



**AEROSIL[®], AEROXIDE[®] and
SIPERNAT[®] products for the
construction materials industry**

Technical Information 1398

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Introduction

One certainty demonstrated during recent times is that the construction industry lies at the very heart of economic life for the World Economy. When considering the various aspects of the industry: engineering, industrial, infrastructural, public, and domestic construction objects, one can see why the annual business volume of construction industry exceeds a thousand billions of Euros world-wide.

The great variety of construction categories needs a huge number of materials for today's engineers from the simple and time tested, such as wood, stone and concrete, to those highly designed and of the latest technology, like plastics, alloys, and composites. Another aspect of construction engineering, however, is the reach back to some of the oldest materials in order to extend their properties and expand their capabilities to fabulous new limits. Concrete certainly is the focus of such recent engineering consideration.

Concrete, plaster and mortar are multi-component systems, which contain chemically reactive ingredients. The peculiarities of these chemical reactions determine the physical and chemical structure of these materials and influence their mechanical strength, pore structure, water permeability, durability, etc. and because silica plays a key role in the chemistry of concrete, plaster, and mortar, its nature has an overwhelming impact on the ultimate properties sought through construction engineering. For example, cured concrete can have different mechanical strength just by variation of the grain size of sand.

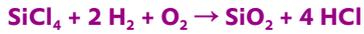
With its comprehensive product portfolio AEROSIL® fumed silica, AEROXIDE® fumed metal oxide grades as well as SIPERNAT® specialty silica, Evonik Industries offers new, powerful ingredients for modern construction design.

Benefits of using the right choice of AEROSIL®, AEROXIDE® and SIPERNAT® in your products include:

- increase of early strength of concrete
- increase of consistency of ultra high-performance concrete
- improvement of mechanical strength for pore (gas) concrete
- reduction of bleeding and segregation in self-compacting concrete
- Improved processability e.g. during spray drying of thermoplastic materials or during sieving of high cohesive powder mixtures
- Improved flowability of powder formulations, ensuring free-flowing behavior
- Anti-caking effect, preventing caking of powder formulations during transportation and/or storage
- Carrier of liquid additives/formulations
- Booster for defoamer formulations
- Improved dispersibility of powder formulations in slurries and dispersions
- Stabilization of dispersions and emulsions
- Rheology modification e.g. thixotropic effect
- Hydrophobization effect, improving water resistance
- improvement of mechanical properties of plasters
- photo catalytic activity of surfaces
- reduction of dirt pick-up on the plaster and concrete surfaces

Properties of AEROSIL® fumed silica, SIPERNAT® specialty silica and AEROXIDE® titanium dioxide

AEROSIL® fumed silica is a highly pure, very fine type of silicon dioxide. The manufacturing process is based on the flame hydrolysis of silicon tetrachloride with overall chemical reaction:



Synthesis temperatures above 1000 °C and complex particle dynamics, which include processes of nucleation, coagulation, surface growth, sintering and aggregation, lead to fractal-like morphology of silicon dioxide – numerous approximately spherical primary particles are comprised in sub-micrometer sized aggregates. Separated from the gas flow by filtering, these aggregates build micrometer-sized agglomerates. All AEROSIL® fumed silica products are completely amorphous as shown by X-ray diffraction [1].

Besides its high chemical purity and amorphous structure, AEROSIL® fumed silica possesses unique morphology, which leads to numerous advantages in a variety of applications. High surface area without a significant amount of micropores results in: a high chemical reactivity for AEROSIL® fumed silica in the pozzolanic reaction, high rheological activity in wet mixtures, and high efficiency as an anti-caking agent in dry mixtures. All these properties are beneficial for use in concrete, mortar, and plaster.

The AEROSIL® process is also used in the manufacture of AEROXIDE® fumed titanium dioxide, leading again to an aggregated fractal-like particle structure. Unlike AEROSIL® however, AEROXIDE® titanium dioxide is a crystalline material (containing a majority anatase phase and the balance rutile).

Evonik Industries also offers the high function of AEROSIL® and AEROXIDE® powders in convenient dispersed form under the trade name: AERODISP®.

In contrast to AEROSIL® fumed silica, SIPERNAT® specialty silica grades are manufactured in a liquid-phase precipitation process [2]. Here a solution of sodium silicate (also called “water glass”) is neutralized by sulfuric acid and as a result of the following chemical reaction, small particles of silicon dioxide are formed:

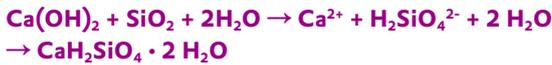


After washing, filtering, and drying steps, one obtains micrometer-sized aggregates of sponge-like structure, which are composed of tiny primary particles. Like AEROSIL® fumed silica, SIPERNAT® specialty silica has amorphous structure and high surface area.

The main chemical and physical properties of AEROSIL® fumed silica, AEROXIDE® fumed titanium dioxide and SIPERNAT® specialty silica grades that are commonly used in construction materials are listed in **Table 1**.

AEROSIL® and SIPERNAT® in concrete

The addition of even a small amount of AEROSIL® or SIPERNAT® products increases early strength of concrete. This effect can be explained by the high pozzolanic reactivity of these finely dispersed silicas. The pozzolanic reaction takes place in concrete between calcium hydroxide and silica or silicic acid in presence of water. This reaction leads to formation of calcium silicate hydrate:



The main reaction product – calcium silicate hydrate $\text{CaH}_2\text{SiO}_4 \cdot 2\text{H}_2\text{O}$ is usually abbreviated as C-S-H – has phases with a fibrous structure that mechanically bind together concrete components. Therefore, formation and concentration of C-S-H phases are decisive parameters for concrete strength. Since AEROSIL® or SIPERNAT® products offer much more surface than commonly used SiO_2 source such as sand, even small amounts of these materials can accelerate pozzolanic reaction significantly.

AEROSIL® fumed silica and SIPERNAT® specialty silica are not comparable with widely used silica fume, also known as microsilica. Silica fume consists of spherical non-aggregated particles with much lower specific surface areas of just several square meters per gram. Typically silica fume is added in high concentrations to cement to increase density and strength of cured concrete. In contrast to silica fume, AEROSIL® fumed silica has specific surface area of hundred square meters per gram and more. Due to the difference of specific surface area, pozzolanic reactivity of AEROSIL® fumed silica is much higher than of silica fume. This higher reactivity leads to higher early strength, but has no significant effect on the strength and density of cured concrete.

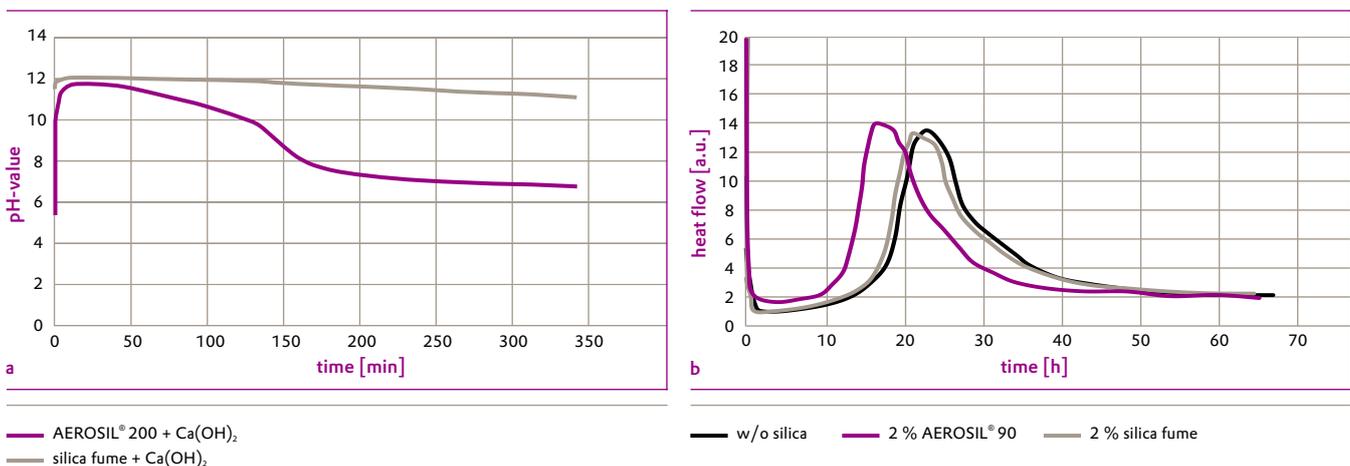
Figure 1a and b demonstrate the effect of increased pozzolanic reactivity of AEROSIL® fumed silica for two different AEROSIL® products – AEROSIL® 200 and AEROSIL® 90

(specific surface area of $200\text{ m}^2/\text{g}$ and $90\text{ m}^2/\text{g}$, respectively). In these diagrams, the reactivity of AEROSIL® 200 and AEROSIL® 90 has been compared with the reactivity of silica fume. The pH-value in a mixture containing AEROSIL® 200 and calcium hydroxide changes much more rapidly than in mixture, containing the same amount of silica fume. The decay of pH-value is characteristic for reduction of concentration of calcium hydroxide, and is proportional to the building of C-S-H phases. The development of heat flow of different mortar mixtures is compared in Figure 1b. It is obviously, that addition of 2% of AEROSIL® 90 accelerates heat release much more than addition of 2% of silica fume.

The acceleration of C-S-H phase formation leads to the increase of early strength, as can be demonstrated in Figure 2a. The compressive strength of a CEM I 52.5 R based mortar is analyzed in dependency on time. As demonstrated in this figure, addition of 0.7% of AEROSIL® 200 (of cement content) increases the compressive strength of concrete by approximately 5 MPa throughout the entire time interval studied. This effect can for instance be used for the acceleration of construction process in pre-cast plants.

Influence of AEROSIL® fumed silica on mechanical properties of concrete depends on concrete composition and, of course, on AEROSIL® fumed silica content, as demonstrated in Figure 2b on example of self-compacting concrete that was prepared with a cement compound, which included very fine cement. Both, compressive and flexural strength of self-compacting concrete increase by adding AEROSIL® 200 into the formulation, this increase has, however, a non-linear character. A continuous increase of compressive and flexural strength is observed for concentration up to 2%–2.5% of AEROSIL® 200 (of cement content), further addition of AEROSIL® 200 leads to decrease of compressive and flexural strength. This non-linearity must be taken into account during formulation of concrete mixtures.

Figure 1 High pozzolanic activity of AEROSIL® fumed silica. Development of pH-value in SiO_2 - Ca(OH)_2 mixtures with and without AEROSIL® fumed silica (a). Heat flow in mortar mixture in dependency on SiO_2 – with and without AEROSIL® fumed silica (b)

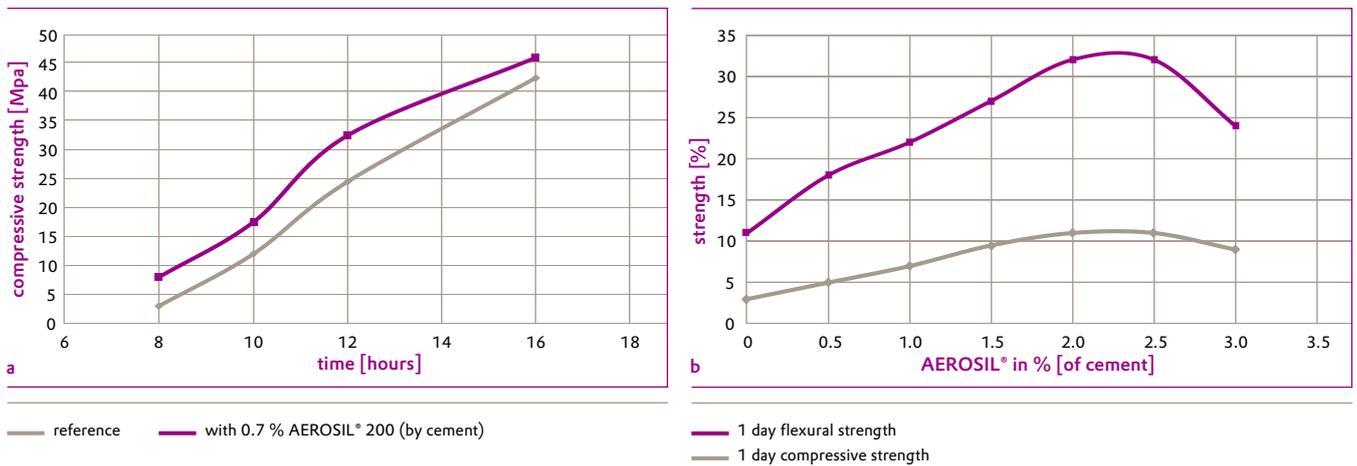


Reactivity and morphology of AEROSIL® fumed silica and SIPERNAT® specialty silica are beneficial for consistency of ultra-high performance concrete (UHPC). As demonstrated in [3], a consistent compressive strength of 150 MPa could be achieved after 28 days. UHPC is a high-density concrete, which has outstanding mechanical properties.

Gas (porous) concrete is just the opposite kind of concrete with respect to its density. The volume of artificial pores inside this kind of concrete is extremely high which leads to light weight and outstanding heat insulating properties. The insulating properties can further be improved by increasing porosity and adding AEROSIL® fumed silica to compensate for the loss of mechanical strength. Usually, 2%–3% of AEROSIL® 200 is sufficient to increase the compressive strength of cured gas concrete by factor of 2.

Although **Figure 1** and **2** show results for different grades of AEROSIL® fumed silica, similar tendencies can be noticed for SIPERNAT® products like SIPERNAT® 22 S, SIPERNAT® 320 DS. The increased chemical reactivity does not just depend only on accessible reaction surface, but also on homogeneity of silica distribution in the mixture. Due to smaller aggregate size AEROSIL® products can be distributed in principle more homogeneously in the concrete mixture and consequently lead to higher early strength than SIPERNAT® specialty silica. However, AEROSIL® products require mixing equipment with higher shear energy what may make SIPERNAT® specialty silica the preferred choice if only low shear equipment is available.

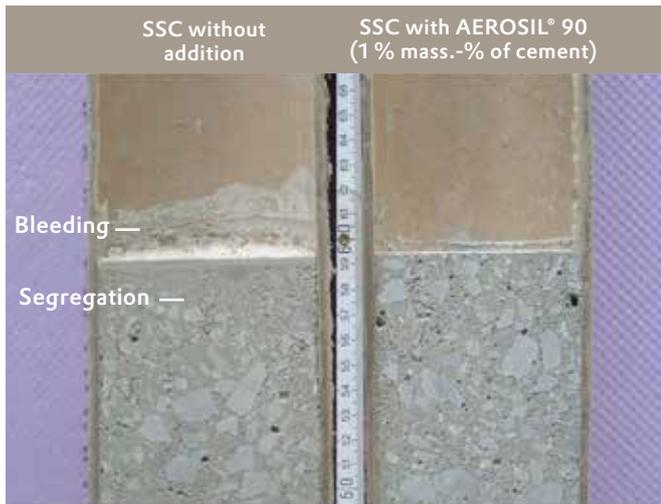
Figure 2 Influence of AEROSIL® fumed silica on concrete strength. Development of the compressive strength of CEM I 52.5 R based mortar with the time (a). Influence of AEROSIL® fumed silica content on strength of self-compacting concrete (b)



AEROSIL® and SIPERNAT® in plaster and mortar

Addition of AEROSIL® fumed silica in concrete influences rheology of wet concrete strongly. It has a positive effect on homogeneity of component distribution within highly flowable concrete, such as self-compacting concrete (SCC). AEROSIL® fumed silica stabilizes SCC against sedimentation of coarse components during initial curing stages, it can reduce negative effects like “bleeding” (see Figure 3), etc.

Figure 3 Influence of AEROSIL® on concrete homogeneity



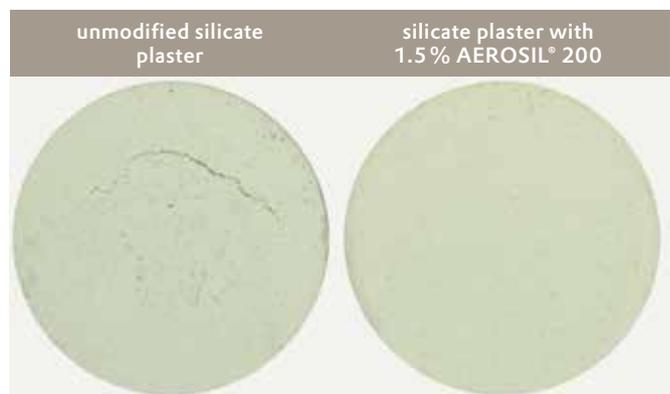
However, one should take into account, that use of AEROSIL® fumed silica grades with high specific area (AEROSIL® 200, AEROSIL® 300) increases the viscosity of wet concrete. If viscosity increase has to be limited, AEROSIL® grades with surface area about 100 m²/g, for example, AEROSIL® 90 should be used.

Mortars and plasters are widely used in construction industry to protect constructions from environmental influence; they are used to “seal” construction joints, for repair of cracks, and for decorative reasons. Among their various technical requirements, durability and layer integrity are the most important. Formulators face the challenge of providing products that are optically attractive, mechanically & chemically stable while also retaining a precise degree of vapor permeability.

Plasters are multi-component system, which include binder, pigment, filler, and functional additives. Curing of such a multi-component systems is often accompanied by migration of filler and pigment particles through the volume of plaster; it is accompanied by volume change, by shrinkage, by transport of water and gases through the pores, etc. All these processes result in gradients of forces, which can cause mechanical deformation, in homogeneities and cracks. If concentration of these defects is large enough, it can lead to failures of plaster after short time, it can necessitate repair and cause unexpected expenses.

Due to aggregate structure and size, AEROSIL® fumed silica can act as stabilizing and reinforcing agent during plaster curing, it can help to achieve a homogeneous pore structure, which is much more stable with respect to shrinkage during plaster curing. Figure 4 demonstrates this kind of influence of AEROSIL® fumed silica on silicate plaster.

Figure 4 Influence of AEROSIL® on plaster structure



The formulation without AEROSIL® 200 has comparably rough surface with macroscopic cracks. Being exposed to atmospheric humidity, to rain and snow, these cracks will definitely be centers for penetration into volume of cured plaster, they will increase with time and become the reason for material failure and increased dirt pick-up. The same plaster formulation enriched with only 1.5% of AEROSIL® 200 shows completely different surface structure. It is smoother, no macroscopic cracks can be observed.

Study of these plasters by means of transmission electron microscopy (TEM) shows, that AEROSIL® fumed silica improves distribution of filler (CaCO_3) and pigment (TiO_2) particles.

In the reference plaster without fumed silica addition, large agglomerates of filler and pigments can be observed (Figure 5a). In contrary to this, in the plaster with AEROSIL® 200 additions (Figure 5b), filler particles are finely dispersed, even though pigment and filler are the same in both formulations.

Moreover, influence on pore structure by addition of AEROSIL® fumed silica has positive influence on mechanical properties of lime mortar, as can be seen in Figure 6b. Here is shown, that addition of 1.5 % of AEROSIL® 90 to lime mortar improves the compressive strength up to 50%. The same time, the water absorption coefficient reduces by approximately 50% (Figure 6a). Both, reduction of water absorption and increase of compressive strength are definitely beneficial for long-leivty of applied lime mortar.

Figure 5 Influence of AEROSIL® on plaster structure (5a: no addition, 5b: 1.5 % of AEROSIL® 200). Large area C in right micrograph is carbon film from TEM grid

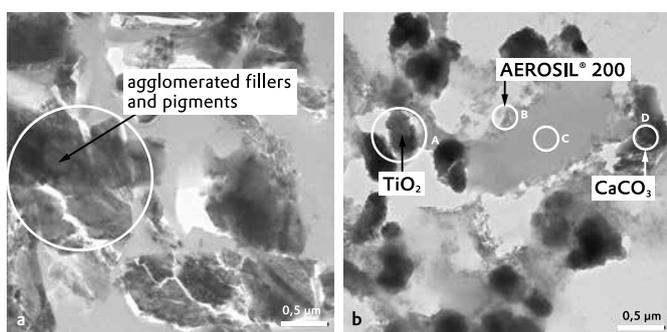
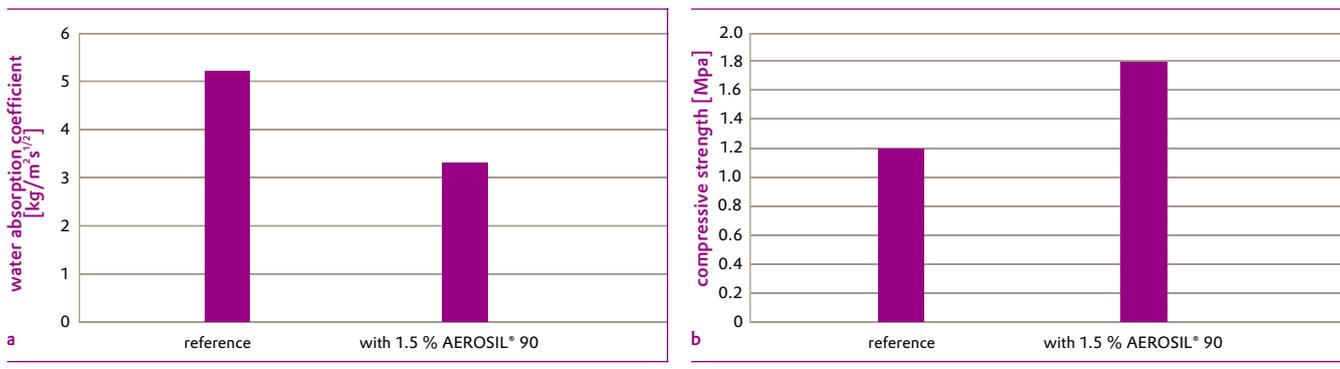


Figure 6 Influence of AEROSIL® on lime mortar properties. Water absorption coefficient (a); compressive strength (b)



AEROSIL® fumed silica and SIPERNAT® specialty silica for construction chemicals

Introduction

The use of construction chemicals and admixtures is an important milestone in the advancement of specialty mortars and concrete technology. Developed to expand the potential use of mortars and concrete, these additives can improve their mechanical and chemical properties, resulting in a better quality and longer durability of the construction under different and challenging conditions.

AEROSIL® fumed silica and SIPERNAT® specialty silica can substantially enhance the performance of your construction additives and/or admixtures, being able to become a key component thereof. Furthermore, the use of AEROSIL® and SIPERNAT® in your formulations could eventually improve as well the performance and properties of the final application, supporting and contributing to advantageous additional effects.

Potential benefits by using AEROSIL® or SIPERNAT®

Benefits of using the right choice of AEROSIL® fumed silica or SIPERNAT® specialty silica in your construction additives and/or admixtures formulations comprise:

- Improved processability e.g. during spray drying of emulsions/dispersions exhibiting thermoplastic behavior or during sieving of high cohesive powder mixtures
- Improved flowability of powder formulations, ensuring free-flowing behavior
- Anti-caking effect, preventing caking of powder formulations in the long term, during transportation, storage or further processing
- Carrier of liquid additives/formulations for exact and controlled dosing, improved mixing efficiency and consistent quality in dry mix formulations
- Booster for defoamer formulations, increasing drastically the defoamer activity
- Improved dispersibility of powder formulations in slurries and dispersions, ensuring an uniform particle distribution through the entire matrix
- Stabilization of dispersions by modification of the viscoelastic properties
- Stabilization of emulsions by Pickering effect
- Rheology modification e.g. thixotropic effect or increased viscosity
- Hydrophobization by surface modified AEROSIL® or SIPERNAT® grades

Additional beneficial effects that could be achieved in the final application when including the right choice of AEROSIL® or SIPERNAT® in your construction additives and/or admixtures formulations could be:

- Faster development of early strength in cementitious systems due to highly pozzolanic reactivity of AEROSIL® and SIPERNAT®
- Improved chemical resistance of concrete in acidic environment by reducing the calcium hydroxide content of the cement paste
- Reduced bleeding and phase segregation in cementitious systems by influencing the rheological behavior as well as by reduction of bleed water channels through pore-blocking
- Improved air void stabilization in air entrained mortar/concrete by modification of the rheological behavior
- Improved water resistance by incorporating hydrophobicity into the system
- Reduced amount of pores by filling the voids and micro-cracks with AEROSIL® or SIPERNAT®, reducing permeability and improving chemical resistance
- Thixotropic effect

Typical AEROSIL® and SIPERNAT® grades recommended for different effects and applications are shown later in **Table 2**.

Working principle of AEROSIL® and SIPERNAT®

Adhesive and cohesive forces between particles which create sticking and caking can be effectively reduced by increasing the surface roughness of the host powder particles. SIPERNAT® specialty silica or AEROSIL® fumed silica will create a protective layer on the surface of the solid particles which will substantially reduce the interparticular forces and avoid the agglomeration of those particles. This reduction of the interparticular forces promotes an effective and uniform distribution of the host particles in an emulsion, dispersion or slurry. This principle is in a similar way responsible for the beneficial properties of AEROSIL® and SIPERNAT® to guarantee free flowing behavior of powders and preventing them from caking in the long term.

Furthermore, AEROSIL® and SIPERNAT® are also acting as stabilization agents by modifying the viscoelastic properties of the slurry or dispersion. The silanol groups present on the surface of AEROSIL® and SIPERNAT® are able to interact not only among themselves but also with e.g. surfactants and/or emulsifiers, creating a stable network which will avoid the segregation of the particles within time. For stabilizing purposes hydrophilic grades are in general performing better than hydrophobic ones. This is due to the fact that to some extent the silanol groups on the surface of hydrophobic grades are saturated with hydrophobization agents, not being available to participate in the creation of the network.

Some SIPERNAT® specialty silica grades offer a very high specific surface and a highly porous structure which makes them very suitable as carrier for liquid formulations. In such case a liquid formulation is transformed into a free-flowing powder. This results in many advantages as e.g. exact and controlled dosing of additives, easy handling of high viscous formulations, improved mixing efficiency and consistent quality in dry mix formulations. The particle size of the final product and the amount of carried liquid will be determined by the SIPERNAT® specialty silica grade selected. A wide range of SIPERNAT® grades with different physical properties is available to meet specific requirements.

Hydrophobicity can be incorporated into your formulation by using hydrophobic grades of AEROSIL® and SIPERNAT®. By surface modification of AEROSIL® and SIPERNAT® with specific reactants different grades of hydrophobicity for different requirements can be achieved.

Examples of Applications: –AEROSIL® and SIPERNAT® in Re-dispersible Polymer Powders

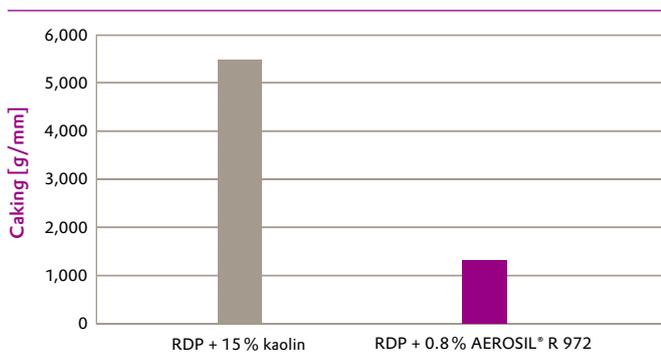
RDPs (redispersible polymer powders) are polymer additives in powdered form used in the construction industry for dry mix mortars applications. RDPs are obtained by spray drying a polymer dispersion which can be based on homopolymer, copolymer or terpolymer combinations, depending on the monomers used during the polymerization. Besides the polymer structure RDPs contain as well water soluble components in order to stabilize the dispersion and protect the polymer during spray drying (mostly polyvinylalcohol) and anti-caking agent in order to ensure the free-flowing behavior of the dried product and prevent its caking in the long term during transportation and/or storage.

All RDPs in the market contain anti-caking agents. In case of mineral anti-caking agents like e.g. kaolin large amounts e.g. 15%–20% are needed to achieve the desired anti-caking effect. Furthermore, often even adding higher amounts of kaolin will not improve significantly the anti-caking behavior. If a better anti-caking behavior or a considerably lower content of anti-caking agent is required, kaolin needs to be replaced partially or completely by AEROSIL® fumed silica or SIPERNAT® specialty silica.

As it is shown in Figure 7, drastically lower concentration of AEROSIL® R 972 (less than 1% based on polymer content) is required to reduce five times the caking behavior of the RDP, compared to adding 15% of kaolin. The addition of kaolin can be completely avoided. This allows the formulation of high performance RDPs in which the polymer is not diluted with high amounts of mineral filler, providing outstanding properties for special performance requirements.

A common problem in spray drying of sticky materials is that product could attach to the walls of the dryer and other equipment and therefore requiring frequent cleaning. AEROSIL® fumed silica and SIPERNAT® specialty silica have the potential to significantly improve the processability when added to the spray drying process. Generally speaking, for better processability as well as for better anti-caking performance of the dried product in the long term, AEROSIL® or SIPERNAT® need to be fed into the process at the top of the tower, close to the atomizer. In the upper part of the tower, silica is getting in contact with dispersion droplets or still wet polymer agglomerates, which increases the probability that silica will stick to the droplet or wet agglomerate significantly. In case of collision in the dry zone, the interparticular forces will remain low and it is likely that a portion of the silica will separate again, not

Figure 7 Effect of AEROSIL® R 972 on the caking behavior of vinyl acetate VeoVa acrylic terpolymer RDP



contributing so effectively to the protective layer. Clear advantages of adding silica directly into the tower are the improvement of the processability by keeping the tower and piping clean, free of powder depositions as well as the advantage of no additional mixing step required. As an example, **Figure 8** shows the beneficial effect of AEROSIL® R 972 on the processability of RDP. A clear improvement of the spray drying process is achieved; the tower remains clean from polymer adhesions at the walls which allows longer and trouble free production runs.

Evonik is offering a wide range of AEROSIL® and SIPERNAT® grades with very different properties regarding e.g. particle size, specific surface area, absorption capacity, hydrophobicity or other surface modifications. Our technical support will help you in selecting the right choice of silica for your specific application and requirements. The amount of SIPERNAT® specialty silica or AEROSIL® fumed silica to be used will depend on the silica grade selected, the nature of the polymer to be spray dried, the process configuration and the expected performance. As a guide a typical concentration range is 0.5%–5%.

– AEROSIL® and SIPERNAT® in Admixtures

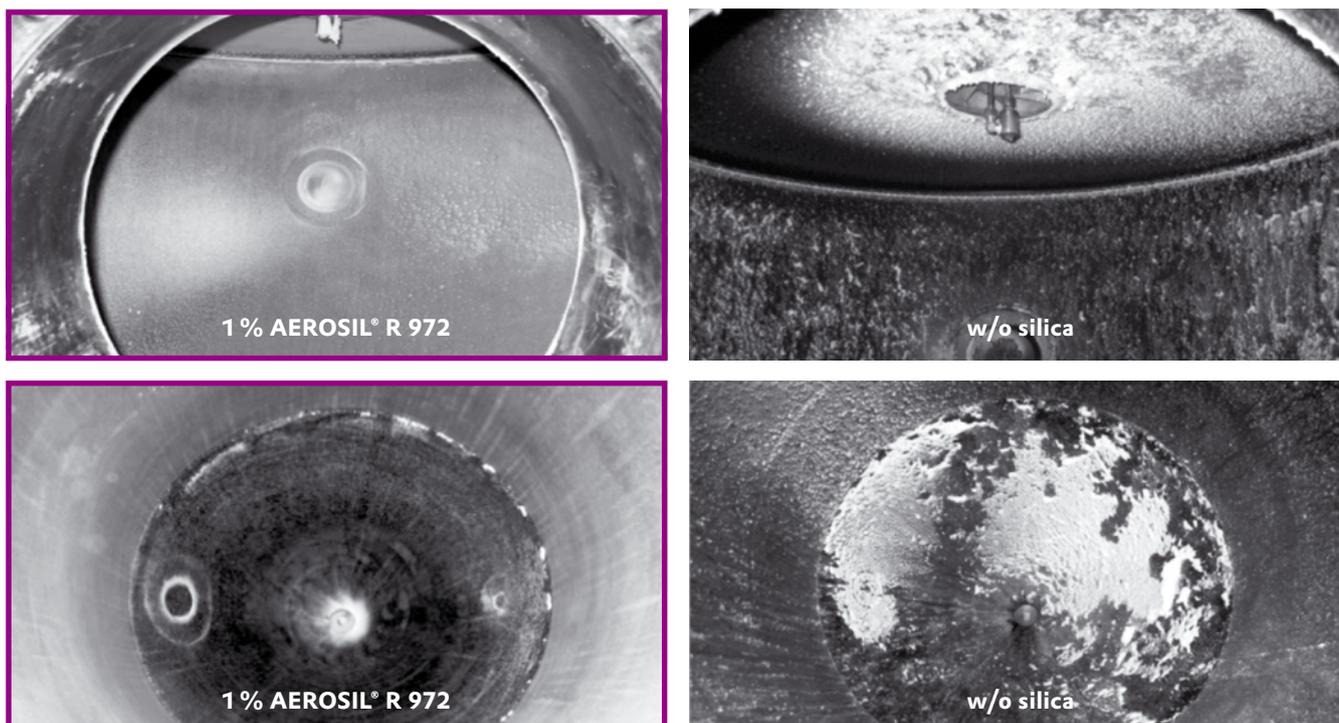
The main role of an air entraining admixture is to incorporate millions of non-coalescing air bubbles evenly distributed in the entire mass of concrete. AEROSIL® fumed silica and SIPERNAT® specialty silica can help your admixture to distribute more efficiently and homogeneously contributing to achieve its required

performance. Furthermore, AEROSIL® and SIPERNAT® can also provide air void stabilization by modifying the viscoelastic behavior. The mechanism behind is an interaction between AEROSIL® or SIPERNAT® molecules between themselves as well as with the surfactants molecules. This creates a network which avoids the segregation of the air bubbles and stabilizes their position within the matrix.

Usually plasticizers and superplasticizers retard the setting of concrete. By combining or including the right choice of AEROSIL® or SIPERNAT® in your plasticizer or superplasticizer it would be possible to accelerate the strength development of concrete at the same time that increasing its workability. AEROSIL® and SIPERNAT® are highly active pozzolans improving the chemical reaction of hydration and accelerating the rate of early strength development. Moreover, AEROSIL® and SIPERNAT® can also improve the homogeneity of component distribution reducing segregation and bleeding. It has to be mentioned that normally, plasticizers and superplasticizers are found to be compatible with accelerators and highly active pozzolans. However, this has to be checked with manufacturers.

In case your formulation is supplied to the end-user in powder form produced by spray drying technology, AEROSIL® and SIPERNAT® can improve both the processability as well as the anti-caking performance of the powder during transportation and/or storage when added directly into the spray drying process as it is shown for RDPs.

Figure 8 Example of improvement of the processability during spray drying of vinyl acetate VeoVa acrylic terpolymer dispersion with 1 wt% of AEROSIL® R 972 (left) and without silica (right)



Use of AEROXIDE® titanium dioxide for photo catalytic applications in the construction industry

With the continuous growth of urban population centers throughout the world, a significant burden on air quality has been widely recognized. It has also been widely recognized that with this environmental pressure the critical technical challenge for the coming decades will be to develop technologies that reduce air-borne pollutants such as nitrogen oxides (NO_x) that are at the heart of smog generation in many of today's cities. One highly attractive technical approach harnesses the energy of the sun to affect the break down of NO_x and is reliant on photo catalytic materials such as AEROXIDE® titanium dioxide. By using photo catalytically active titanium dioxide AEROXIDE® TiO₂ in construction materials, such as concrete, paving stones, and facade coatings a multi-functional surface can be created that mediates the conversion of pollutants to less harmful compounds.

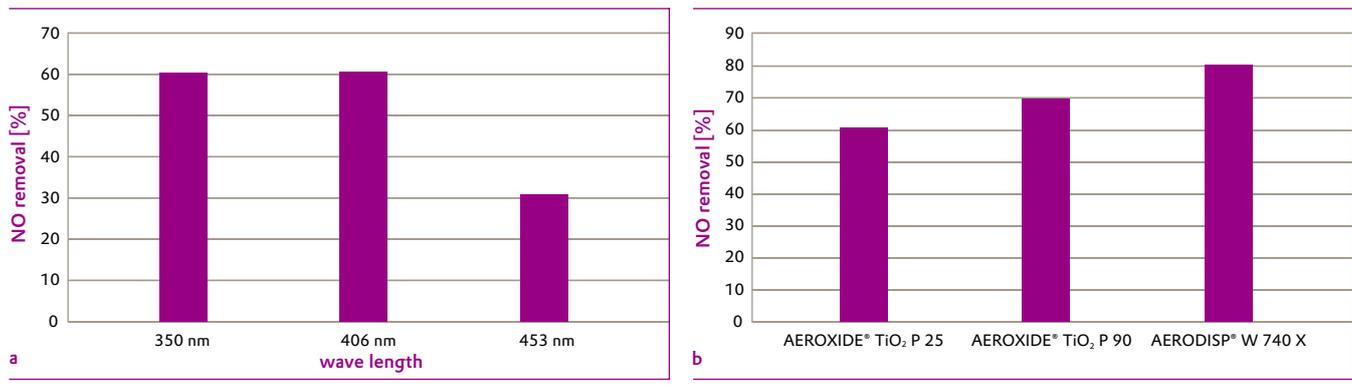
Evonik offers two outstanding titanium dioxide products – AEROXIDE® TiO₂ P 25 and AEROXIDE® TiO₂ P 90 and their water-based dispersions AERODISP® W 740 X and VP Disp. W 2730 X exactly for these applications [6]. Due to high surface area and, consequently, small primary particle size, AEROXIDE® TiO₂ P 25 and AEROXIDE® TiO₂ P 90 have high photo catalytic activity, high chemical reactivity, and nearly no pigment properties – a combination of characteristics that distinguish these titanium dioxides from all others on the market.

To demonstrate the photo catalysis of these materials, three LEDs with different wavelengths and narrow line widths were used to irradiate the surface of AEROXIDE® TiO₂ P 25 under a gas flow with constant NO concentration. As can be seen in **Figure 9a**, the concentration of nitrogen monoxide reduces significantly at all irradiation wave length studied.

The comparison of NO-removal efficiency of AEROXIDE® TiO₂ P 25 and AEROXIDE® TiO₂ P 90 is presented in **Figure 9b**. This comparison, carried out at a visible wavelength of 406 nm, shows the increased activity of AEROXIDE® TiO₂ P 90 versus that for AEROXIDE® TiO₂ P 25. It is likely that the greater activity is due to the higher specific and, consequently, reaction area of AEROXIDE® TiO₂ P 90. Lastly, the substrate treated with AERODISP® W 740 X shows a significantly higher efficiency of NO-removal than AEROXIDE® TiO₂ P 25 and even AEROXIDE® TiO₂ P 90, again most likely due to the ideal particle size, and thereby reactive surface, available from the pre-made dispersion.

These results represent a basis for photo catalytic application of titanium dioxide in construction – as surface treatments for pavement stones, concrete walls, or roofing tiles. When developing such a pollution combating surface, the thickness of the AEROXIDE® TiO₂ layer should be just sufficient to withstand the mechanical influences, erosion, several millimetres will be definitely enough. Generally, a few percent of titanium dioxide in the coating layer is sufficient to achieve significant removal of nitrogen oxides. Particular note should be drawn to AERODISP® W 740 X as it can be easily incorporated into wet concrete mixture without the need for any special dispersing equipment. This is not the case with the powders, AEROXIDE® TiO₂ P 25 or AEROXIDE® TiO₂ P 90, where high-shear mixing and proper dispersion is required in order to achieve maximum performance.

Figure 9 Efficiency of photo catalytic removal of NO by AEROXIDE® TiO₂ products.
 (a) NO removal by AEROXIDE® TiO₂ P 25 at different wave lengths. (b) NO removal by different AEROXIDE® TiO₂ products at 406 nm



Conclusions

This brochure gives a brief overview on effects in construction materials, which can be achieved by use of AEROSIL® fumed silica, SIPERNAT® specialty silica, and AEROXIDE® fumed titanium dioxide. Unique morphology (particle size, phase composition) makes these products to versatile functional additives, which can be used to improve mechanical properties of concrete, plaster and mortar, their handling properties,

their long-leevity. A range of special environmentally relevant effects can be achieved by use of photo catalytically active AEROXIDE® TiO₂ fumed titanium dioxide. Recommendations on use of silica or titanium dioxide in construction materials according to the desired effect are summarised in Table 2.

Table 1 Properties of selected grades of AEROSIL® fumed silica, AEROXIDE® fumed titanium dioxide and SIPERNAT® specialty silica that are commonly used in construction materials

Product name	interaction with water	BET [m ² /g]	Loss on drying [%]	pH-value
AEROSIL® 90	hydrophilic	90	<1.0	3.7–4.7 ¹
AEROSIL® 200	hydrophilic	200	<1.5	3.7–4.7 ¹
AEROSIL® R 972	hydrophobic	110	<0.5	3.6–5.5 ¹
AEROSIL® R 816	hydrophobic	190	<1.0	4.0–5.5 ¹
AEROSIL® R 812	hydrophobic	260	<0.5	2.0–3.0 ¹
AEROSIL® R 202	hydrophobic	100	<0.5	3.5–5.0 ¹
AEROXIDE® TiO ₂ P 25	hydrophilic	50	<1.5	3.5–4.5 ¹
AEROXIDE® TiO ₂ P 90	hydrophilic	90	<4.0	3.2–4.5 ¹
SIPERNAT® 22 S	hydrophilic	190	<6.0	6.5 ²
SIPERNAT® 320 DS	hydrophilic	175	<6.0	6.3 ²
SIPERNAT® 360	hydrophilic	50	<6.0	9.0 ²
SIPERNAT® 820 A	hydrophilic	95	<7.0	10.1 ^{2,3}
SIPERNAT® 2200	hydrophilic	185	<5.0	6.0 ²
SIPERNAT® D 17	hydrophobic	100	<4.0	8.0 ²
SIPERNAT® D 13	hydrophobic	85	<2.5	10.5 ²

¹ Based on 4% dispersion ² Based on 5% dispersion ³ Sodium aluminum silicate

Table 2 Recommendations on use AEROSIL®, SIPERNAT®, and AEROXIDE® products

Application	Recommended products
Concrete: improvement of early strength	AEROSIL® 200, AEROSIL® 90, AERODISP® W 7520 P SIPERNAT® 22 S, SIPERNAT® 320 DS
Concrete: consistency of UHPC	AEROSIL® 90, SIPERNAT® 320 DS
Concrete: improve of SCC homogeneity	AEROSIL® 200, AEROSIL® 90
Concrete: air cleaning	AEROXIDE® TiO ₂ P 25, AEROXIDE® TiO ₂ P 90, AERODISP® W 740 X
Concrete: self-cleaning /low dirt pick-up	AEROXIDE® TiO ₂ P 25, AERODISP® W 740 X
Dry cement-based mixture: anti-caking	AEROSIL® 200, AEROSIL® 90, AEROSIL® R 972, SIPERNAT® D 17, SIPERNAT® 22 S
Silicate plaster: reinforcement, low dirt pick-up	AEROSIL® 200, AERODISP® W 7520 P
Plaster: self-cleaning /low dirt pick-up	AEROSIL® 200, AERODISP® W 7520 P, AEROXIDE® TiO ₂ P 25, AERODISP® W 740 X
Lime mortar: reinforcement	AEROSIL® 200, SIPERNAT® 22 S, SIPERNAT® 350
Dry mortar: anti-caking	AEROSIL® 200, AEROSIL® R 972, SIPERNAT® D 17, SIPERNAT® 22 S
RDPs: spray drying/free-flow/anti-caking	AEROSIL® R 972, AEROSIL® 200, SIPERNAT® D 17, SIPERNAT® 22 S, SIPERNAT® 820 A
Admixtures: dispersant/stabilization/faster early strength	AEROSIL® 90, AEROSIL® 130, AEROSIL® 200, SIPERNAT® 22 S, SIPERNAT® 880
Liquid to powder: carrier	SIPERNAT® 22, SIPERNAT® 320, SIPERNAT® 360, SIPERNAT® 2200
Water resistance: Hydrophobization	AEROSIL® R 202, AEROSIL® R 812, AEROSIL® R 972, , AEROSIL® R 8200, SIPERNAT® D 17, SIPERNAT® D 13

Literature

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