Facade emulsion paints:

Silfit Z 91

vs. precipitated calcium carbonate

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1 Introduction

An outstanding performance profile and high resistance properties and functionality are essential characteristics of modern dispersion-based facade paints. As decorative coating systems, they contain a mostly relatively high portion of titanium dioxide, which, however, as energy and cost intensive filler suffers from increasingly strong variations concerning price and demand, and, therefore, decidedly determines the cost structure of a given facade paint.

As a consequence, recently more often a partial replacement of the white pigment by suitable mineral TiO_2 extenders is desired. Representatives for this class frequently are light-colored fine precipitated calcium carbonates, silicates or also calcined clays.
The basic requirement refers to at least comparable performance properties of the coatings, in order to offer an attractive combination of price related and technical advantages.

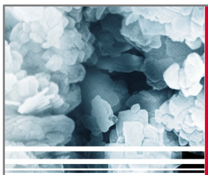
The objective of the present study is an evaluation of calcined Neuburg Siliceous Earth Silfit Z 91 as a TiO_2 extender in comparison with precipitated calcium carbonate in a TiO_2 reduced facade emulsion paint.

The main properties looked at concerned optical criteria such as color neutrality and brightness as well as hiding power and formulation prices as an index for efficiency and cost effectiveness. Other relevant aspects as processing properties, wet-scrub resistance and effects involving the humidity balance will be judged by accompanying tests.

2 Experimental

2.1 Base formulation

The base of the evaluations is a European market approved formulation for a matted facade paint based on a styrene-acrylate dispersion from BASF (*Fig. 1*). Aside from a classical filler combination of predominantly carbonate materials and a smaller part of lamellar talc, pigmentation relies on 180 pbw of a surface treated rutil-type titanium dioxide. As TiO_2 extender, a precipitated calcium carbonate is included.



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Base Formulation

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Ingredient	Function	Parts by weight
Water deionized	-	250
Natrosol 250 HR	Thickener	2
Ammonia, conc. 25 %	Neutralising agent	2
Dispex AA 4030	Dispersing additive	2
Calgon N New, 10 % in water	Wetting- / Dispersing	3
Parmetol MBX	Can preservation	2
Foamaster MO 2134	Defoamer	2
Propylene glycol : Butyl diglycol : Texanol = 1 : 1 : 1	Cosolvent	30
Kronos 2190	TiO_2 Pigment	**180**
Omyacarb 5 GU	Filler	180
Finntalc M 15	Filler	50
Precipitated Calcium Carbonate	TiO_2-Extender	**100**
Acronal S 790 (Styrene acrylic)	Emulsion Binder	220
Foamaster MO 2134	Defoamer	3
Acticide MKB 3	Film preservation	10
Rheovis PE 1330	Thickener	12
Water deionized	-	12
Total		**1060**
Solids content w/w	[%]	59.9
PVC	[%]	61.9

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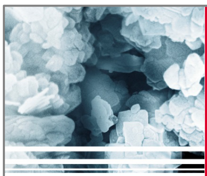
Fig. 1

2.2 Formulation variations

The original TiO_2 content of the control formulation in a first step has been reduced by 30 pbw (about 17 %). Following this, the part of the precipitated calcium carbonate is substituted 1:1 by mass with calcined Neuburg Siliceous Earth Silfit Z 91.

As the comparative results in *Fig. 2* confirm, the relevant properties of the variants remain largely maintained.



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Formulation Data

	Control		
	Full TiO_2 PCC	- 17 % TiO_2 PCC	- 17 % TiO_2 Silfit Z 91
Precipitated Calcium Carbonate (PCC)	100	100	---
Silfit Z 91	---	---	100
Kronos	180	150	150
Data calculated			
Solids content w/w [%]	59.9	58.7	58.7
PVC [%]	61.9	60.9	61.1
Density wet [g/cm³]	1.50	1.47	1.47
Density dry [g/cm³]	2.25	2.20	2.19

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Fig. 2

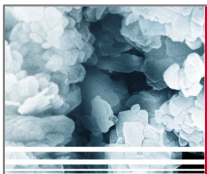
2.3 Characteristics of TiO_2 Extenders

Neuburg Siliceous Earth, which is exploited near Neuburg-on-the-Danube, is a naturally formed mixture of corpuscular Neuburg silica with lamellar kaolinite: a loose conglomerate that cannot be separated by physical methods. The silica portion, due to its natural formation, offers a rounded grain shape and consists of aggregated cryptocrystalline primary particles about 200 nm diameter.

During the calcination process of the Neuburg Siliceous Earth into Silfit Z 91, the water content of the kaolinite portion is split off, and new, largely amorphous mineral phases are formed. At the temperature applied, the silica portion remains unchanged. Via an integrated air classifier process, grain sizes >15 µm are eliminated.

As seen in *Fig. 3*, the precipitated calcium carbonate used as TiO_2 extender offers high fineness along with fairly low oil absorption. Silfit Z 91 is distinguished by moderately higher oil absorption, while density and specific surface area of the two TiO_2 extenders are comparable.

Both TiO_2 extenders in powder form along with very good color neutrality are characterized by high brightness; the particularly high L* value of the precipitated calcium carbonate, however, is not quite equalled by Silfit Z 91.



TiO_2-Extender

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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 Calcium Carbonate	0.3	10	26	2.7	8	97.9	0.0	0.6
Silfit Z 91	2.0	10	55	2.6	8	95.5	- 0.1	0.7
Other Fillers in Formulation (for comparison only)								
Omyacarb 5 GU	5.5	26	16	2.7	2	96.0	- 0.2	0.7
Finntalc M 15	4.5	17	41	2.8	6	92.8	- 0.5	1.1

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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 equipped with a toothed disc under cooling with water. Pigment, TiO_2 extender and fillers were pre-mixed and, after adding to the mixer, dispersed for 20 min with a peripheral speed 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 28 days of storage were done in an air-conditioned laboratory at 23 °C and 50 % relative humidity. Detailed indication is given in *Figs. 4* and *5*.

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Testing

HOFFMANN MINERAL

Paint Preparation	
Filler incorporation Foam formation	Subjective assessment during preparation
Wet Paint	
Fineness of grind	Grindometer 0 – 50 µm
Viscosity	1d after preparation, 23°C Rheometer, Searle system
Storage stability	Undiluted in 1l-metal can, 6 months 23°C
Application with doctor blade gap 300 µm on Leneta film, DFT ~ 70 µm	
Wet-scrub resistance	200 Cycles on automated wet-scrub resistance tester according to ISO 11998. Classification along with DIN EN 13300

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Fig. 4

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Testing

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Application 400 ml in total (equal to 2 coats with 5 m²/l each), DFT ~ 160 µm	
Liquid Water Permeability W	Priming + 2 coats brush-applied on sand lime bricks Testing according to DIN EN 1062-3 Classification along with DIN EN 1062-1
Water-vapour Transmission Rate V	2 coats brush-applied on filter paper grade 1575 Testing according DIN EN ISO 7783, wet-cup method; classification along with DIN EN 1062-1
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, Spreading Rate	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 respectively contrast ratio at given spreading rate

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Fig. 5

3. Results

3.1 Processing properties and storage stability

The formulations could be prepared without problems. In particular, due to the excellent dispersion behavior of the Neuburg Siliceous Earth in water, Silfit Z 91 will be incorporated equally easily and rapidly as the two comparison variants with precipitated calcium carbonate. According to grindometer tests, the grain size of the completed facade paints is in the region of 20 µm.

Fig. 6 offers an illustration of the largely comparable rheology profile of the tested formulation variants with the strong shear thinning typical of facade paints. The markedly reduced viscosity under high shear load is indicative of the easy applicability and spreadability. Higher values at low shear signalize low run-off tendency and favor the high film layer thicknesses required for good hiding power and sufficient weather resistance.

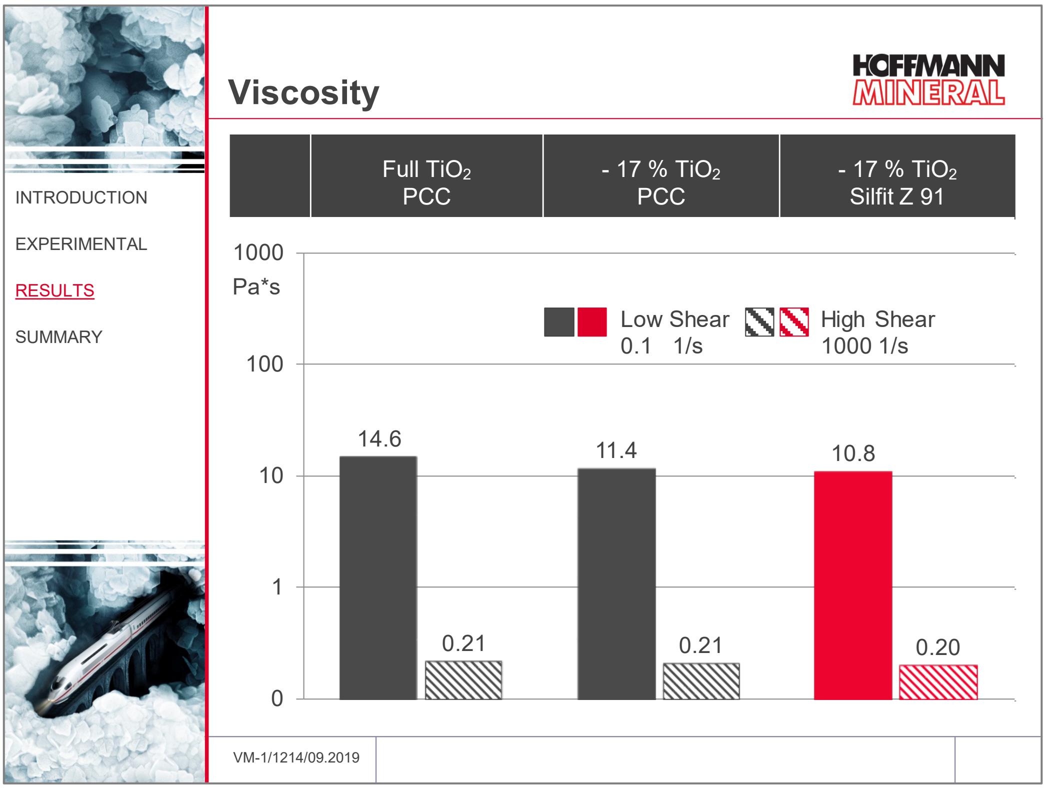


Fig. 6

All formulations after 6 months give evidence of excellent storage stability without phase separation or sedimentation phenomena.

3.2 Wet-scrub resistance

The very good overall performance of the evaluated formulations with results in the area of the best class for wet-scrub resistance comes out somewhat different when regarding the two TiO_2 extenders (*Fig. 7*).

Contrary to the precipitated calcium carbonate, the use of Silfit Z 91 in the TiO_2-reduced formulation gives rise to a marked positive effect on the wet-scrub resistance, which even surpasses the very good mechanical durability of the control formulation.

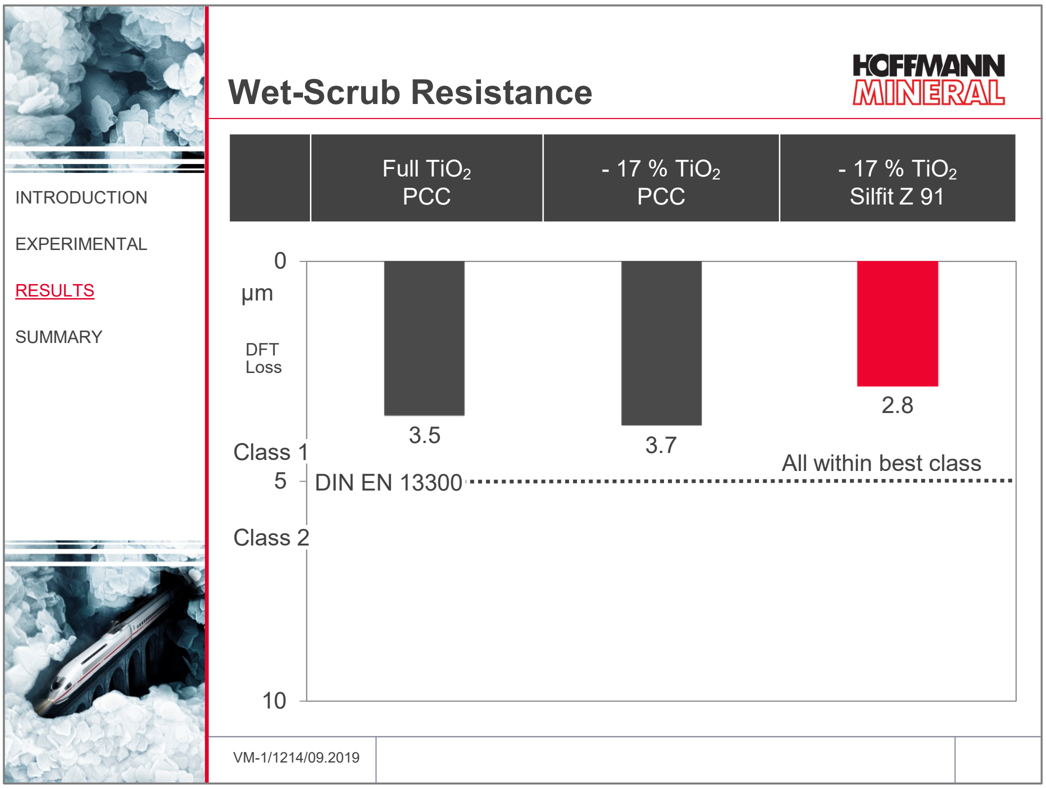


Fig. 7

3.3 Liquid water permeability

For the evaluation of the water permeability of the facade paints, the capillary water uptake of a lime-sand brick coated with the formulation variant to be tested, will be determined gravimetrically after 24 h of immersion. This internationally standardized test method gives concern close to reality to the normally suction determined properties of the underground, which further tend to increase the water uptake. The transport of the water is realized from the outside across the facade paint coating which should offer the best barrier effect possible.

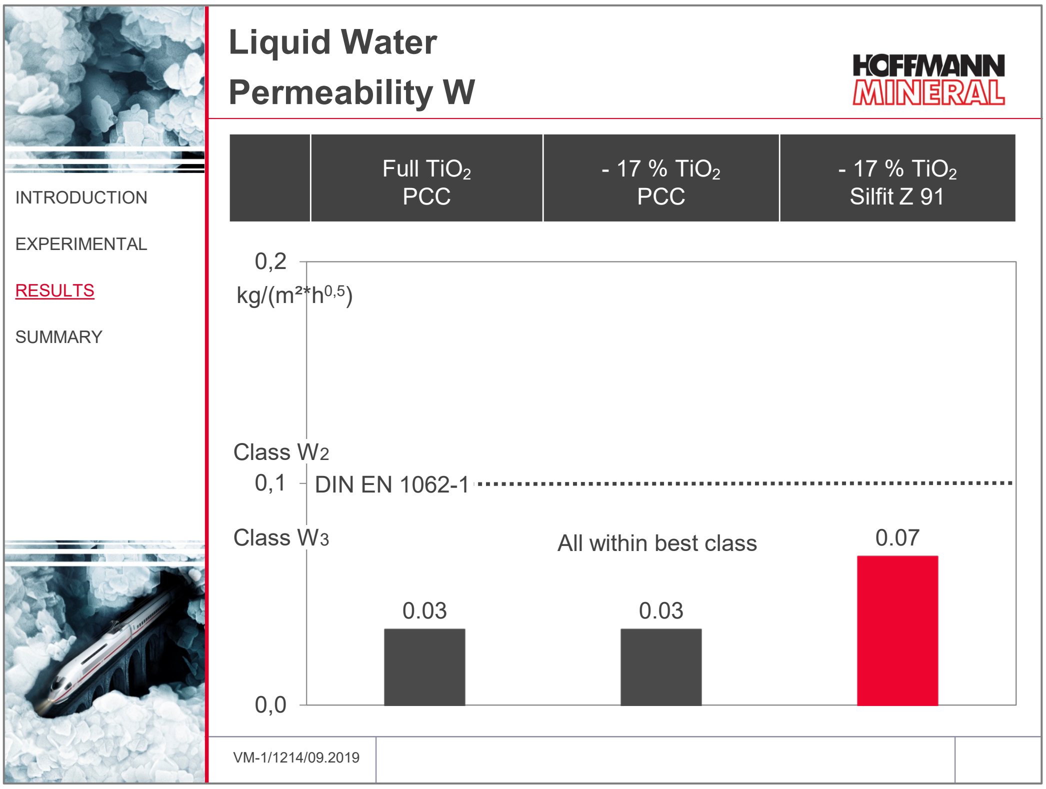


Fig. 8

In comparison with precipitated calcium carbonate, as *Fig. 8* shows, Silfit Z 91 comes off with slightly higher figures for the water permeability. This effect, however, has not yet negative consequences, as Silfit Z 91 clearly remains in the class of the smallest permeability, i.e. with highly water repellent characteristics.

3.4 Water vapor permeability

After applying the formulation to be tested in two layers onto filter paper, drying and conditioning, the coated paper is bonded to a dish with saturated aqueous ammonium dihydrogen phosphate solution. The defined high humidity generated in the test chamber causes a diffusion of water vapor across the coating into the surrounding air (23 °C, 50 % relative humidity) and the total weight of the dish with time goes down correspondingly. The result is expressed as "water vapor transmission rate V", i.e. as weight loss in grams per m^2 per day.

While the water vapor permeability of the control is slightly reduced with going down of the TiO_2 content, Silfit Z 91 gives rise to a marked improvement of the diffusion rate (*Fig. 9*). The replacement of the precipitated calcium carbonate with Silfit Z 91, therefore, brings about a nearly twofold breathability of the coating.

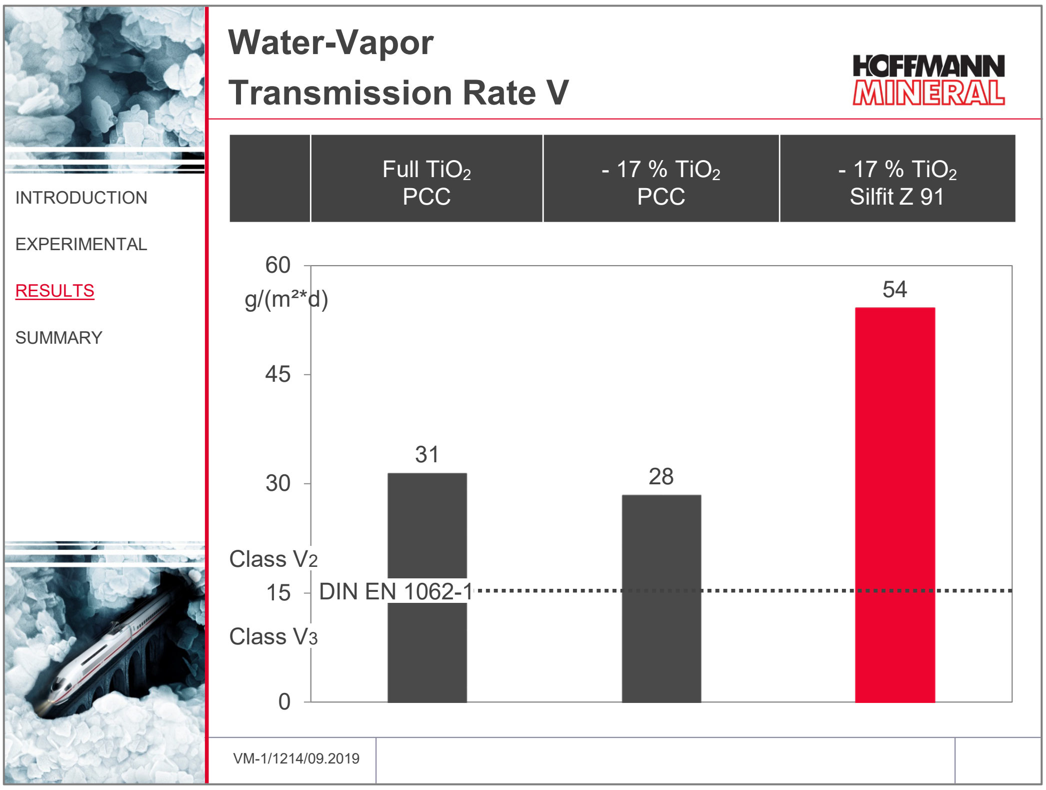
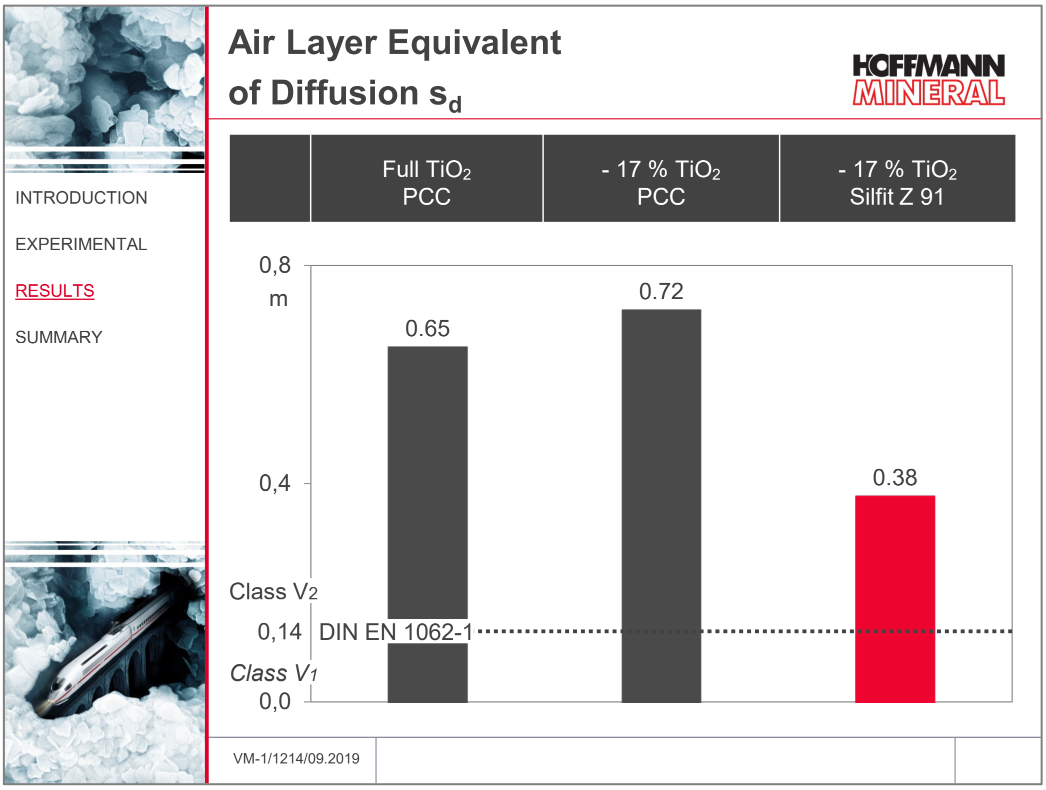


Fig. 9

The permeability of a coating for water vapor in practice is often quoted in form of the calculable "diffusion equivalent air layer thickness s_d". This index illustrates the thickness of a layer of stationary air which resists to the diffusion of water vapor in the same way as the considered and tested coating. The lower the figure, the higher the water vapor diffusion.

The coating with Silfit Z 91 is distinguished by the lowest equivalent air layer thickness, which is a result that comes close to the best class V_1 (highly open to diffusion, see *Fig. 10*).


Air Layer Equivalent
of Diffusion s_d
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Full TiO2
PCC
- 17 % TiO2
PCC
- 17 % TiO2
Silfit Z 91
0,8
m
0,4
0,14
0,0
0.65
0.72
0.38
Class V2
DIN EN 1062-1
Class V1
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Fig. 10

3.5 Facade protection according to Künzel

The theory originally developed by Künzel and presented here allows an evaluation of the suitability of a coating system for facade (facade) paints. For a good moisture balance of coating and substrate (normally masonry) after rain periods or humidity condensation capillary absorbed water has to return to the surrounding air with the help of good water vapor permeability. Otherwise in the case of higher entry of humidity into the facade subsequent damages can develop such as blooming, loss of adhesion and chipping after frost exposure.

The experimental results already discussed in the sections 3.3 and 3.4, in the new *Fig. 11* should find themselves in the region of the area defined by the black line. This area meets the frame conditions of the Künzel theory as derived from extensive studies ($s_d \leq 2$ m, W ≤ 0.5 kg/(m^2*h$^{0.5}$) and s_d*W ≤ 0.1 kg/(m*h$^{0.5}$)).

As the data show, the best result comes from Silfit Z 91 with a very well balanced ratio of the two characteristical parameters. Compared with the formulations with the precipitated calcium carbonate, the measuring point of the calcined Neuburg Siliceous Earth is markedly closer to the starting point of the diagram which indicates the theoretical property optimum.

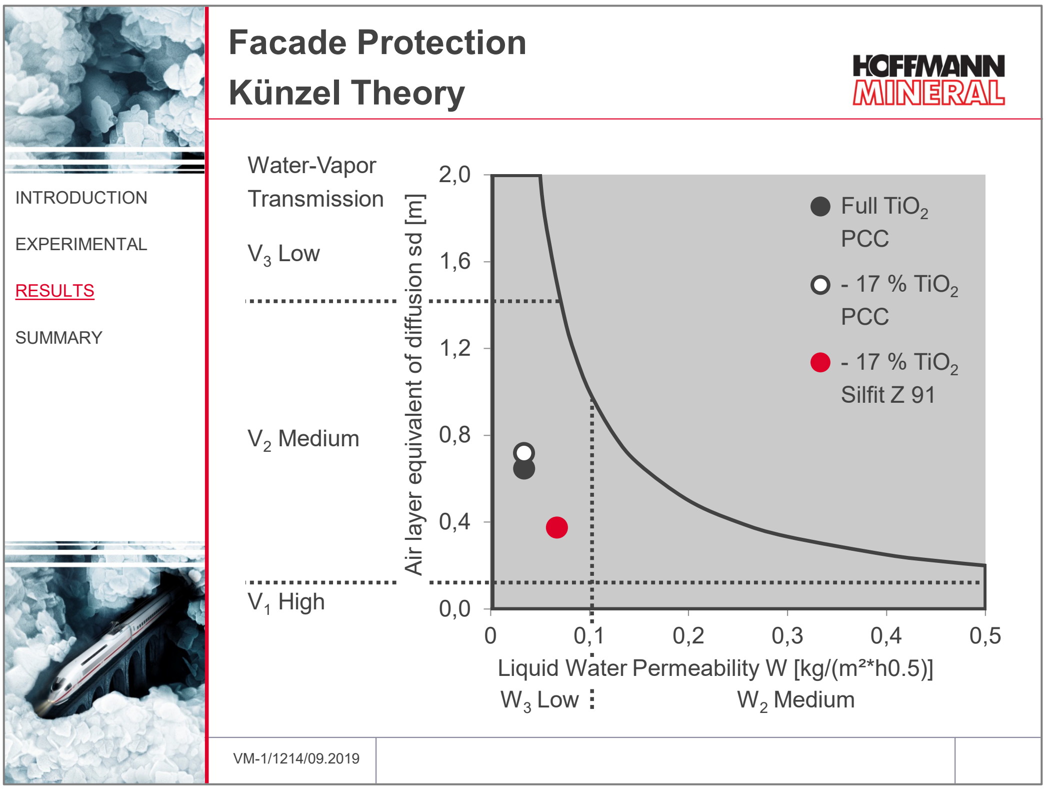


Fig. 11

3.6 Gloss

All formulations with a degree of gloss of < 5 units at 85° give evidence of a "dull-mat" appearance according to DIN EN 13300.

3.7 Color

The decrease of the TiO_2 concentration has only little effect on the color values of the facade paints. Despite the brightness differences of the extenders as straight powders Silfit Z 91 gives rise to a relatively high, almost comparable brightness of the coating with the precipitated calcium carbonate (*Fig. 12*).

At the same time, the color neutrality of the control formulation with the regular TiO_2 addition does not change with the use of Silfit Z 91.

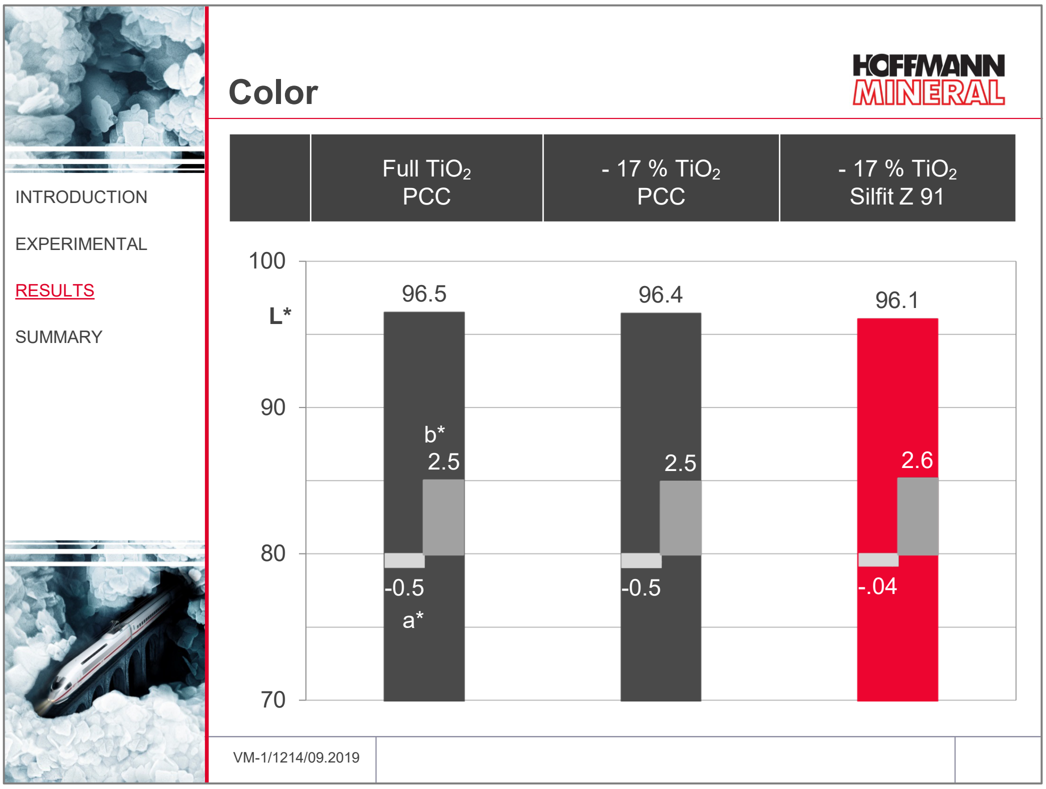


Fig. 12

3.8 Hiding power

For the definition of the hiding power, the EU Ecolabel offers a good starting point. As a support for the user, it distinguishes and honors products which help serve the high quality requirements of the market and in particular offer as high as possible an environmentally and health preserving contribution during production and application. The objective of the recognized voluntary environment sign is to sensibilize for an improved environmental protection by working with correspondingly labeled products.

The reduction of the white pigment titanium dioxide which is ecologically precarious during production represents a step in this direction, and is already considered and quantified by the requirements of the Ecolabel for facade paints:

- Spreading rate ≥ **6 m² / liter** at a hiding power with contrast ratio of 98 %
- Content of white pigments (refractive index > 1,8) ≤ **38 g / m²** of dried film at a hiding power with contrast ratio of 98 %

An environmentally friendlier formulation approach by reducing the titanium dioxide concentration on principle looks possible, but with precipitated calcium carbonate according to *Fig. 13* leads to a marked decrease of spreading rate outside of the required performance level.

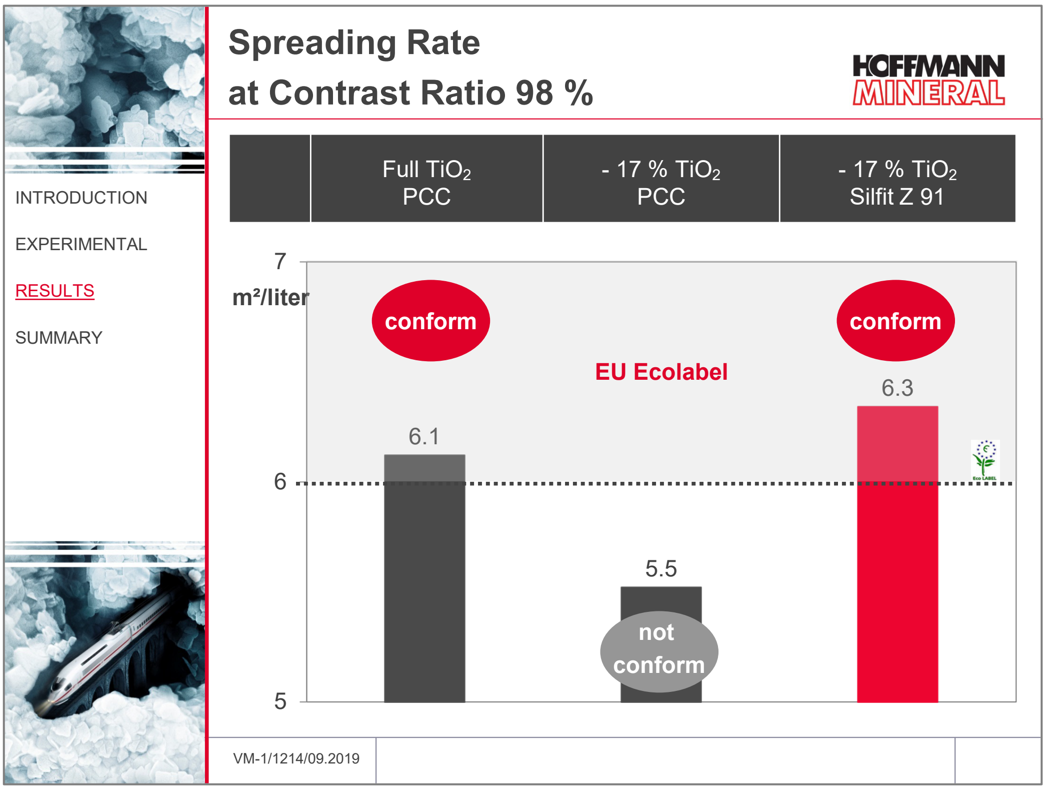


Fig. 13

By contrast, Silfit Z 91 via its very good hiding power as TiO_2 extender offers the possibility to significantly reduce the portion of the white pigment, and along with this even to surpass the requirement of a spreading rate of 6 m²/liter. This situation looks particularly favorable regarding the TiO_2 consumption per surface area coated (*Fig. 14*).

The high titanium dioxide concentration of the control, as shown in *Fig. 14*, cannot be decreased just by the partial reduction of the white pigment portion into the required region on the low side of the limit value.

Only via the additional replacement of the precipitated calcium carbonate by Silfit Z 91 the markedly lower TiO_2 content comes off under the limiting threshold of 38 g/m².

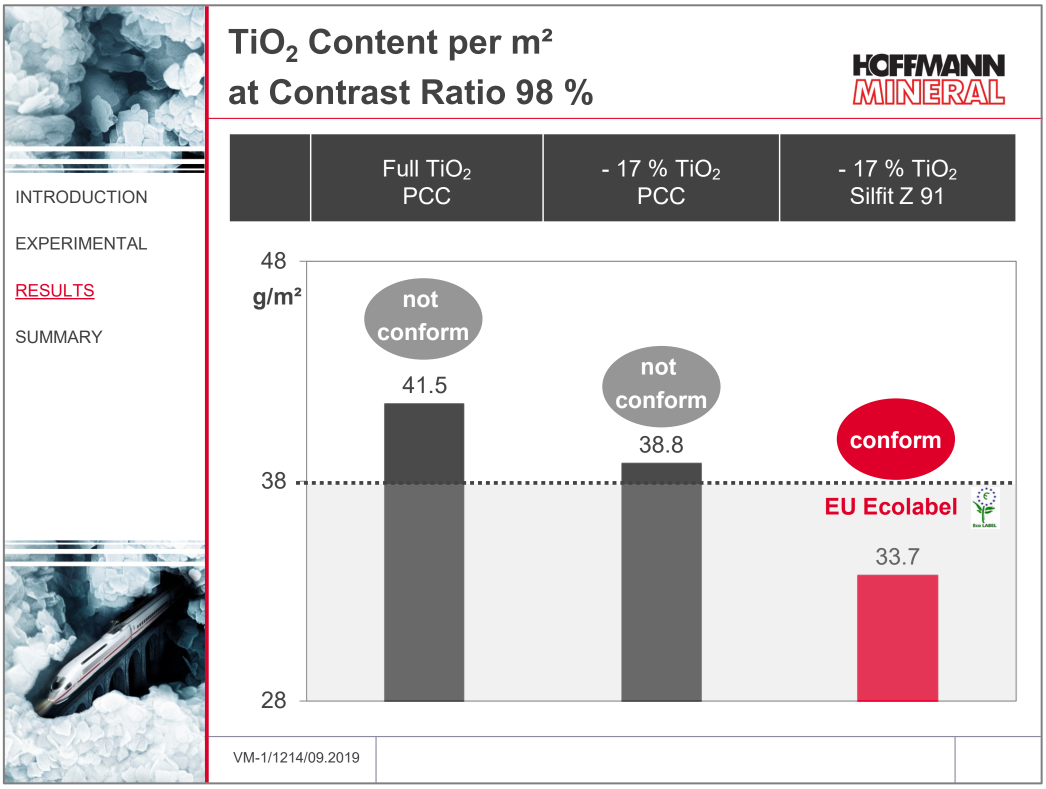


Fig. 14

Compared with precipitated calcium carbonate, Silfit Z 91 brings about a distinct contribution towards decreasing the consumption of white pigments and thus to better preserve the environment. At the same time, with Silfit Z 91 additional cost savings are possible, as shown in the following paragraph.

3.9 Cost / Performance calculations

The base of the relations illustrated in *Fig. 15* are the volume related raw material costs in Germany 2019 (upper graph, left-hand column) as well as the volume related spreading rate resulting from the hiding power (upper graph, right-hand column). The results are expressed as the relative change (in %) with respect to the control formulation with an index of 100.

The lower part of the graph summarizes the corresponding changes in costs and spreading rate as an index for the effective performance capability.

With precipitated calcium carbonate, the partial replacement of TiO_2 gives rise to a moderate advantage in the raw material costs. This effect is, however, more than compensated by the over-proportionally strong decrease of the hiding power which finally results in a negative total balance.

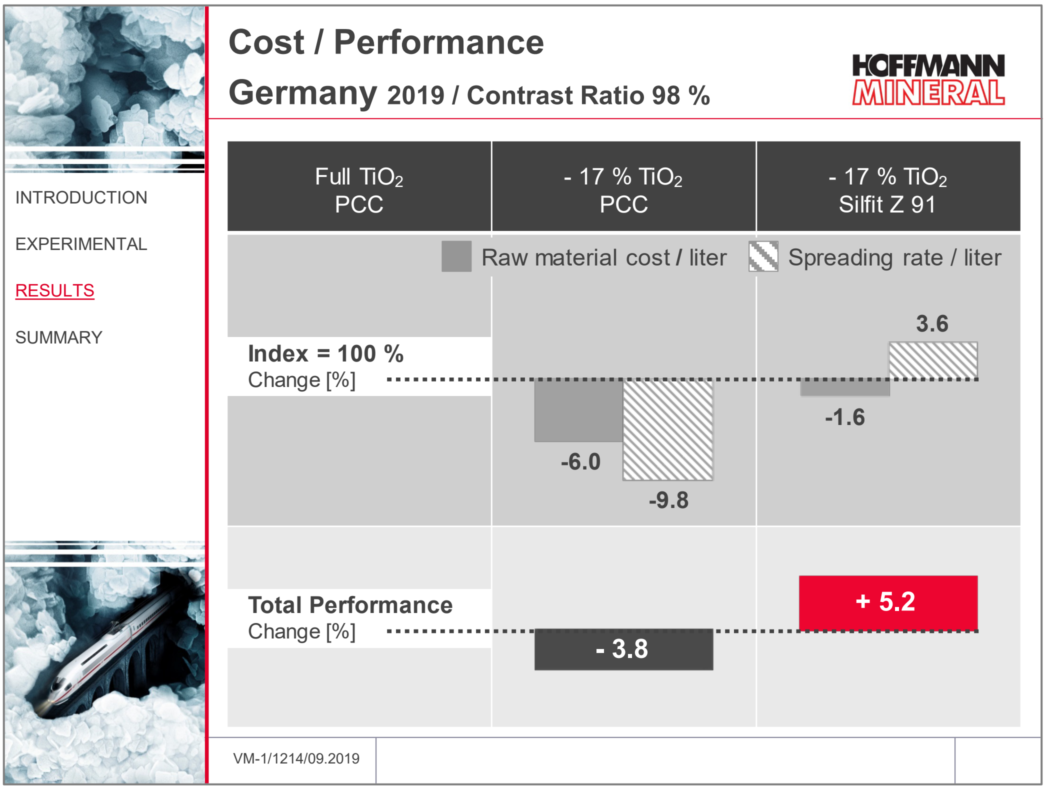


Fig. 15

Silfit Z 91 offers, however, a somewhat lower reducing potential of the raw material costs, but in combination with the added spreading rate results in a gain of performance of about 5 % versus the control formulation. In the direct comparison of the TiO_2 reduced variants, there results even a total balance difference of 9 % with Silfit Z 91 versus precipitated calcium carbonate.

4 Summary

The decrease by 17 % of titanium dioxide and the replacement of precipitated calcium carbonate with Silfit Z 91 lead to the following performance profile:

- Practically comparable properties with respect to processing, storage stability, color, gloss and water permeability
- Optimized wet-scrub resistance
- Significant improvement of water vapor permeability and hiding power

This gives rise to the following benefits when using Silfit Z 91 in facade paints:

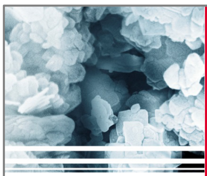
- Higher toughness of the coating
- Optimized breathability in favor of an improved moisture balance of the facade
- Higher spreading rate
- Cost saving potential via reduced TiO_2 content

Along with raw material cost saving possibilities, Silfit Z 91 in total assures a better performance compared with regular TiO_2 content and precipitated calcium carbonate.

Via the optimized spreading rate in addition the surface area related material consumption can be reduced, which also helps save costs and reduce the TiO_2 requirements.

With white pigment levels markedly below the EU Ecolabel limits, Silfit Z 91 offers an important contribution to formulating more environmentally friendly coating systems, and underlines in particular its suitability as an effective TiO_2 extender for modern facade paints.

A recommended formulation based on these results is offered in *Fig. 16*.



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Starting Formulation

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Water deionized		250
Natrosol 250 HR		2
Ammonia, conc. 25 %		2
Dispex AA 4030		2
Calgon N New, 10 % in water		3
Parmetol MBX		2
Foamaster MO 2134		2
Propylene glycol : Butyl diglycol : Texanol = 1 : 1 : 1		30
Kronos 2190		150
Omyacarb 5 GU		220
Finntalc M 15		50
Silfit Z 91		100
Acronal S 790		220
Foamaster MO 2134		3
Acticide MKB 3		10
Rheovis PE 1330		12
Water deionized		12
Solids content w/w	[%]	58.7
PVC	[%]	61.1

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Fig. 16

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