisil AM | Aktisil Q |
|---|-------|-------------|------------|----------------|------------|----------------|------------|-----------|
| <b>Storage in Fuel FAM B, 70 h / 23 °C</b>            |       |             |            |                |            |                |            |           |
| Hardness  | Sh. A | 57          | 58         | 59             | 58         | 58             | 58         | 58        |
| Tensile Strength                                      | MPa   | 9.3         | 14         | 11             | 12         | 9.9            | 11         | 10        |
| Elongation at Break                                   | %     | 335         | 220        | 255            | 246        | 268            | 238        | 206       |
| Δ Hardness  | Sh. A | -9          | -7         | -7             | -8         | -7             | -8         | -7        |
| Δ Tensile Strength                                    | %     | -56         | -46        | -51            | -48        | -50            | -53        | -49       |
| Δ Elongation at Break                                 | rel.% | -16         | -19        | -27            | -23        | -21            | -24        | -24       |
| Δ Weight  | %     | +7.9        | +7.3       | +7.8           | +8.0       | +8.0           | +6.8       | +8.0      |
| Δ Volume  | %     | +19         | +18        | +19            | +19        | +19            | +17        | +19       |
| <b>Storage in Engine Oil OS206304, 168 h / 150 °C</b> |       |             |            |                |            |                |            |           |
| Hardness  | Sh. A | 66          | 65         | 65             | 65         | 66             | 65         | 64        |
| Tensile Strength                                      | MPa   | 18          | 19         | 21             | 22         | 16             | 22         | 21        |
| Elongation at Break                                   | %     | 383         | 210        | 295            | 291        | 231            | 281        | 291       |
| Δ Hardness  | Sh. A | 0           | 0          | -1             | -1         | +1             | -1         | -1        |
| Δ Tensile Strength                                    | %     | -14         | -26        | -7             | -3         | -20            | -9         | +2        |
| Δ Elongation at Break                                 | rel.% | -4          | -23        | -16            | -9         | -32            | -10        | +7        |
| Δ Weight  | %     | +0.6        | +0.8       | +0.7           | +0.6       | +0.6           | +0.7       | +0.6      |
| Δ Volume  | %     | +1.0        | +1.4       | +1.2           | +0.9       | +1.4           | +1.2       | +0.7      |
| VM-01/0718/04.2019                                    |       |             |            |                |            |                |            |           |



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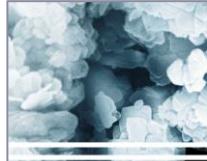


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| Loading 30 phr                                    |       | Silfit<br>Z 91 | Aktifit<br>VM | Aktifit<br>PF 111 | Aktifit<br>AM | Aktifit<br>PF 115 | Aktisil<br>AM | Aktisil<br>Q |
|---|-------|----------------|---------------|-------------------|---------------|-------------------|---------------|--------------|
| <b>Storage in Acetic Acid pH3, 168 h / 100 °C</b> |       |                |               |                   |               |                   |               |              |
| Hardness  | Sh. A | 44             | 52            | 51                | 51            | 52                | 47            | 51           |
| Tensile Strength                                  | MPa   | 12             | 21            | 15                | 18            | 16                | 19            | 20           |
| Elongation at Break                               | %     | 306            | 265           | 355               | 316           | 304               | 300           | 274          |
| Δ Hardness  | Sh. A | -22            | -13           | -15               | -15           | -13               | -19           | -14          |
| Δ Tensile Strength                                | %     | -42            | -20           | -35               | -24           | -18               | -22           | -3           |
| Δ Elongation at Break                             | rel.% | -23            | -3            | +1                | -1            | -10               | -4            | +1           |
| Δ Weight  | %     | +36            | +20           | +17               | +26           | +19               | +24           | +23          |
| Δ Volume  | %     | +68            | +37           | +34               | +50           | +37               | +47           | +43          |

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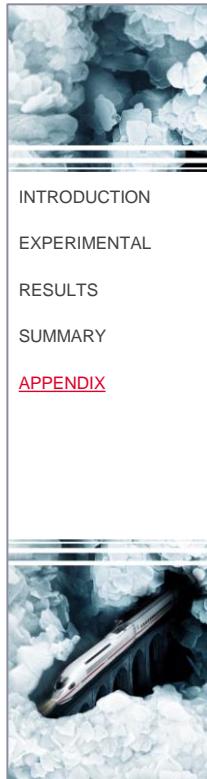


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|  |         | 30 phr Wollastonite<br>AST | 30 phr Wollastonite<br>EST | 49 phr Barium<br>Sulfate |
|--|---------|----------------------------|----------------------------|--------------------------|
| <b>Rheology</b>  |         |                            |                            |                          |
| Mooney Viscosity,<br>ML Min., 120 °C   | MU      | 39                         | 37                         | 43                       |
| Rotorless Curemeter<br>M <sub>min</sub> 177 °C                               | Nm      | 0.03                       | 0.03                       | 0.04                     |
| Rotorless Curemeter<br>V <sub>max</sub> 177 °C                               | Nm/min. | 3.4                        | 3.1                        | 3.4                      |
| Rotorless Curemeter<br>t <sub>90</sub> 177 °C                                | min.    | 0.9                        | 0.9                        | 0.9                      |
| <b>Mechanical Properties – Cure Conditions 7 min. / 177 °C, no post-cure</b> |         |                            |                            |                          |
| Hardness   | Sh. A   | 61                         | 63                         | 61                       |
| Tensile Strength   | MPa     | 18                         | 16                         | 15                       |
| Modulus 50 %   | MPa     | 1.88                       | 1.64                       | 1.44                     |
| Modulus 100 %  | MPa     | 4.2                        | 3.2                        | 2.1                      |
| Elongation at Break  | %       | 397                        | 393                        | 421                      |
| Tear Resistance  | N/mm    | 6.0                        | 5.9                        | 4.7                      |
| CS ISO,<br>70 h / 200 °C, 25 % def.  | %       | 24                         | 21                         | 22                       |
| CS ISO<br>70 h / 232 °C, 25 % def.   | %       | 35                         | 28                         | 31                       |

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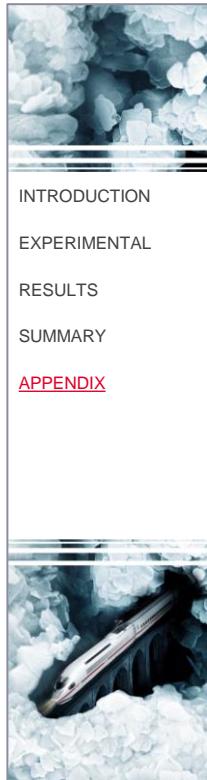
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|  |                 | 30 phr Wollastonite<br>AST | 30 phr Wollastonite<br>EST | 49 phr Barium<br>Sulfate |
|--|-----------------|----------------------------|----------------------------|--------------------------|
| <b>Mechanical Properties – Cure Conditions 7 min. / 177 °C, Post-cure 2 h / 232 °C</b> |                 |                            |                            |                          |
| Hardness   | Sh. A           | 67                         | 64                         | 67                       |
| Tensile Strength   | MPa             | 19                         | 20                         | 16                       |
| Modulus 50 %   | MPa             | 1.71                       | 1.67                       | 1.44                     |
| Modulus 100 %  | MPa             | 3.9                        | 3.5                        | 2.4                      |
| Elongation at Break  | %               | 337                        | 399                        | 407                      |
| Tear Resistance  | N/mm            | 6.2                        | 6.9                        | 6.1                      |
| CS ISO,<br>70 h / 200 °C, 25 % def.  | %               | 22                         | 18                         | 22                       |
| CS ISO<br>70 h / 232 °C, 25 % def.   | %               | 29                         | 24                         | 28                       |
| CS VW PV3307<br>94 h / 23 °C, 50 % Ddf.  | %               | 51                         | 51                         | 49                       |
| CS VW PV3307<br>94 h / 150 °C, 50 % def.   | %               | 35                         | 36                         | 36                       |
| Abrasion Loss  | mm <sup>3</sup> | 104                        | 114                        | 124                      |

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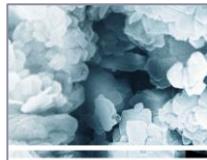
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|--|-------|----------------------------|----------------------------|--------------------------|
| <b>Hot Air Aging, 504 h / 210 °C, determined after 30 min. after removal</b> |       |                            |                            |                          |
| Hardness   | Sh. A | 64                         | 64                         | 65                       |
| Tensile Strength   | MPa   | 20                         | 21                         | 24                       |
| Elongation at Break  | %     | 331                        | 390                        | 372                      |
| Δ Hardness   | Sh. A | -3                         | 0                          | -2                       |
| Δ Tensile Strength   | %     | +6                         | +3                         | +43                      |
| Δ Elongation at Break  | rel.% | -2                         | -2                         | -9                       |
| <b>Hot Air Aging, 94 h / 230 °C, determined after 30 min. after removal</b>  |       |                            |                            |                          |
| Hardness   | Sh. A | 65                         | 65                         | 65                       |
| Tensile Strength   | MPa   | 22                         | 22                         | 25                       |
| Elongation at Break  | %     | 325                        | 335                        | 353                      |
| Δ Hardness   | Sh. A | -2                         | +1                         | -2                       |
| Δ Tensile Strength   | %     | +18                        | +8                         | +51                      |
| Δ Elongation at Break  | rel.% | -4                         | -16                        | -13                      |

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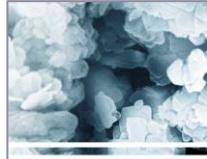
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|   |       | 30 phr Wollastonite<br>AST | 30 phr Wollastonite<br>EST | 49 phr Barium<br>Sulfate |
|---|-------|----------------------------|----------------------------|--------------------------|
| <b>Storage in FAM B, 70 h / 23 °C</b>                 |       |                            |                            |                          |
| Hardness  | Sh. A | 56                         | 55                         | 52                       |
| Tensile Strength                                      | MPa   | 8.6                        | 7.0                        | 7.7                      |
| Elongation at Break                                   | %     | 241                        | 261                        | 329                      |
| Δ Hardness  | Sh. A | -11                        | -9                         | -15                      |
| Δ Tensile Strength                                    | %     | -53                        | -66                        | -53                      |
| Δ Elongation at Break                                 | rel.% | -28                        | -35                        | -19                      |
| Δ Weight  | %     | +7.6                       | +7.2                       | +7.4                     |
| Δ Volume  | %     | +19                        | +18                        | +20                      |
| <b>Storage in Engine Oil OS206304, 168 h / 150 °C</b> |       |                            |                            |                          |
| Hardness  | Sh. A | 62                         | 62                         | 62                       |
| Tensile Strength                                      | MPa   | 17                         | 13                         | 11                       |
| Elongation at Break                                   | %     | 286                        | 297                        | 340                      |
| Δ Hardness  | Sh. A | -5                         | -2                         | -5                       |
| Δ Tensile Strength                                    | %     | -7                         | -35                        | -34                      |
| Δ Elongation at Break                                 | rel.% | -15                        | -26                        | -17                      |
| Δ Weight  | %     | +0.6                       | +0.6                       | +0.5                     |
| Δ Volume  | %     | +1.2                       | +1.1                       | +1.3                     |
| VM-01/0718/04.2019                                    |       |                            |                            |                          |



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|   |       | 30 phr Wollastonite<br>AST | 30 phr Wollastonite<br>EST | 49 phr Barium<br>Sulfate |
|---|-------|----------------------------|----------------------------|--------------------------|
| <b>Storage in Acetic Acid pH3, 168 h / 100 °C</b> |       |                            |                            |                          |
| Hardness  | Sh. A | 37                         | not determinable           | 35                       |
| Tensile Strength                                  | MPa   | 2.6                        | 2.8                        | 10                       |
| Elongation at Break                               | %     | 54                         | 84                         | 252                      |
| Δ Hardness  | Sh. A | -30                        | not determinable           | -32                      |
| Δ Tensile Strength                                | %     | -86                        | -86                        | -37                      |
| Δ Elongation at Break                             | rel.% | -84                        | -79                        | -38                      |
| Δ Weight  | %     | +288                       | +227                       | +55                      |
| Δ Volume  | %     | +593                       | +499                       | +121                     |
| VM-01/0718/04.2019                                |       |                            |                            |                          |