Silfit Z 91

vs. Na/Al-silicate and alumosilicate

in low cost, solvent-free straight

acrylic paint

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1 Introduction

An attractive price/performance ratio with good optical properties, sufficient wear resistance as well as largely absence of emissions and solvents are essential characteristics of modern low-cost interior emulsion paints. As decorative coating systems, they contain a certain amount of titanium dioxide which represents an energy and cost intensive raw material that suffers more and more from strong variations in price and demand, and, therefore, decidedly determines the cost structure of the pertinent paint formulations.

As a result, at present a partial replacement of the white pigment by suitable mineral TiO_2 extenders looks desirable. Representatives of this class of materials are often light-colored fine precipitated calcium carbonates, silicates or also calcined clays.

The objective of the present study is the evaluation of calcined Neuburg Siliceous Earth Silfit Z 91 as a TiO_2 extender in comparison with precipitated sodium aluminum silicate and an alumosilicate in such an interior emulsion paint.

The focus concerns in particular optical criteria such as brightness, color neutrality and hiding power as well as especially the formulation costs as an index for the efficiency and economical viability. Other relevant aspects such as processing properties and wet-scrub resistance will be judged by accompanying trials.

2 Experimental

2.1 Base formulation

As a starting point for the evaluations serves a European market approved formulation for solvent-free interior emulsion paints (*Fig. 1*) based on a straight acrylate dispersion. This guide formulation from BASF for a low-cost paint is characterized by a low portion of white pigment and binder. The TiO_2 extenders used are a precipitated Na/Al silicate as well as Socal P2. A special alumosilicate is added as a matting agent. In addition, two conventional calcium carbonate grades and a talc grade at higher loadings are included.

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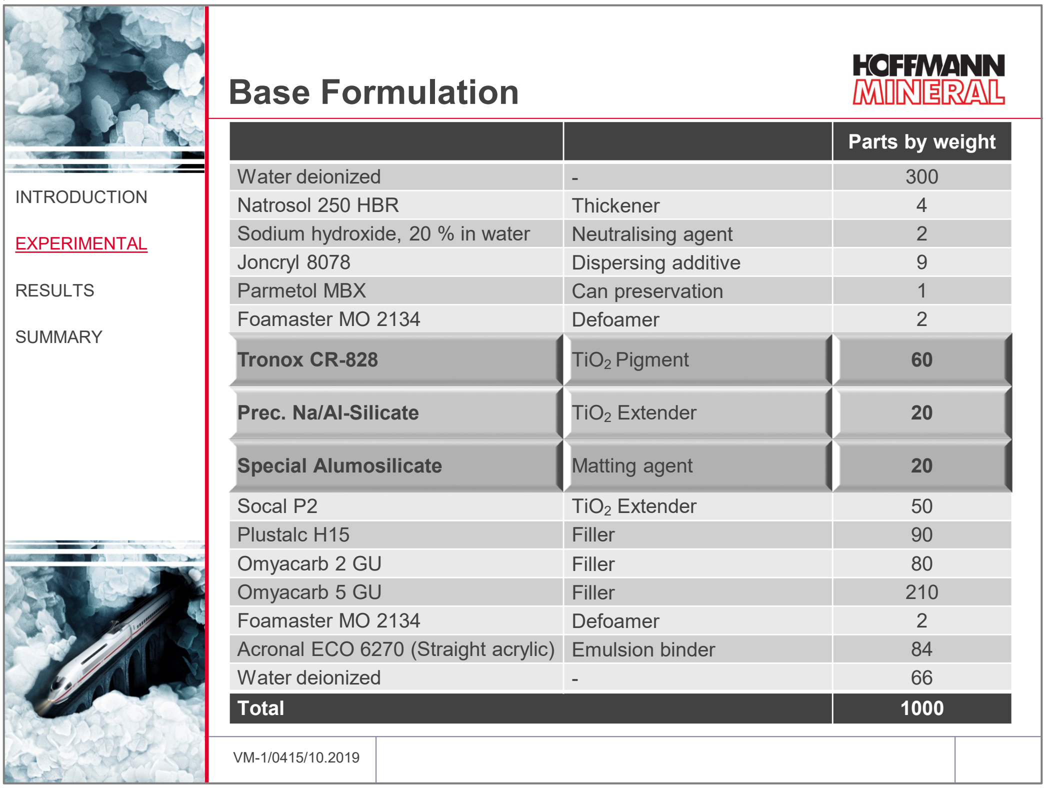


		Parts by weight
Water deionized	-	300
Natrosol 250 HBR	Thickener	4
Sodium hydroxide, 20 % in water	Neutralising agent	2
Joncryl 8078	Dispersing additive	9
Parmetol MBX	Can preservation	1
Foamaster MO 2134	Defoamer	2
Tronox CR-828	TiO_2 Pigment	**60**
Prec. Na/Al-Silicate	TiO_2 Extender	**20**
Special Alumosilicate	Matting agent	**20**
Socal P2	TiO_2 Extender	50
Plustalc H15	Filler	90
Omyacarb 2 GU	Filler	80
Omyacarb 5 GU	Filler	210
Foamaster MO 2134	Defoamer	2
Acronal ECO 6270 (Straight acrylic)	Emulsion binder	84
Water deionized	-	66
Total		**1000**

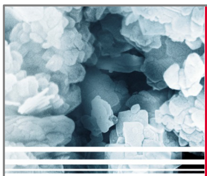
Fig. 1

2.2 Formulation variations

The present study is oriented towards a replacement of the two silicate components with Silfit Z 91. Socal P2 as a very fine and cost-effective extender in this study remains unchanged.

According to *Fig. 2*, the replacement takes place first of all at a regular TiO_2 loading. After that, the addition of white pigment will be successively reduced along with an increasing use of Silfit Z 91.

As shown by the data reported, the relevant typical properties of the formulation remain approximately maintained.



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Formulation Variations

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Replacement of Na/Al-Silicate + Alumosilicate / TiO_2 content varied
All other ingredients remain unchanged

	Control	Silfit Z 91					
		Full TiO_2			TiO_2 reduced		
					- 10 %	- 15 %	- 20 %
TiO_2	60	60			54	51	48
Na/Al-Silicate	20	---			---		
Alumosilicate	20	---			---		
Silfit Z 91	---	40	60	80	40	60	80
Solids content w/w [%]	58.3	58.3	59.2	59.9	59.2	59.2	59.3
PVC [%]	83.5	83.2	83.8	84.3	83.9	83.9	84.0

TiO_2-Extender, Matting agent

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Fig. 2

The very high portion of fillers/extenders in the formulations leads to a fairly high PVC of over 80 %. A typically desired high and partly over-critical PVC level is favorable for the "Dry Hiding" phenomenon. This effect comes from an incomplete embedding of all solid components by the binder, which means part of the pigment/filler surfaces will at first be wetted by water. In the course of the drying process air pores are formed at these places, which through diffuse light dissipation offer an additional and desired contribution to the dry hiding power.

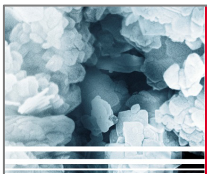
2.3 Characteristics of TiO_2 Extenders and matting agent

Neuburg Siliceous Earth, as mined close to Neuburg-on-the-Danube, is a naturally formed mixture of corpuscular Neuburg silica with lamellar kaolinite: a loose conglomerate which cannot be separated by physical means. The silica portion, as a result of its natural formation, shows a rounded grain shape, and consists of aggregated, cryptocrystalline primary particles about 200 nm.

The calcination of the Neuburg Siliceous Earth into Silfit Z 91 splits off the crystal water of the kaolinite portion and gives rise to the formation of new, largely amorphous mineral phases. At the temperatures applied, the silica portion remains unchanged. An integrated air classifier process eliminates grain sizes > 15 µm.

Remarkable in the direct comparison with Silfit Z 91 are the high oil absorption values and the relatively low comparable densities of the two silicates (*Fig. 3*). Both types show within each other big differences with respect to grain size distribution, specific surface area and in particular the color indexes.

Silfit Z 91 is characterized by a higher grain fineness and a markedly lower oil absorption. Compared with the Na/Al silicate, the calcined Neuburg Siliceous Earth offers equally good color neutrality; the somewhat lower brightness leaves still markedly the alumosilicate behind.



Characteristics
Extender, Matting Agent

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	Particle size		Oil absorption	Density	Specific Surface BET	Color		
	d_{50} [µm]	d_{97} [µm]	[g/100g]	[g/cm³]	[m²/g]	L*	a *	b*
Precipitated Na/Al-Silicate	5.0	18	140	2.1	95	98.9	-0.1	0.6
Special Alumosilicate	28	84	174	2.0	1.6	90.5	1.0	3.3
Silfit Z 91	2.0	10	55	2.6	8	95.5	- 0.1	0.7

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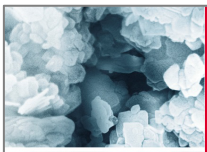
Fig. 3

2.4 Preparation of batches, application and testing

The preparation of the batches followed the sequence of the raw materials indicated in the pertinent formulation, and was carried out in a laboratory dissolver under cooling with water.

Pigment, TiO_2 extenders and fillers were pre-mixed and, after adding to the mixer, dispersed for 20 min with a peripheral speed of the toothed disc of 15 m/s. After adding the binder and the other additives, a maturing time of 12 h was observed.

The coatings were applied undiluted and usually per doctor blade with an automated applicator. The drying and conditioning of the paint films as well as the tests after 7 days of storage (28 days for wet-scrub resistance) were done in an air-conditioned laboratory at 23 °C and 50 % relative humidity. Detailed indications are given in *Fig`s 4* and *5*.



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Preparation

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Mixing and dispersing	Mixing with dissolver, in sequence of mentioning in the formulation Peripheral speed of toothed disc (Cowles blade) 15 m/s for 20 min, water cooling with T max. = 60°C
Let Down	With Binder and further additives
Maturation	Over night
Application	Undiluted with doctor blade on automated film applicator or as indicated
Substrate	As indicated, depending on testing
Conditioning	Drying conditions before / during tests: 23 °C / 50 % relative humidity (RH) Drying time before testing: 28 days for wet-scrub resistance, otherwise 7 d

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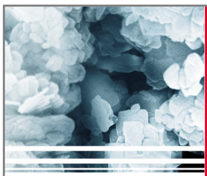
Fig. 4



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Testing

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Paint Preparation	
Incorporation, Foam formation	Subjective assessment
Wet Paint	
Fineness of grind	Grindometer 0 – 50 µm
Viscosity	1d after preparation, Rheometer 23°C, Searle system
Storage stability	Undiluted in 1l-metal can, 6 months 23°C
Application with doctor blade gap 300 µm on Leneta film, DFT* ~ 120 µm	
Wet-scrub resistance	200 Cycles on automated wet-scrub resistance tester according to ISO 11998. Classification along with DIN EN 13300
Application: gap 100 - 400 µm gradually with doctor blade on cardboard	
Color / Gloss	L*, a*, b* over white, 85°-Gloss (Sheen) at full hiding film with DFT 120 µm
Hiding Power	Contrast ratio over black/white depending on dry film thickness. Calculation of minimum dry film thickness to comply with DIN EN 13300 classifications and resulting spreading rates, contrast ratio at given spreading rate respectively

* Dry film thickness

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Fig. 5

3 Results

3.1 Processing properties and storage stability

As a result of the generally very good dispersion properties of Neuburg Siliceous Earth particularly in aqueous systems, Silfit Z 91 offers rapid, foam-free and even easier incorporation during the batch preparation compared with the control. The grain size of the completed interior emulsion paints with Silfit Z 91 according to grindometer tests is situated uniformly around 15 µm. The higher grain size of the control formulation with about 30 µm goes back to the usage of the fairly coarse alumosilicate.

The rheology profile gives evidence of the strong shear thinning typical for interior emulsion paints, while the markedly reduced viscosity of 0.09 to 0.13 Pas under higher shear load (1000 s^{-1}) reflects the easy processability and spreadability. Higher viscosity levels of 8.6 to 10.7 Pas at low shear (0.1 s^{-1}) indicate low run-off tendency after application and allow to apply film layer thicknesses necessary for good hiding power.

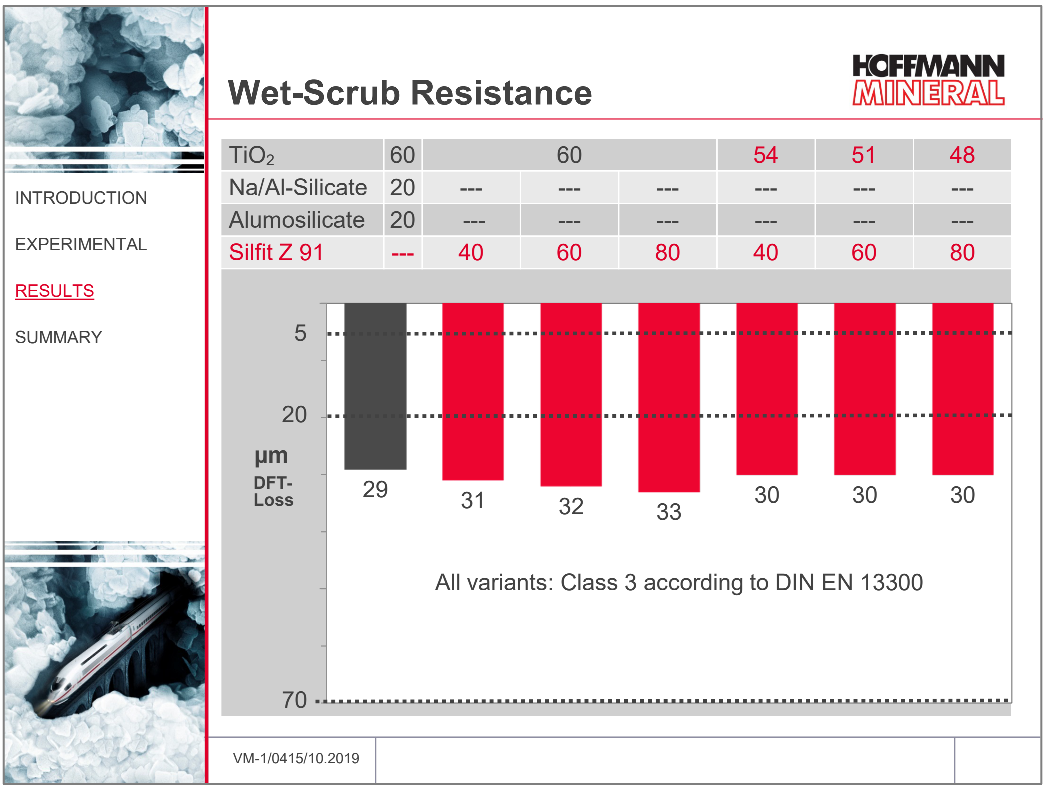
All formulations after 6 months show good storage stability. The batches only give rise to marginal phase separation and are easy to stir up and homogenize.

3.2 Wet-scrub resistance

When replacing the Na/Al silicate and the alumosilicate with Silfit Z 91, as shown in *Fig. 6* with the highly comparable results, the resistance level against wet-scrub remains unchanged.

With a classification in Class 3, however, the wear resistance here is basically lower than with high quality paints. This mainly goes back to the very high PVC which at the surface facilitates the detachment of the solid particles from the surrounding polymer matrix.

All the same, even with higher additions of calcined Neuburg Siliceous Earth Silfit Z 91 and at the same time reduced TiO_2 additions, wash resistant coatings are obtained without sacrifices in the mechanical durability.



TiO_2	60	60			54	51	48
Na/Al-Silicate	20	---	---	---	---	---	---
Alumosilicate	20	---	---	---	---	---	---
Silfit Z 91	---	40	60	80	40	60	80

Fig. 6

3.3 Gloss

As a result of the over-critically high PVC, all coatings are characterized by a slightly micro-rough surface. When using Silfit Z 91, as shown in *Fig. 7* the gloss will be slightly higher with increasing loading; the surfaces, however, still remain in the mat region according to DIN EN 13300 with 85° gloss results between 5 and 10 units.

More strongly matted coatings similar to the level of the control can be obtained with Silfit Z 91 by an appropriate addition of fine natural cellulose fibers (e.g., “Arbocel B 600”, recommended amount 2 % on the total formulation).

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Gloss 85° (Sheen)

TiO_2	60		60		54	51	48
Na/Al-Silicate	20	---	---	---	---	---	---
Alumosilicate	20	---	---	---	---	---	---
Silfit Z 91	---	40	60	80	40	60	80

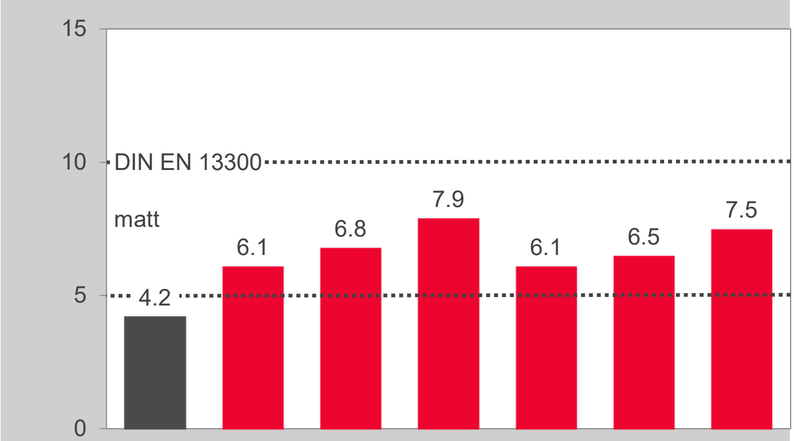

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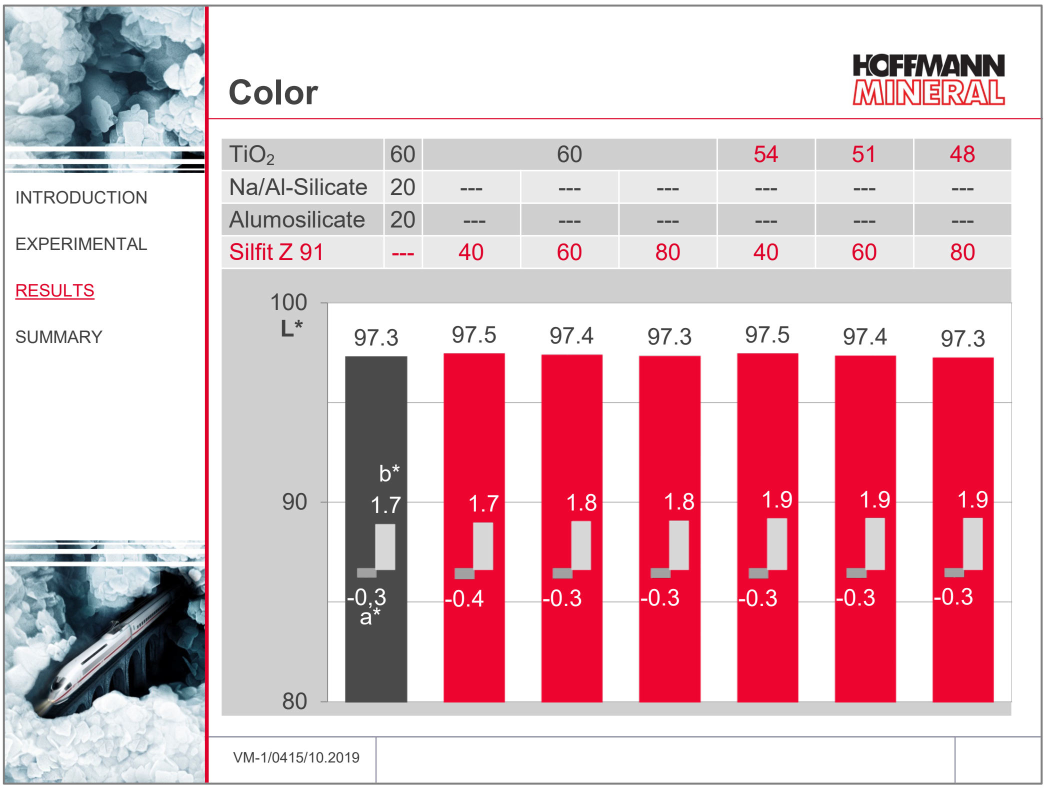
Fig. 7

3.4 Color

The differences in brightness of the two evaluated TiO_2 extenders in powder form do hardly affect the resulting formulations. The pertinent and largely beneficial properties of the Na/Al silicate cannot be transferred to the control formulation, as the effect is counteracted by the markedly lower brightness of the alumosilicate. As a result, the level of the control remains somewhat behind the variant with a weight-even addition of Silfit Z 91 (*Fig. 8*).

In view of the good optical properties of the calcined Neuburg Siliceous Earth, the already low amount of titanium dioxide can further be reduced without affecting the brightness. With this, the color neutrality of the interior emulsion paints remains practically unchanged.



TiO_2	60		60		54	51	48
Na/Al-Silicate	20	---	---	---	---	---	---
Alumosilicate	20	---	---	---	---	---	---
Silfit Z 91	---	40	60	80	40	60	80

Fig. 8

3.5 Hiding power

The calcined Neuburg Siliceous Earth Silfit Z 91 offers a very beneficial contribution to the hiding power of the coatings. Under the condition of a good hiding film with a contrast ratio of at least 98 %, Silfit Z 91 leads to visibly higher spreading rates as shown in *Fig. 9*. An increasing addition of Silfit Z 91 affects the properties in a particularly positive way. In analogy to the results for the color values, the white pigment portion in the corresponding formulations can be reduced without replacement and without drawbacks versus the control. The expected decrease of the hiding power comes out rather low, which means despite the TiO_2 savings still a visible gain in performance is realized.

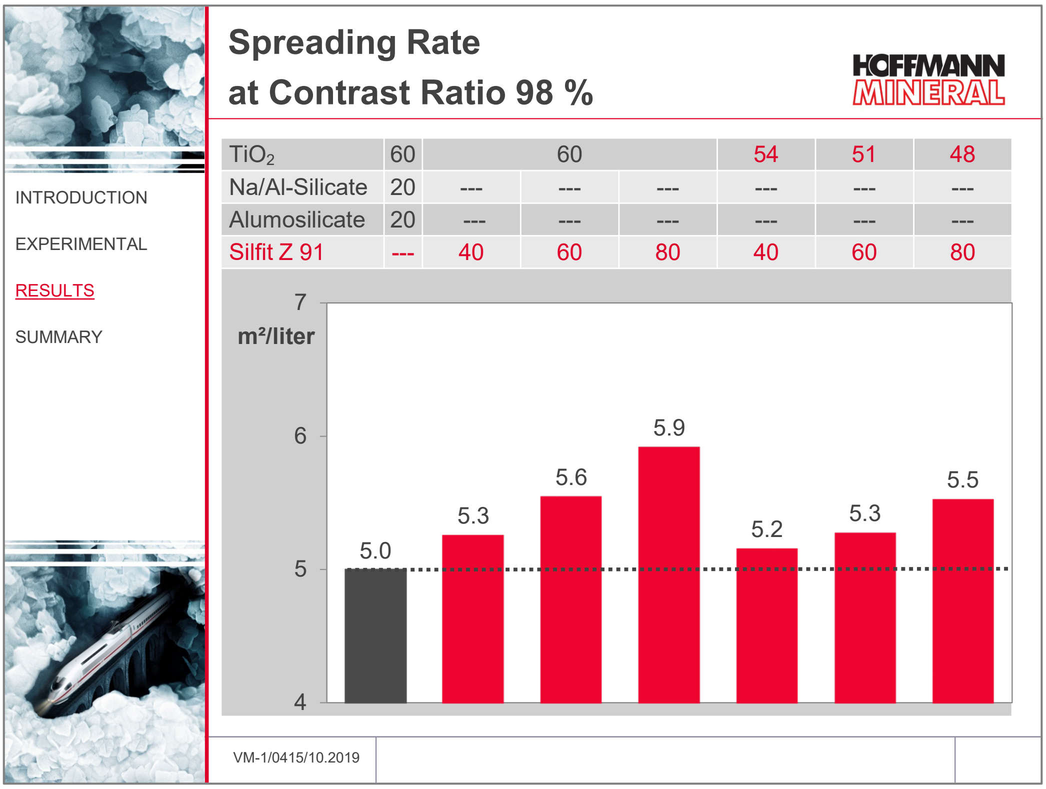


Fig. 9

The benefits in covering power and spreading rate directly and positively affect the overall performance of the coating, as confirmed in the following paragraph.

3.6 Cost / Performance calculations

The data in *Fig. 10* refer to volume related raw material costs in Germany 2019 (upper graph, left-hand column), as well as to the volume related spreading rate resulting from the hiding power (upper graph, right-hand column). The figures indicate the relative change (in %) with respect to the control formulation with an index of 100. The lower graph summarizes the pertinent additive result of the changes in costs and spreading rate as an index for the effective performance of the coatings.

Already without replacing titanium dioxide the use of Silfit Z 91 is recommended because of the savings in formulation costs in combination with increasingly improved performance. The corresponding TiO_2 reduced variants in the overall assessment exhibit a nearly comparative picture, with the advantage primarily in a reduction of the formulation costs through the savings in white pigment.

The higher spreading rates in all formulations with Silfit Z 91 correlate with a lower surface related material consumption and additionally help to obtain an optimized cost structure.

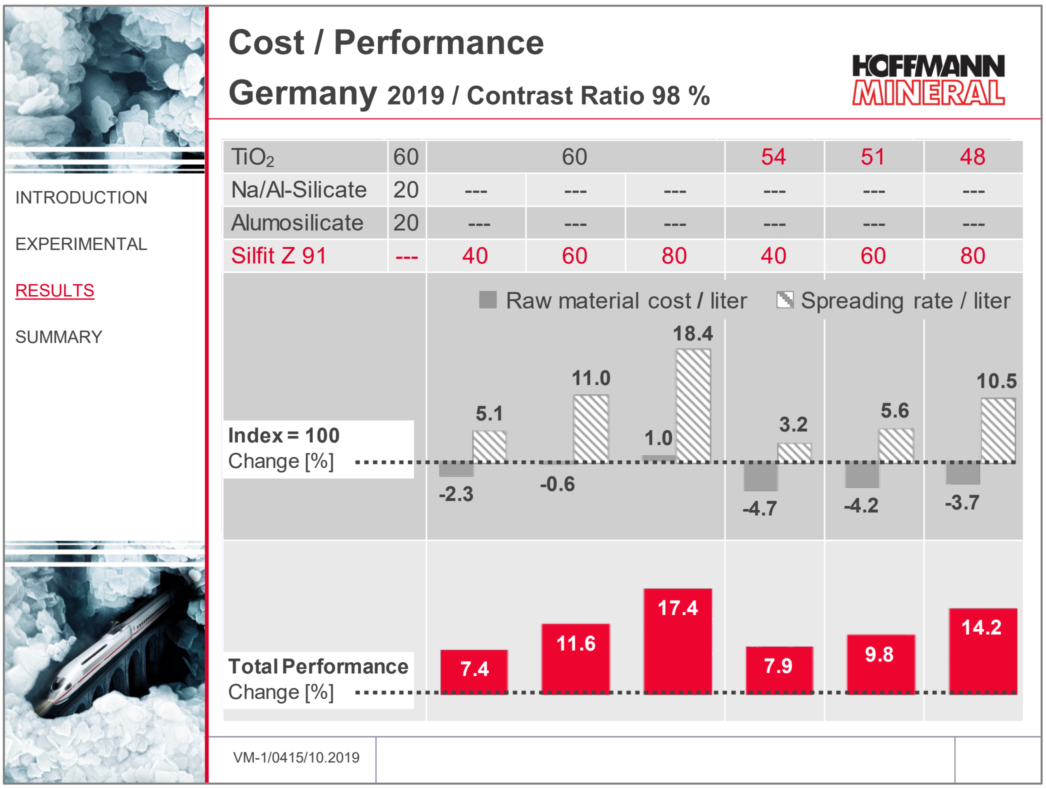


Fig. 10

4 Summary

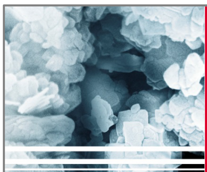
According to the present study, Silfit Z 91 compared with a blend of a precipitated Na/Al silicate and an alumosilicate arrives at the following performance:

- Practically comparable processing properties, storage stability, wet-scrub resistance and color
- Somewhat higher gloss level, with further matting possible via addition of up to 2 % of fine cellulose fibers
- Distinctly optimized hiding power and higher spreading rate along with simultaneously reduced formulation costs
- Despite a lower white pigment addition of 10 to 20 % improved performance with further cost savings

The calcined Neuburg Siliceous Earth Silfit Z 91, therefore, with its property profile is able to markedly improve the performance of existing low-cost interior emulsion paints.

In addition, Silfit Z 91 via the high potential for cost savings offers a distinct contribution to formulating even more cost effective coating systems and underlines in a particular way its suitability as an effective TiO_2 extender for modern dispersion-based interior paints.

Recommended formulations with Silfit Z 91 can be found in *Fig. 11*.



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Starting Formulations

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[1] Highest brightness and matting * [2] Best hiding power / spreading rate [3] TiO_2-reduction for high cost saving with good hiding power		[1]	[2]	[3]
Water deionized			300	
Natrosol 250 HBR			4	
Sodium hydroxide, 20 % in water			2	
Joncryl 8078			9	
Parmetol MBX			1	
Foamaster MO 2134			2	
Tronox CR-828		60	60	48 (to 54)
Silfit Z 91		40	80	(40 to) 80
Socal P2			50	
Plustalc H15			90	
Omyacarb 2 GU			80	
Omyacarb 5 GU			210	
Foamaster MO 2134			3	
Acronal ECO 6270 (Straight acrylic)			84	
Water deionized			66	
Solids content w/w	[%]	58.3	59.9	59.3
PVC	[%]	83.2	84.3	84.0

** Dosage of +/- 20 pbw Arbocel B 600 if required*

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Fig. 11

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