

Hydrophobing Agents

TEGO® Phobe



Because of their pore and capillary structure, mineral building materials absorb moisture on contact with water. This often leads to visible and invisible damage caused either by the water itself or by processes in the walls which are initiated or enhanced by water.

Examples of facade damage caused by water are:

- growth of algae, fungi or spores
- salt efflorescence
- frost damage
- loss of insulating effect
- flaking off of coatings

An effective method of protecting walls which are exposed to weathering is by treating the surfaces with materials which are impenetrable to water or are water repellent (hydrophobic materials).

Hydrophobic means water-hating. A surface is described as hydrophobic if it is not or is not fully wetted by water droplets. A parameter characterizing the hydrophobicity of a surface is the contact angle.

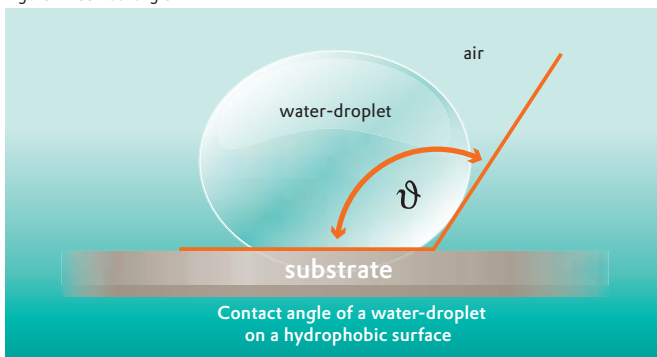
It can be determined by applying water droplets to the surface (fig. 2) and using contact-angle measuring equipment which measures the tangent at the substrate/liquid/air boundary. The result is quoted as the interior angle of the liquid droplet with the substrate. Surfaces with contact angle greater than 90 degrees are classified as hydrophobic. If the contact angle is less than 90 degrees, they are said to be hydrophilic. A video "Measurement of contact angle" can be found on our homepage.



Figure 1: Damage to facades caused by inadequate water vapor permeability

Hydrophobicity

Figure 2: Contact angle



Chemistry of hydrophobing agents

Silicone-based hydrophobing agents

Chemistry of silicone products

The fundamental building blocks of silicones are chlorosilanes, produced by the Rochow synthesis method, which are condensed to higher siloxanes by hydrolysis or alcoholysis. The number of chlorine substituents gives the number of valences available for condensation. Chlorosilanes are classified into four types depending on their degree of chlorination.

Designation	Abbreviation	Reactivity
Monochlorosilane	M	1
Dichlorosilane	D	2
Trichlorosilane	T	3
Quatroschlorosilane	Q	4

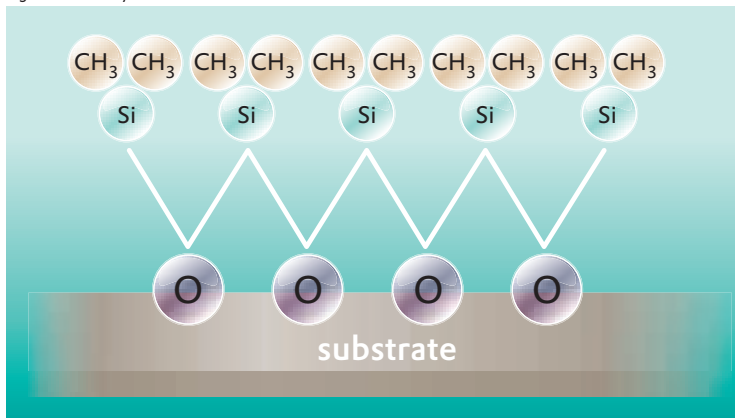
Different types of silicone hydrophobing agents are obtained depending on the types of units reacting together.

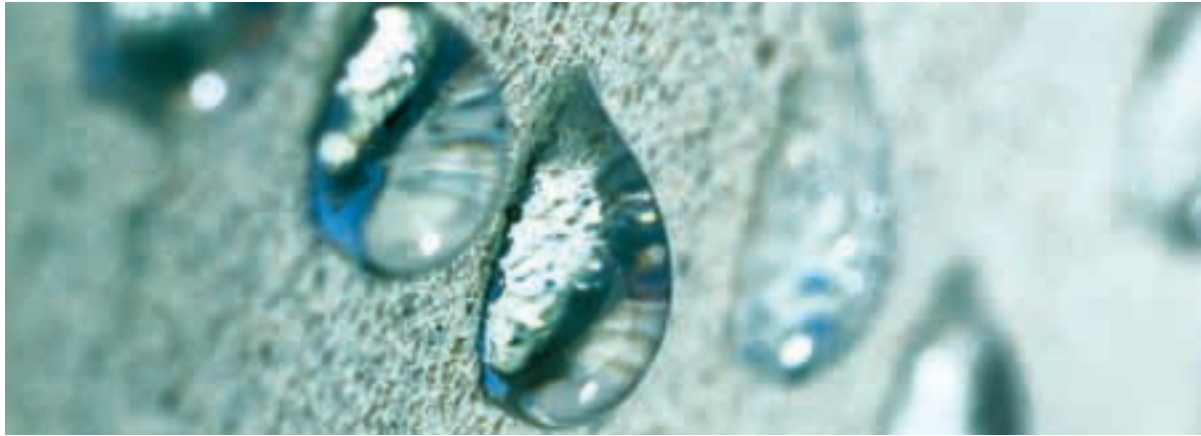
Silicones have a very high spreadability; they attach very readily to surfaces. The hydrophobic effect involves orientation to the wetted surface. The oxygen atoms of the siloxane chain orient themselves to the surface while the alkyl (usually methyl) groups point away from the surface thus producing a hydrophobic surface (fig. 3). The ability of silicones to bond via Si-O-Si links to siliceous surfaces gives a system which is long-lasting.

Siliconates

Siliconates are highly alkaline solutions. After application, they initially react with atmospheric carbon dioxide (CO₂) to form silanols which then react together to produce a silicone resin. Methyl- or propyl-potassium silicates are used almost exclusively. Reaction with CO₂ also produces potassium carbonate as a by-product which is deposited as a salt on the surface. Because the potassium carbonate formed is water soluble, siliconates are used for interior use, e.g. for hydrophobing plasterboard.

Figure 3: Activity of silicones on mineral substrates





Silanes

Silanes are used for hydrophobing mineral materials. Silanes are manufactured by reacting chlorosilanes with alcohol, usually methanol or ethanol. The low molecular weight of silanes is both an advantage and a disadvantage. Compared with higher molecular weight silicones, they are much smaller and can therefore penetrate noticeably better. The disadvantage is their high volatility and the associated possible loss during application.

Upon curing, a silane reacts first with moisture from the air or the building material to give a silanol which, in a subsequent condensation step, crosslinks with itself and the substrate. The speed of the condensation reaction of silanes is strongly affected by the temperature and alkalinity of the substrate. Higher temperatures and high pH favor the condensation reaction. Among the alkoxy silanes, types with methyl groups have the highest reactivity. As methanol is formed as a by-product of the reaction, the more inert ethoxy silanes are increasingly used. The reaction of the silane can be accelerated by suitable catalysis.

Silanes are mainly used for hydrophobing mineral building materials. A distinction is made between internal hydrophobing in which the silane is added to the building material, e.g. concrete, and external hydrophobing in which it is applied in a subsequent step by impregnation.

Oligomeric Siloxanes

Self condensation of chlorosilanes produces reactive low-molecular weight (oligomeric) siloxanes which are used for hydrophobing mineral surfaces. As with silanes, oligomeric siloxanes have a high penetrating power. However, compared with the silanes, they have the advantage of a low vapor pressure and, therefore, do not evaporate. Analogously to the silanes, oligomeric siloxanes can be further cross-linked by condensation reactions. They are mainly used as internal or external hydrophobing agents for mineral building materials.

Polydimethylsiloxanes

Polydimethylsiloxanes are higher molecular weight linear condensation products of D- and M-units. They have a lower penetrating power than oligomeric siloxanes. Polydimethylsiloxanes are mainly used as hydrophobing agents in coatings and plasters, for example in silicate paints, siloxane-modified coatings or lotus-effect coatings. Amino-modified polysiloxanes in these formulations produce good hydrophobing combined with a high water-beading effect.

Silicone resins

The use of hydrophobing agents based on silicone resins gives rise to the names silicone resin paints and silicone resin plasters. Compared with organic resin binders silicone resins have a relatively low molecular weight of between 2,000 and 3,000 g/mol. The residual reactivity in the resin enables the resin to crosslink by a condensation reaction. The water repellent effect is already fully developed immediately after drying. Silicone resins are also used as hydrophobing agents in silicone-silicate formulations.



Waxes

Waxes both as dispersions in organic solvents and as aqueous emulsions have limited penetrating power. Hydrophobing with waxes is therefore mainly a surface effect. As a result of this, hydrophobing with waxes is of limited durability as the wax layer is eroded by the effects of water and weathering. Additionally, the thermoplasticity of the waxes leads to a higher dirt uptake by the surfaces.

Polyfluorocarbon compounds

Surfaces treated with polyfluorocarbon compounds are particularly hydrophobic and also have oil repelling (oleophobic) properties. The high cost of these products and their poor biodegradability limits their use to special niche applications.

Formulation concepts for exterior coatings

Facade protection theory

The protection of a facade against moisture by appropriate treatment is a very important factor for maintaining a building. At first sight, sealing the facade with a waterproof coating seems to be the best solution to protect surfaces against moisture. On closer consideration, however, it is apparent that there are numerous origins of water in a facade.

For example, cracks or other defects in the coating of the facade, rising moisture, damage in roof drainage or dampness from the interior contribute to entry of moisture and transport of salts into the masonry. It is important for a facade to have functioning "moisture management". This involves two parameters which can be measured by standardized methods:

1. Protection of the facade from direct ingress of water through the facade surface (Permeability for water to DIN EN 1062-3).
2. Maintenance of the porous structure of the facade thus allowing a moist or wet wall to dry. (Water vapor transmission rate to EN ISO 7783-2).

Water permeability, w-value (EN ISO 1062-3)

The water permeability, often called capillary water absorption, describes the amount of water which can be absorbed by capillary suction by a square meter of building material within a certain time interval. In EN ISO 1062-1, there are three classes of capillary water uptake. Building materials in the best (class 3) have a maximum of 0.490 kg capillary water uptake on one square meter in 24 hours.

Water permeability classes, w-value, (EN ISO 1062-1)

Class	Water uptake	w-value
III	low	< 0.1
II	medium	0.1 – 0.5
I	high	> 0.5

Water vapor transmission rate, s_d-value (EN ISO 1062-1)

Class	Water vapor diffusion	s _d -value
I	high	< 0.14
II	medium	0.14 – 1.40
III	low	> 1.40

Water vapor transmission rate (permeability) (V-value or s_d-value)

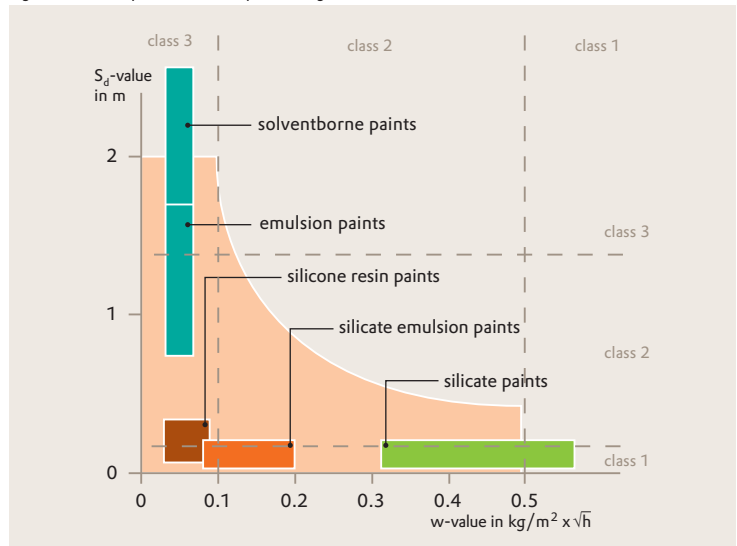
The water vapor transmission rate is determined by EN ISO 7783-2. The V-value describes the amount of water vapor in grams which can diffuse in one day from a coating area of one square meter. More often than the water vapor transmission rate, the diffusion equivalent thickness of air (s_d-value) is given. The s_d-value, which can be calculated from the V-value, describes the thickness of an imaginary layer of still air which has the same resistance to water vapor diffusion as the coating. EN 1062-1 divides the s_d-value into three classes. Coatings with an s_d-value less than 0.14 m are assigned to the best class (class 1) and have very good water vapor transmission.

The relationship of these parameters to each other is given in Künzel's facade theory. Optimally formulated facade coatings have coordinated w- and s_d-values and will lose water as water vapor can be taken up faster than rain. This property is fulfilled by paints where the product of

w-value and s_d-value is at the most 0.1 kg/(m · √h). Ideally formulated paints have a low capillary water uptake (class 3) and very high water vapor transmission rate, characterized by a low s_d-value in class 1. Figure 4 shows quantitatively the relationship of w- and s_d-values to each

other. The yellow area shows the region in which the product of w- and s_d-values is 0.1 kg/(m · √h) or smaller. The extent to which individual facade coating systems fulfill this condition is shown by the colored areas.

Figure 4: Facade protection theory according to Künzel



Formulation of paints which satisfy the requirements of Künzel's facade protection theory

The most important parameter affecting w - and s_d -values is the pigment volume concentration (PVC). The pigment volume concentration describes the volume ratio of the powder-form pigments and filler to the total including the binder in the dried coating film. It is calculated from the following formula.

$$\text{PVC} = \frac{\sum V_{\text{Pigments}} + \sum V_{\text{Fillers}}}{\sum V_{\text{Pigments}} + \sum V_{\text{Fillers}} + \sum V_{\text{Binders}}} \cdot 100\%$$

The PVC for a formulation with a small amount of binder and thus a correspondingly large proportion of pigments and fillers is a high value. Such formulations are indicated by the terms "formulations with high PVC" or (because of the small amount of binder) "weakly bound formulations". Conversely, formulations with a high proportion of binder and low amounts of pigments and fillers are

called "formulations with low PVC" or "strongly bound formulations". Clear coats have, according to the formula, a PVC of zero and theoretically a paint formulated with no binder has a PVC of 100%. In practice, paints are found with extremely low amounts of binder up to a PVC of 90 to 95%.

If the PVC of a formulation is altered stepwise over the complete PVC range, a PVC range is reached in which the film has a high tension. This can lead to cracks in the coating. That point is known as the critical PVC, and in this region the paint undergoes a change between a binder excess at low PVC to binder deficiency at high PVC. Paints with binder excess at low PVC are termed sub-critically formulated. This means that the formulation contains an excess of binder which will fill all cavities between pigments and fillers.





In contrast, super-critically formulated paints with high PVC are binder-deficient. That means that in super-critically formulated paints, the pigments and fillers are not completely wet out by the binder and cavities are formed. Super-critically formulated paints are therefore often termed open pored.

Sub-critical formulations have very good water permeability characteristics (w -value). The binder excess and corresponding continuous film provides protection against water penetration. However the film strongly reduces the water vapor transmission rate which leads to high s_d -values. In practice, too low a water vapor transmission rate can allow the evaporating moisture from the walls to produce a water vapor pressure under the coating which can cause defects in the coating such as blistering.

In contrast, super-critically formulated, open-pore coatings have very good water vapor transmission rates. However, their porosity leads at the same time to high capillary water uptake which means that super-critical formulations do not offer adequate protection from the moisture.

Neither super-critical formulation nor sub-critical formulation can give low water uptake and high water vapor transmission. Only formulations with hydrophobing agents simultaneously offer very good water permeability and water vapor transmission rates. The various formulation concepts and coating types are described below.

Formulation concepts for facade paints and plasters

Silicone resin paints and plasters

The best protection for facades is offered by paints with low water uptake and good water vapor transmission. For this, silicone resin paints and plasters offer advantages over emulsion paints and plasters, as they satisfy both requirements. Silicone resin paints and plasters are super-critically formulated, i.e. with high PVC. The resulting open microporous structure produces excellent water vapor transmission allowing wet walls to dry out. This avoids damage to buildings such as loss of insulating effect, attack by mold or damage to the paint by blistering or flaking. Dry masonry is also an effective contributor to a healthy and pleasant indoor environment.

Guiding formulation for silicone resin paint

Item	Component	Amount by weight	Ingredient/Effect
1	Water	28.75	
2	WALOCEL® XM 6000 PV	0.30	Cellulose thickener
3	TEGO® Foamex 855	0.20	Defoamer
4	ACTICIDE® MBS	0.15	Biocide
5	CALGON® N new	0.05	Wetting and dispersing additive
6	TEGO® Dispers 715 W	0.30	Wetting and dispersing additive
7	AMP90®	0.10	Neutralizing agent
8	KRONOS® 2310	12.50	Titanium dioxide
9	SOCAL® P 3	10.00	Calcium carbonate, precipitated
10	OMYACARB® 5	15.00	Calcium carbonate
11	OMYACARB® 2	10.00	Calcium carbonate
12	AICA® TG	3.00	Mica
13	SIPERNAT® 820 A	2.00	Aluminum silicate
14	TEGO® Phobe 1650	4.00	Hydrophobing additive
15	DOWANOL® DPnB	1.00	Coalescing agent
16	ACRONAL® S 790	12.00	Styrene acrylate binder
17	TEGO® ViscoPlus 3000	0.65	Polyurethane thickener
		100.00	

TEGO® Phobe 1650 effectively prevent capillary water uptake by the coated masonry. Further advantages of TEGO® Phobe 1650 include its high effectiveness in small amounts, excellent early water resistance and low dirt pick-up by the coating. Addition of the polysiloxane TEGO® Phobe 1401 or TEGO® Phobe 1505 produces an additional water beading effect. For this, an added quantity of 1 to 2% is recommended.

According to European Standard (EN 1062-1), facade coatings are grouped according to their w -values (EN 1062-3) and s_d -values (EN ISO 7783-2) each into three classes. With silicone resin paints, the highest demands can be achieved with w -value in class 3 (lowest water uptake) and s_d -value in class 1 (highest water vapor permeability).

Exterior coatings based on nanohybrid binders

The addition of silicone resin emulsions produces protection against water, for example, driving rain. The silicone resin coats the open pores without closing them. Thus water vapor transmission is preserved but the hydrophobic coating efficiently prevents water from penetrating into the pores.

Silicone resin coatings offer the most effective protection for buildings. TEGO® Phobe 1650 is one of the newest generations of silicone resin hydrophobing additives. Formulations incorporating the waterborne silicone resin emulsion

Hybrid binders of an acrylate dispersion and an amorphous silica are relatively new commercial products. These binders allow paints to be formulated which, despite having a high binder content, are more open to water vapor transmission than similar coatings based on pure polymer binders, that is with lower PVC. Compared with conventional dispersions, nanohybrid binders have the advantage that the amorphous silica imparts thermo-plasticity to the coating film and makes it less susceptible to dirt pick up. Formulating silicone resin paints with nanohybrid dispersions combines the low dirt pick-up

of the latter with the good properties of the former. A three-fold combination of a conventional binder with a nanohybrid dispersion and the silicone resin TEGO® Phobe 1650 has proved particularly effective.

Siloxane facade paint with water-beading effect

Since the end of the 1990s, facade paints with marked water beading effect (also known as Lotus-Effect®) have become established. Such coatings are characterized by a very strong water-beading effect with a contact angle between water/coating of more than 140°. This is often associated with a low dirt pick-up as well as a self-cleaning effect (Lotus-Effect®). Experience in various regions of the world has shown that environmental influences such as air pollution, climate or type and frequency of rain have a decisive effect on self-cleaning ability.

The water-beading effect is obtained by using a special hydrophobing additive, TEGO® Phobe 1505, and a special surface texture of the coating. This desired micropimple structure is obtained by using highly crystalline quartz or calcium carbonate filler with a particle size between 15 and 20 micrometers and a narrow particle size distribution. Surface-active water-soluble materials in the coating reduce the water-beading effect and, in choosing raw materials, care must be taken to ensure that they are low in surfactant. As with silicone resin paints, siloxane paints have very low water uptake and excellent water vapor transmission.

Guiding formulation for a silicone resin paint based on nanohybrid dispersion

Item	Component	Amount by weight	Ingredient/Effect
1	Water	14.8	
2	TYLOSE® MH 30000 YP2	0.2	Cellulose thickener
3	TEGO® Foamex 855	0.3	Defoamer
4	ACTICIDE® MBS	0.4	Biocide
5	DOWANOL® DPnB	3.2	Coalescing agent
6	TEGO® Dispers 755 W	1.3	Wetting and dispersing additive
7	AMP90®	0.4	Neutralizing agent
8	KRONOS® 2190	22.5	Titanium dioxide
9	OMYACARB® 5 GU	6.0	Calcium carbonate
10	OMYACARB® 2 GU	6.0	Calcium carbonate
11	AICA® TG	4.0	Mica
12	SIPERNAT® 820 A	3.2	Aluminum silicate
13	TEGO® Phobe 1650	7.5	Hydrophobing additive
14	COL.9® DS 1200 X	15.0	Nanohybrid binder
15	ACRONAL® A 684	10.5	Acrylate binder
16	COLLACRAL® LR 8990 (1:1 in Water)	2.7	Polyurethane thickener
17	TEGO® Foamex 855	0.4	Defoamer
18	ACTICIDE® MKB	1.6	Film preserving agent
		100.00	

Guiding formulation for a siloxane coating with water-beading effect

Item	Component	Amount by weight	Ingredient/Effect
1	Water	29.70	
2	TEGO® Foamex 825	0.10	Defoamer
3	SURFYNOL® E 104	0.25	Wetting and dispersing additive
4	WALOCEL® XM 6000 PV	0.30	Cellulose thickener
5	ACTICIDE® MBS	0.10	Biocide
6	KRONOS® 2044	20.00	Titanium dioxide
7	SIBELITE® M 3000 or CALCIMATT®	32.00	Quartz Calcium carbonate
8	Ammonia 25 %	0.15	Neutralizing agent
9	TEGO® Phobe 1505	2.40	Hydrophobing additive
10	ACRONAL® S 790	15.00	Styrene acrylate binder
		100.00	

Guiding formulation for a dispersion silicate paint

Item	Component	Amount by weight	Ingredient/Effect
1	Water	22.30	
2	BETOLIN® V 30	0.10	Thickener
3	TEGO® Dispers 735 W	0.30	Wetting and dispersing additive
4	BETOLIN® Q 40	0.30	Stabilizer
5	TEGO® Foamex 825	0.20	Defoamer
6	NATROSOL® 250 HHR	0.30	Cellulose thickener
7	KRONOS® 2310	10.00	Titanium dioxide
8	OMYACARB® 5	30.00	Calcium carbonate
9	PLASTORIT® 000	5.00	Talc
10	TEGO® Phobe 1401	4.00	Hydrophobing additive
11	ACRONAL® S 559	6.00	Styrene acrylic binder
12	White spirit	1.50	Coalescing agent
13	BETOLIN® K 28	20.00	Potassium water glass binder
		100.00	

Guiding formulation for a silicone-silicate paint

Item	Component	Amount by weight	Ingredient/Effect
1	Water	22.30	
2	BETOLIN® V 30	0.10	Thickener
3	TEGO® Dispers 715 W	0.30	Wetting and dispersing additive
4	BETOLIN® Q 40	0.30	Stabilizer
5	TEGO® Foamex 825	0.20	Defoamer
6	NATROSOL® 250 HHR	0.30	Cellulose thickener
7	KRONOS® 2310	10.00	Titanium dioxide
8	OMYACARB® 5	30.00	Calcium carbonate
9	PLASTORIT® 000	5.00	Talc
10	TEGO® Phobe 1650	4.00	Hydrophobing additive
11	ACRONAL® S 559	6.00	Styrene acrylic binder
12	White spirit	1.50	Coalescing agent
13	BETOLIN® K 28	20.00	Potassium water glass binder
		100.00	

Silicate paints and plasters

Silicate paints and plasters contain water glass, usually in combination with polymer dispersions as binders. The ability of water glass to react with silicate substrates and form a strong chemical bond makes silicate systems very attractive for coating the most common mineral substrates found outdoors. This property, known as silicification, makes silicate paints very durable. The high proportion of inorganic components gives the silicified coating a mineral appearance and excellent water vapor transmission. A disadvantage however is the high capillary water uptake of such formulations. This can be reduced by using hydrophobing agents specially suited to silicate paints, for example TEGO® Phobe 1505 or 1401.

Silicone-silicate paints

These are a variant of silicate paints in which the binder is a three-fold combination of emulsion, silicone resin and water glass. In terms of values for capillary water uptake and water vapor diffusion, they are similar to other silicate paints but have the advantage of lower dirt pick-up.

Emulsion paints with silicate character

Because of their formulation with quartz flour or other mineral fillers, emulsion paints with silicate character are particularly open-pored or capillary active and thus permeable to water vapor.

Emulsion paints and plasters

Using polymer dispersions as binders in emulsion paints and plasters prevents water uptake by the coating. If water beading is needed, this can be achieved by adding TEGO® Phobe 1401 and TEGO® Phobe 1500 N.

Guiding formulation for a dispersion paint with silicate character

Item	Component	Amount by weight	Ingredient/Effect
1	Water	14.70	
2	TYLOSE® MHB 10.000 YP2	0.20	Cellulose thickener
3	TEGO® Dispers 715 W	0.30	Wetting and dispersing additive
4	TEGO® Foamex 825	0.30	Defoamer
5	KRONOS® 2310	12.00	Titanium dioxide
6	OMYACARB® 5	10.00	Calcium carbonate
7	Talkum AT 1	1.50	Talc
8	SIKRON® Feinstmehl SF 3000	35.00	Quartz
9	ACTICIDE® MBS	0.20	Biocide
10	TEGO® Phobe 1401	2.50	Hydrophobing additive
11	White spirit	0.80	Coalescing agent
12	DOWANOL® DPnB	0.80	Coalescing agent
13	DESAVIN®	0.70	Plasticizer
14	ACRONAL® S 559	21.00	Styrene acrylate binder
		100.00	



Hydrophobing additive for impregnation and primers

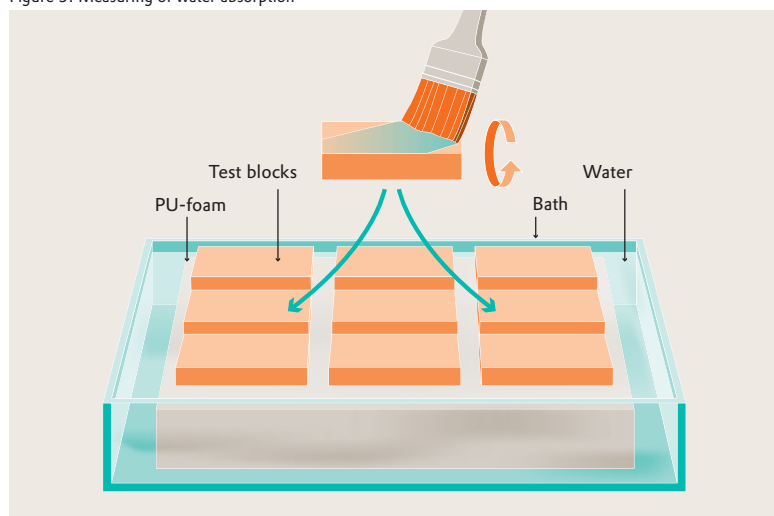
Impregnation is performed on building materials when it is not intended to coat them further. The aim of impregnation is to reduce the water uptake of a building material without otherwise altering its characteristics such as porosity or appearance. The impregnating agent must not impair water vapor and carbon dioxide permeability. Impregnation with siloxane products can be achieved with TEGO® Phobe 6010 for solvent-based impregnation or TEGO® Phobe 6510 and 6600 for water-based impregnation. Impregnation should not be used for materials which have little or no absorbency.

Primers are used to reduce the absorbency and consolidate the substrate. For this, the primer must be able to penetrate the substrate adequately. Otherwise, too much material would remain on the surface and consolidation of the substrate would not be sufficient. Adhesion problems might arise with subsequent coats. The right primer can have a decisive influence on the durability of the complete coating system.

Effective priming protects the coating from infiltration of salts and water which can damage the building. If the top coat is damaged, the primer must additionally protect the building material from further damage by water penetration.

With siloxanes of the TEGO® Phobe 6xxx series, Evonik offers products for formulating solvent- and water-borne primers.

Figure 5: Measuring of water absorption



Test methods

Determination of water vapor permeability by the wet cup method

Evonik uses a gravimetric method from EN ISO 7783-2 to determine the water vapor permeability by comparison with an inert carrier material. The substrates are polyethylene frits with a diameter of 60 mm. The coating material is applied to the frit with a flat brush in the amount per

unit area recommended for use in practice. If details of the amount to be applied for a given area are not available, Evonik applies the paint in two coats using 400 ml/m² in total. The coating is dried overnight in a standard climate (23°C, 50% relative humidity) followed by 24 hours at 50°C.

A weighing dish with a diameter of 61 mm and height of 30 mm is filled with 20 ml of distilled water. A small sponge is placed in the dish to stop the underside of the frit coming into contact with liquid which could otherwise invalidate the measurement. The dish is closed with the coated frit and the joint between the frit and the weighing glass sealed with hot melt adhesive. The whole is then weighed accurately using an analytical balance to ±0.1 mg and kept for five days in a climate chamber at 23°C and 50% relative humidity. After this, it is weighed again. By comparison with a non-coated specimen, the amount of water diffused is determined from the weight loss of the sample (fig. 6). The performance of the test can be seen on our internet site under "Measurement of water vapor permeability (s_d -value)".

Determination of water vapor permeability by the dry cup method

The dry-cup method is another way of measuring the water vapor permeability. Preparation of the sample is the same as that for the wet-cup method. However, in the dry cup method the weighing dish is filled with phosphorous pentoxide (P₂O₅) to produce an internal humidity of 0%

and the glass is then kept in a standard climate of 23°C and 50% relative humidity. The water vapor diffusion is thus in the opposite direction.

Comparison of wet- and dry-cup methods has shown that the wet-cup method is more accurate.

Measurement of capillary water uptake

The capillary water uptake is measured by Evonik from EN 1062-3. The test specimens are calcium sandstone blocks with an area of 115 x 70 mm = 0.008 m² and a thickness of 20 mm. The blocks are prepared by scrubbing them free of dirt with water and then drying for 24 hours at 50°C.

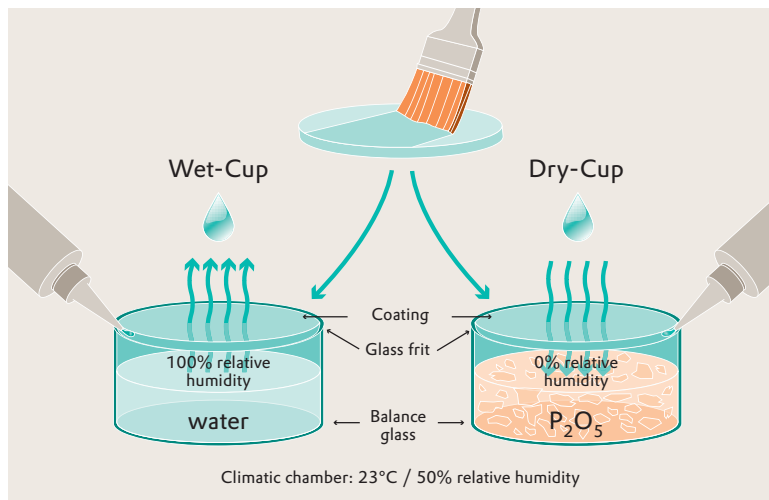


Figure 6: Wet-cup method

The correct amount of coating is then poured onto the block and distributed with a flat brush ensuring that the sides are coated as well. The amount of coating material is based on the recommended amount used in practice. If there are no recommendations as to the amount to be used for a given area, Evonik uses a total of 400 ml/m² applied in two coats. Care must be taken to ensure that all the pores of the block are closed. The coated block is kept overnight in a standard climate (23°C, 50% relative humidity) followed by drying for 24 hours at 50°C.



The test samples are placed on foam in a water-filled tray (fig. 5). The level of the water must reach the underside of the samples and from time to time the water level is checked and water replenished if necessary. After 24 hours, the blocks are removed from the water bath, placed on paper, blotted and weighed. DIN EN 1062-3 specifies a fourfold watering of the block. In the first watering, water-soluble components of the coating are washed out. For classification of EN ISO 1063-1, the result of the fourth watering is taken and specified as the w_{24} -value, e.g. $w_{24} = 0.5 \text{ kg}/(\text{m}^2 \cdot \sqrt{\text{h}})$

The method of measuring the capillary water uptake can also be seen on our internet site.

Determination of the contact angle

The contact angle describes the wettability of a substrate by a liquid, predominantly water in the case of exterior paints. To determine the contact angle, a water droplet with a specified volume is placed on the coating. Using an optical method, the angle of the tangent of the drop to the substrate is measured. High contact angles indicate poor wetting and consequently good water beading. In contrast, low contact angles indicate good wetting and poor water beading. The contact angle can change during the course of the measurement. In particular, with fresh paints which have not been exposed to water or weathering, the contact angle decreases during the course of the mea-

surement. The reason for this is that emulsifiers and other water-soluble components are dissolved out of the paint film and these lower the interfacial tension of the water droplet. If the coating is irrigated for 24 hours prior to the measurement, higher and more stable values of the contact angle are obtained. When comparing results of contact angle measurements, it is therefore always necessary to know details of the pre-treatment.

No statements about the capillary water uptake can be made from the contact angle of a coating.

Dirt pick-up

In addition to the technical properties of a coating, it is also important that it retains its appearance over a long period of use. One obvious visible aspect of an exterior coating is its soiling characteristics. This can be tested in several years of outdoor weathering but the tendency of an external coating to soil can be simulated in a fast test developed by Evonik. Using a converted washing machine, test samples of coatings are sprayed with a dirt dispersion and then dried. This is repeated several times. The dirt dispersion used con-

tains both organic and inorganic matter such as would typically be found in highly polluted urban or industrial areas. The results of the soiling test are specified as delta L of the sample before and after the test. Experience shows that this soiling test produces results which would otherwise only be obtained by several years of outdoor weathering tests.



Determination of the contact angle using an optical method.



FAQs

Vertical tracks which differ from the original color are caused by rain. How can this sensitivity to sudden rain of a recently applied silicone resin paint be improved?

We offer TEGO® Phobe 1650, a silicone resin with early water resistance. That means that the hydrophobic effect of TEGO® Phobe 1650 develops very quickly after application. According to the method for determination of capillary water uptake, EN 1062-1, coatings must reach their full effectiveness after the fourth exposure to water. TEGO® Phobe 1650 actually achieves this after only two exposures.

Does the silicone resin in silicone facade paints affect the s_d value and is the PVC of the coating altered?

The amount of silicone resin has practically no effect on the s_d -value. Investigations have shown that silicone resins do not behave like binders in their effect on wet abrasion resistance or s_d -value. In calculating the PVC, silicone resins should therefore not be incorporated into the calculation as binders.

We have found that our silicone resin paints show a strong increase in viscosity after storing for 5 to 6 months. How can we prevent this?

The order of addition during the manufacture of the paint plays an important role. After manufacturing the millbase, the silicone resin emulsion should be added first and the binder dispersion only added after further stirring.

How much silicone resin do I need to formulate a silicone resin paint?

There is no clear rule as to how much silicone resin a formulation must contain. More important than the quantity used is that the formulation must fulfill the physical demands made on it, such that it achieves class 3 in permeability of water and class 1 in water vapor transmission rate. Older formulations contain up to 10% silicone resin emulsion to satisfy these demands. With the newest generation of silicone resin emulsions, similar properties can be reached with only 4 to 7%.

In choosing the silicone resin, it should be noted that, by definition, silicone resin paints must be made hydrophobic with a silicone resin. Even if linear polysiloxanes can produce a similar hydrophobing effect they cannot, by definition, be used to hydrophobe silicone resin coatings.

How do silicone resin paints behave with respect to dirt pick-up?

The claim that silicone-containing coatings with a high water-beading (lotus) effect are self-cleaning has not been shown in practice. On the contrary, silicones in coatings tend to promote soiling of the surface. As silicones are necessary to reduce the capillary water uptake, it is necessary to find the best compromise amount. With the most recent generation of silicone resins, between 4-7% produces a good balance between dirt pick-up and capillary water uptake.

What is the difference between a silicone resin and a silicone oil?

In terms of chemical structure, silicone resins and silicone oils differ in the way the molecules are branched. Silicone oils (also known as polysiloxanes) have a linear structure composed of M- and D-units. Silicone resins are branched and contain T- and/or Q-units. Silicone resins which contain only T- and Q- units have a very closely meshed resin network and high hardness. If they also contain D- and/or M-units, the resin forms a more open network with lower hardness. The real physical difference between a silicone oil and a silicone resin is the film forming properties. Silicone oils do not form films; that is to say that from an emulsion or solution they dry to an oily layer. In contrast, silicone resins form a non-tacky soft to hard silicone resin film.

(The abbreviations M-, D-, T- and Q-units are explained in the section "Chemistry of silicone products" in this chapter.)

How is a silicone resin defined?

Silicone resins are silicone structures that contain branching T- and/or Q-units. They can also contain linear components of D- and M-units. Depending on the amount of linear components, customized resins with high or low hardness can be formulated.

Should silicone resin hydrophobing additives be regarded as binders?

Silicone resin paints are formulated with an organic binder dispersion and a silicone resin. Often the amount of binder dispersion is in the region of 8 to 20% and that of the silicone resin between 4 and 10%. If the amount of silicone resin in the formulation is altered and coating properties such as water vapor transmission or wet abrasion resistance compared with a formulation in which the organic binder has been altered by a similar amount, it is noticeable that both formulations do not change in the same way. Raising the amount of organic binder leads to a higher water vapor diffusion resistance and a higher wet abrasion resistance; whereas these two properties remain virtually unchanged for changes in silicone resin. This indicates that the silicone resin is not behaving as a binder. It is therefore questionable if the silicone resin should be included as a binder when calculating the PVC.

Can I improve the wet abrasion resistance of a coating by using silicone hydrophobing additives?

Investigations have shown that silicone hydrophobing materials have only a slight effect on wet abrasion resistance.

Can I impart especially good cleaning properties to a matte interior paint by adding silicone resins?

Producing a hydrophobic paint surface by adding silicone resin is not sufficient to impart good cleaning properties to a coating. Whether or not a coating can be cleaned easily is determined by the overall formulation. A silicone hydrophobing additive can nevertheless contribute to the cleanability of the coating.

Can I make deductions about the capillary water uptake of a paint from the contact angle?

The contact angle and the capillary water uptake refer to two fundamentally different things. The contact angle describes the wettability of a coating surface by water. High contact angles indicate poor wettability and a concomitant water beading effect. The capillary water uptake describes the capillary hydrophobicity of a coating. It is quite possible for a coating to have high (and consequently unfavorable) capillary water uptake even though the beading effect is very strong.