Neuburg Siliceous Earth

in 3D printing (FFF process)

of ABS (acrylonitrile butadiene styrene)

Author: Petra Zehnder
Hubert Oggermueller

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HOFFMANN MINERAL GmbH • Muenchener Strasse 75 • D-86633 Neuburg (Donau) • Phone +49 (0) 8431 53-0
www.hoffmann-mineral.com • e-mail: info@hoffmann-mineral.com

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1 Introduction

ABS is a widely used plastic for a wide range of applications in the automotive and electrical industries as well as in the model making and the hobby sector.

It has many important positive properties such as high stiffness, strength and impact resistance, can be easily reworked and is cost-effective.

However, a decisive disadvantage of ABS in 3D printing is its tendency to warp, which can cause the part to partially or completely detach from the printing bed during the printing process.

The use of suitable fillers can significantly reduce this distortion, allowing ABS to be processed at higher speeds and/or lower temperatures and thus also on printers without a heated build chamber/print bed.

Due to its morphology, Neuburg Siliceous Earth is suitable for application in 3D filaments of ABS: the round grain shape of the corpuscular silica results in reduced isotropic distortion and the aggregate structure improves the layer adhesion.

The present study is intended to show the possible applications of Neuburg Siliceous Earth as a mineral filler for ABS in filaments for 3D printing.

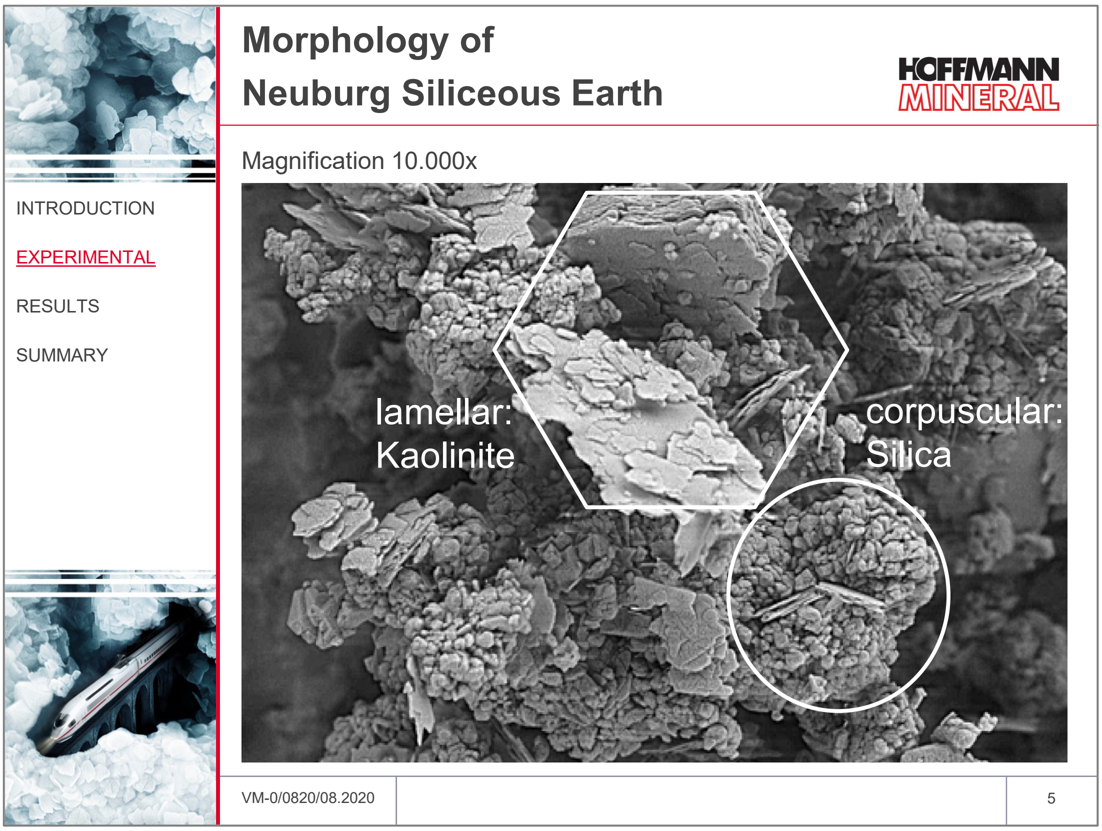
In addition to processability and warpage, the mechanical properties and layer adhesion were tested.

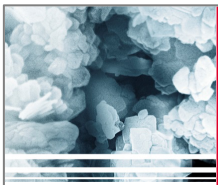
2 Experimental

2.1 Neuburg Siliceous Earth

Classic Neuburg Siliceous Earth is a natural combination of corpuscular Neuburg Silica and lamellar kaolinite: a loose mixture impossible to separate by physical methods. The silica portion exhibits a round grain shape and consists of aggregated primary particles of about 200 nm diameter.

The special morphological composition of Neuburg Siliceous Earth, which represents a class of minerals on its own, in the following is illustrated by a SEM photograph.





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Calcined Neuburg Siliceous Earth

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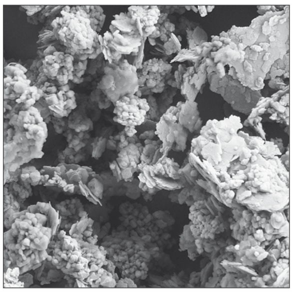
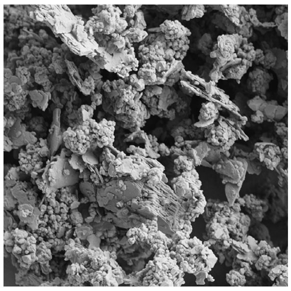
A downstream thermal process lead to the calcined products Silfit and Aktifit, based on SILLITIN Z 86.



Neuburg Siliceous Earth

Calcination Process →



Calcined Neuburg Siliceous Earth

Additional application benefits, as well as the removing of crystal water included in the kaolinite. The silica part remains inert.

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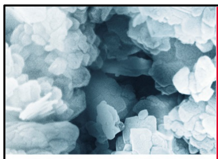
The basis for the calcined Neuburg Siliceous Earth is the standard product Sillitin Z 86. In a thermal process, the water of crystallization in the kaolinite portion is removed and new, largely amorphous mineral phases are formed.

The resulting product Silfit Z 91 is characterized by high brightness and color neutrality.

The Aktifit grades are special products where Silfit Z 91 has been surface treated with functional additives.

2.2 Mineral additives

The table summarizes the mineral additives evaluated and some of their typical properties.



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Fillers and Characteristics

		Calcined Neuburg Siliceous Earth		
		Silfit Z 91	Aktifit AM	Aktifit PF 115
Sieve residue > 40 µm	[mg/kg]	10	10	10
Particle size d_{50}	[µm]	2.0	2.0	2.0
Particle size d_{97}	[µm]	10	10	10
Oil absorption	[g/100g]	65	65	60
Specific surface area BET	[m²/g]	10	9	9
Functionalization		none	Amino	Amino
Surface character		hydrophilic	hydrophilic	hydrophobic

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From the Neuburg Siliceous Earth product range, only calcined grades were used.

Besides Silfit Z 91 as a cost-effective standard product, two products surface-treated with different amino functionalized groups were used. Aktifit AM has a hydrophilic surface character, whereas Aktifit PF 115 is hydrophobic.

2.3 Filament production and print parameter

Elix 3D HI, a high-impact ABS type, was chosen for preparing the filaments. Compounds with 10% filler content were produced and filaments with a target diameter of 1.75 mm were extruded from it.
Printing with 100% infill was performed on an Anycubic MEGA-S with a 0.4 mm nozzle and 0.2 mm layer thickness. Blue Tape was used for better adhesion to the printing table.
For the filled compounds, the temperature of the printing bed was 100 °C and the printing speed 55 mm/min. For pure ABS, the printing conditions for producing the tensile specimens had to be adjusted to 120 °C and 45 mm/min.

Preparing of Filaments
Printing Parameters

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Compound	90 % ABS Elix 3D HI 10 % Filler
Compounding	Thermo TSE 24 (twin screw extruder) Melt temperature: 250 °C
Filament	Horizontal nozzle: 2 mm (target diameter 1.75 mm) Spinning pump: 1.2 cm³ Temperature zones: 240-260 °C
Printing	Anycubic MEGA-S Nozzle: 0.4 mm strand width Layer thickness: 0.2 mm Temperature material: 260 °C Temperature print bed: 100 °C (ABS: 120 °C) Print speed: 55 mm/s (ABS: 45 mm/s) Infill: 100 % Adhesive: Blue Tape, partly with brim

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2.4 Specimens

In addition to the warping cubes, horizontal and upright type 1B tensile specimens according to DIN EN ISO 527 were printed for testing the tensile properties and impact strength. Shortened tensile specimens printed upright were used to test the adhesion of the layers. For this purpose, an additional printed edge (Brim) was applied.

Test Samples

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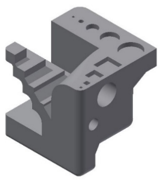
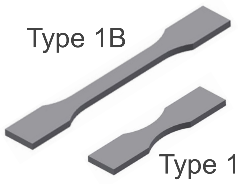
Warping cube

Tensile specimens



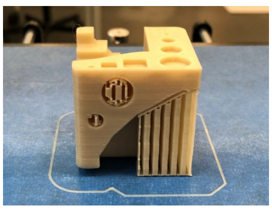
Type 1B

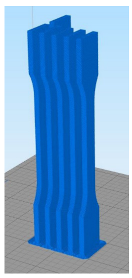


Type 1B short

upright (Z)

printed with Brim





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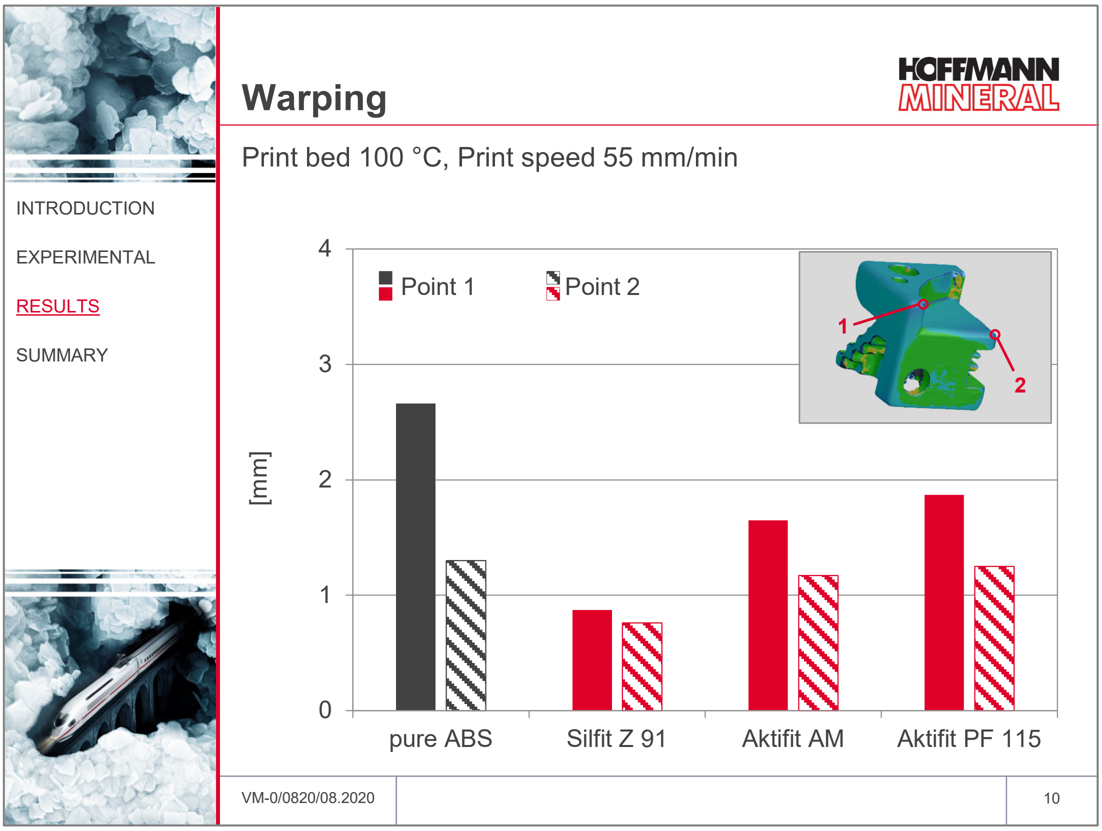
3 Results

3.1 Warping

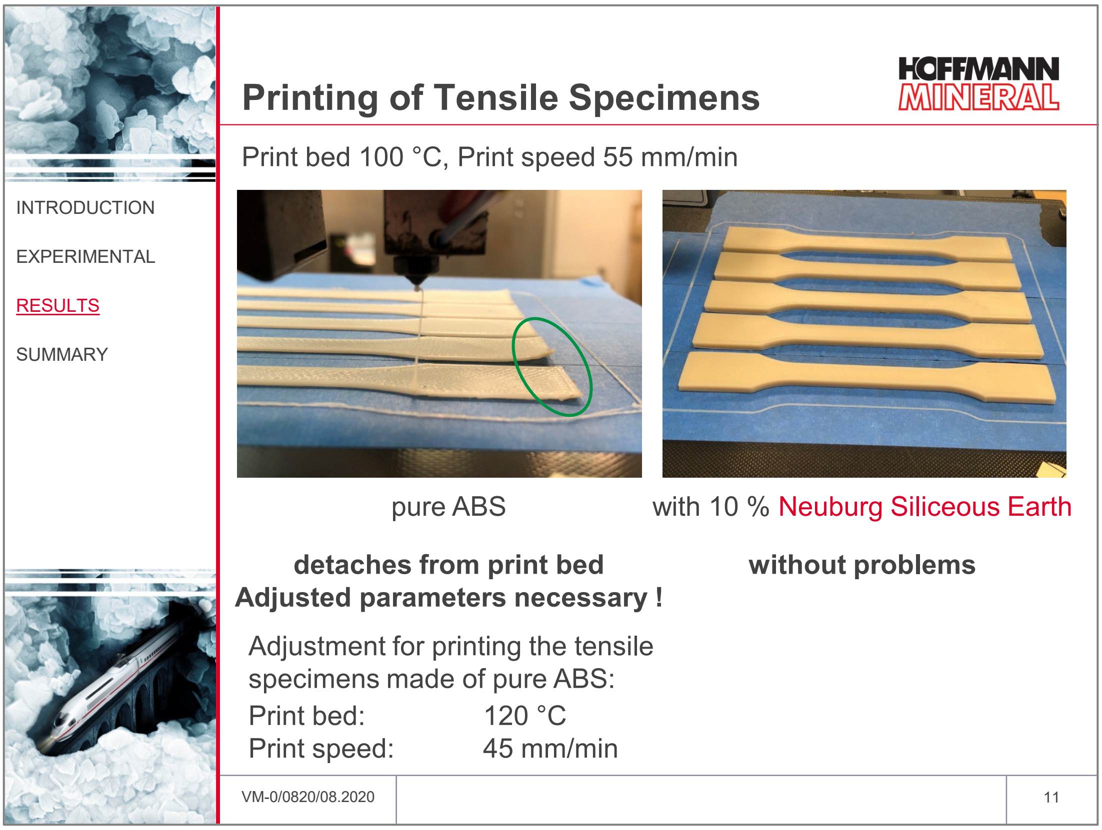
Warping is caused by unevenly distributed internal stresses in the printed product as a result of different cooling rates and temperatures of the individual layers. Warping is caused by the uneven shrinkage of the plastic during the cooling process. ABS has a relatively pronounced tendency to shrink.

This thermally induced warping was measured on the warping cubes. A scanning system was used to record the surface of the printed parts and the virtual body was fused with the CAD reference model. The deviation was calculated for two selected measuring points, which from experience show strong deviations.



The warpage of pure ABS is significantly higher under the given printing conditions than with the filled filaments. Here, Silfit Z 91 achieves the best results with the lowest warping, but also the surface-treated products give a relatively low warpage.

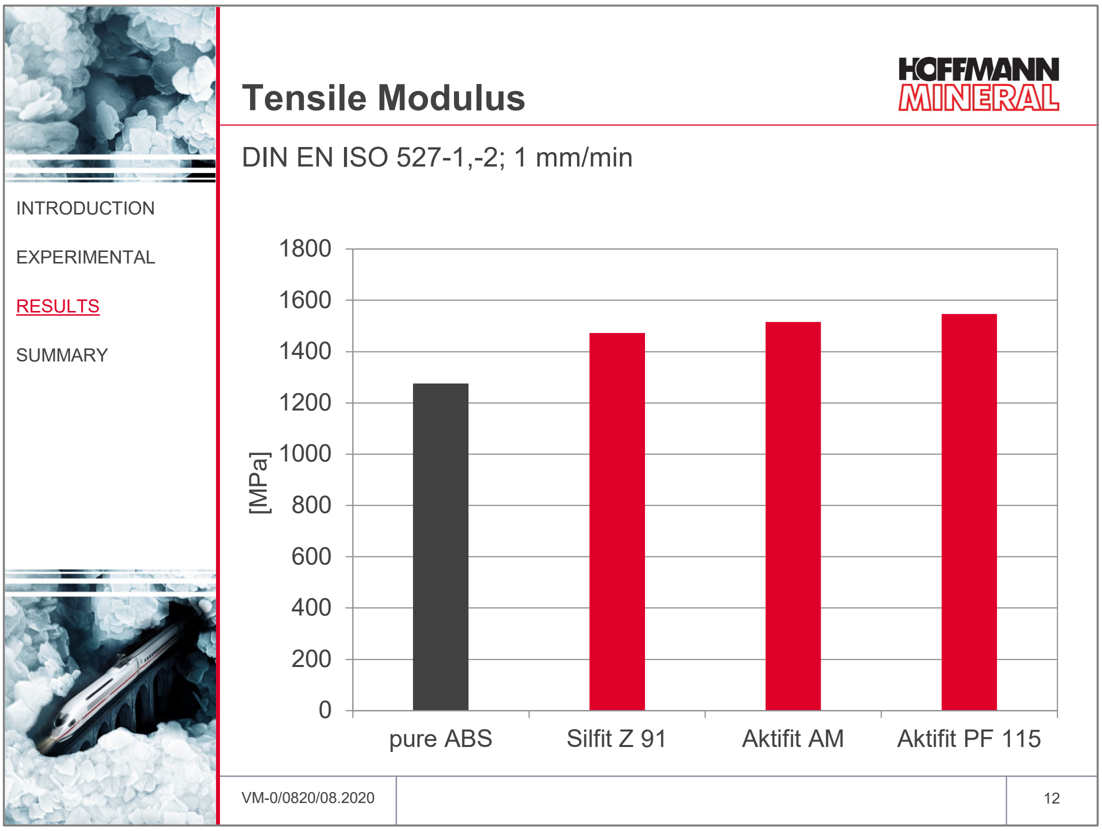
The different warping behavior has a clear effect when printing the tensile specimens.
At a printing bed temperature of 100 °C, the filled filaments could be printed without any problems at 55 mm/min. The pure ABS, on the other hand, showed significantly more warpage and detached from the printing bed, so that it was absolutely necessary to increase the printing bed temperature to 120 °C and simultaneously reduce the printing speed to 45 mm/min.



3.2 Mechanical properties

3.2.1 Tensile modulus

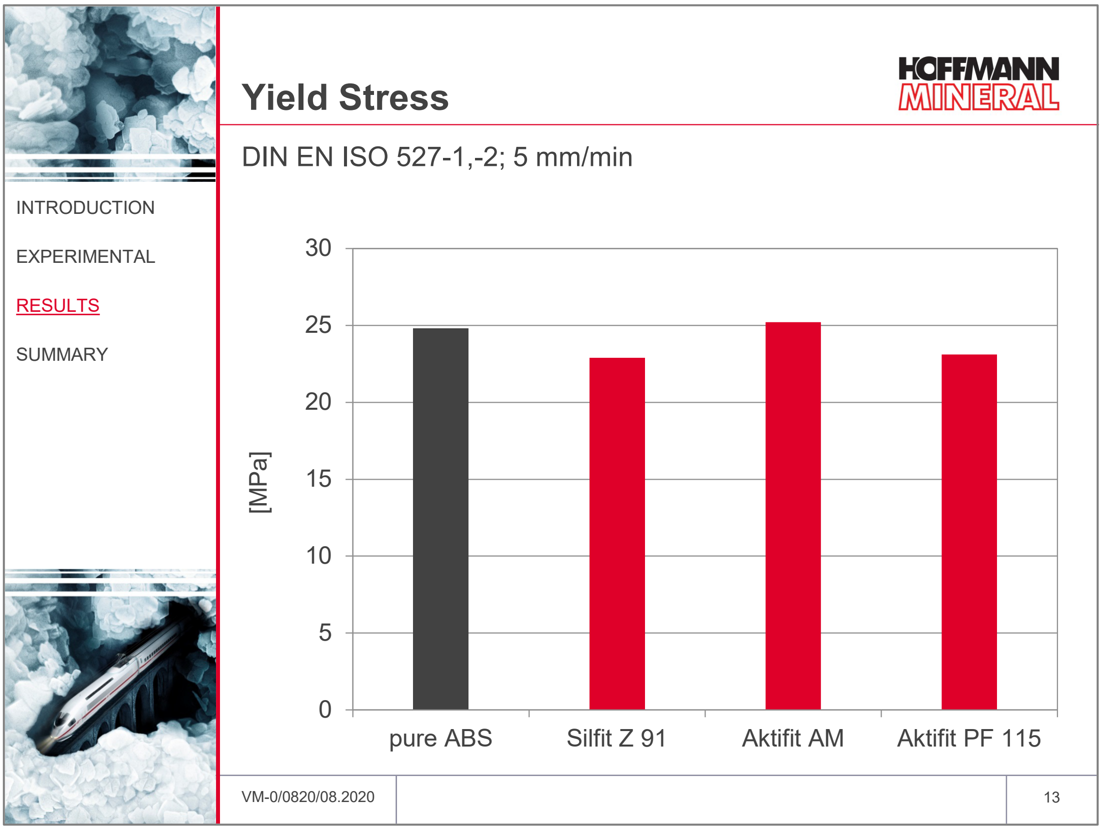
Representing the stiffness of the material, the tensile modulus was determined on horizontally printed specimens at a test speed of 1 mm/min.



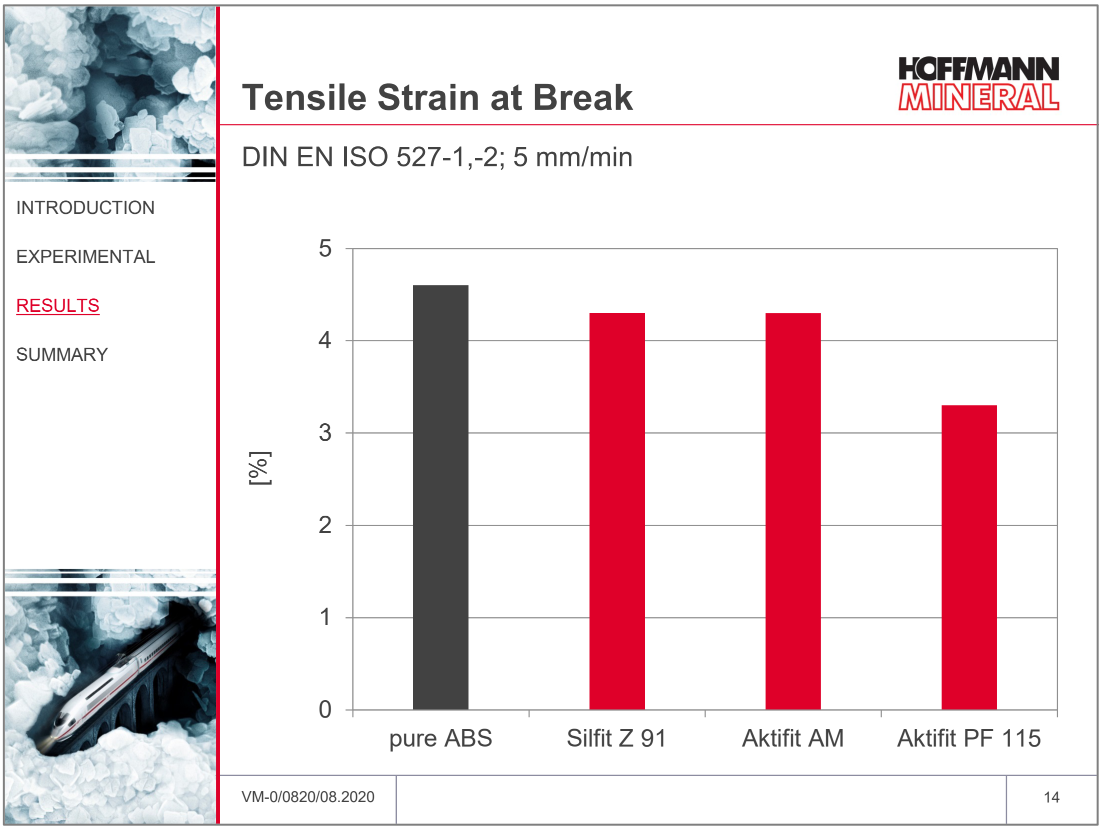
As expected, the addition of 10 % Neuburg Siliceous Earth causes an increase in stiffness compared to pure ABS.

3.2.2 Yield stress and tensile strain at break

The test was performed on horizontally printed specimens at a test speed of 5 mm/min up to break.



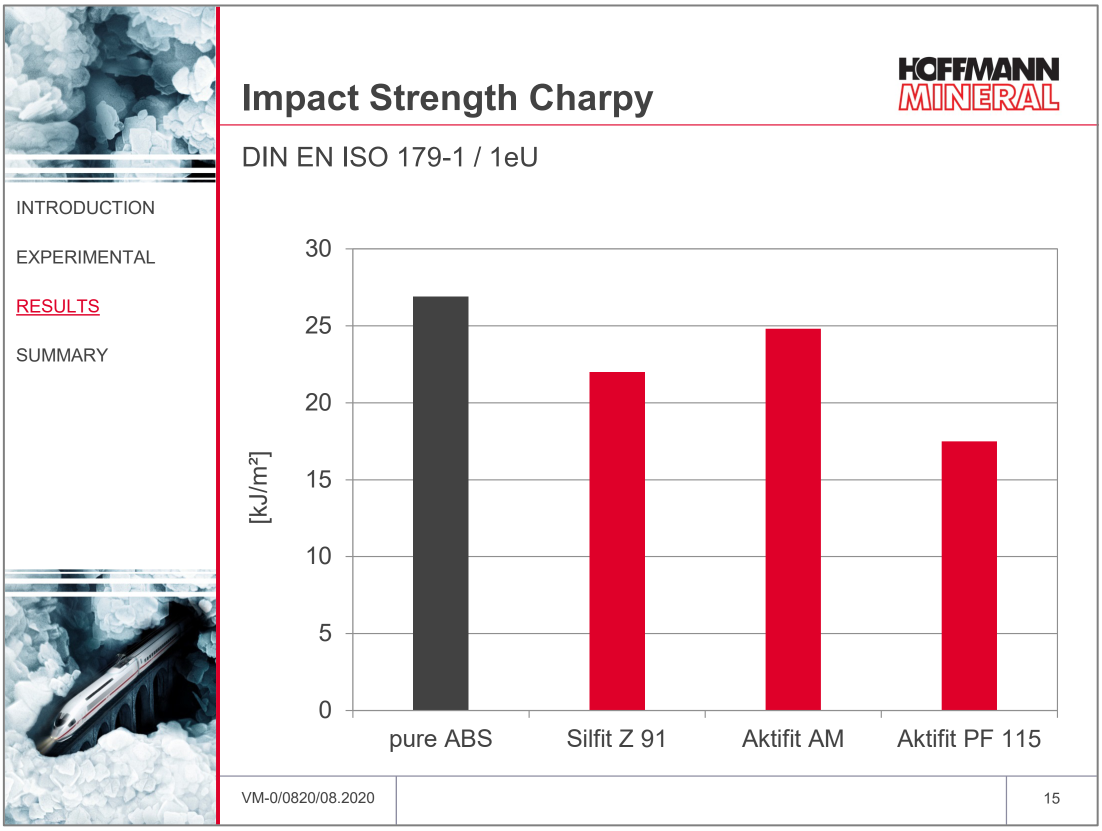
Even after the addition of filler, the strength in the tensile test remains at a level similar to that of unfilled ABS.



While Silfit Z 91 and Aktifit AM show a comparable elongation at break to unfilled ABS, the samples with Aktifit PF 115 break somewhat earlier.

3.2.3 Impact strength

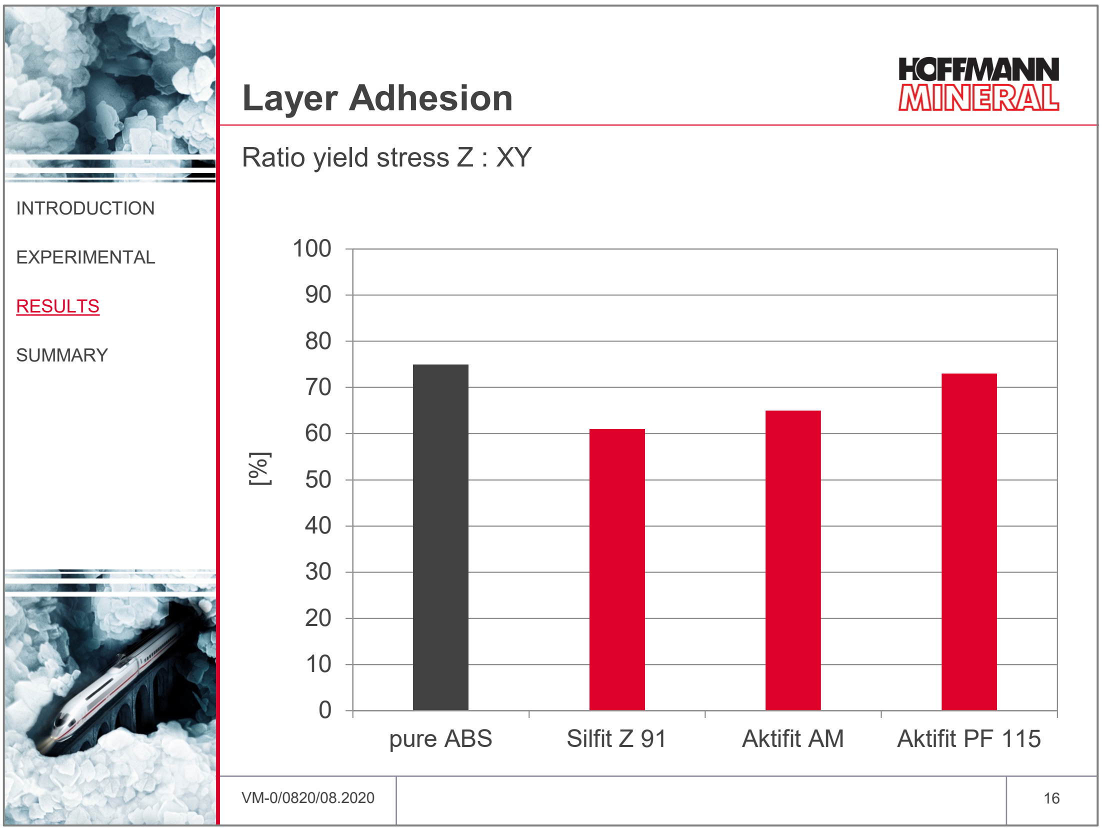
The specimens for the impact strength were taken from the parallel middle part of the horizontally printed tensile specimens. The test was performed on unnotched specimens.



The resulting impact strength with Silfit Z 91 and Aktifit PF 115 is somewhat lower than with the unfilled ABS. In contrast, the compound modified with Aktifit AM behaves almost comparably to pure ABS.

3.3 Layer adhesion

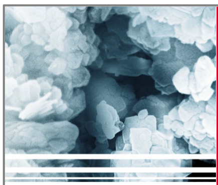
To evaluate the layer adhesion, the quotient of the measured values of the upright and the horizontally printed test specimens is formed. The evaluation is carried out for slow stressing with the measured values of the yield stress.



Silfit Z 91 shows a slight loss of layer adhesion. However, the surface treatment of the fillers improves the layer adhesion and with Aktifit PF 115 it almost reaches the level of the unfilled ABS.

3.4 Feedback from customers

The table shows the results in a different ABS grade compared to other mineral fillers. The ABS Novodur HD M203 FC used is a standard grade for injection molding, i.e. not adapted to the 3D printing process.
In contrast to the previous results, the layer adhesion is not shown in percent, but as an absolute value of the tensile strength in the Z-direction.



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Compound	Layer adhesion [MPa]	Warping [mm]
pure ABS Novodur HD M203 FC	30	11
+ 2 % Glass fibers	15	8
+ 5 % Wollastonite (L/D 7:1)	21	6
+ 5 % Silfit Z 91	23	3

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Silfit Z 91 shows a significantly lower warpage in combination with a partly significantly better layer adhesion compared to competitive fillers.

4 Summary

Calcined Neuburg Siliceous Earth is very well suited as a functional, mineral filler for ABS filaments for 3D printing in the FFF process.

During compounding, calcined Neuburg Siliceous Earth as mineral filler is easy to incorporate and disperse.

The mechanical properties of the printed parts remain at a very good level, and also the layer adhesion is almost comparable to that of pure ABS when using amino functionalized Aktifit grades.

Due to the significantly reduced warpage, a lower printing temperature is sufficient and processing is also possible on printers without heated build chamber or printing bed. In addition, parts can be printed at a faster speed.

Distinguishing features of the NSE grades:

Silfit Z 91	cost-effective standard product lowest warping good mechanical properties
Aktifit AM	low warping good mechanical properties higher impact strength
Aktifit PF 115	low warping very good layer adhesion