

WACKER

CREATING TOMORROW'S SOLUTIONS

STRENGTH

WITH HDK®.

HDK®

PYROGENIC SILICA | ADHESIVES

HDK® – THE PYROGENIC SILICA WITH
PERSONALIZED SERVICE

EXPERIENCE COUNTS

WACKER has produced pyrogenic silica under the brand name HDK® for over 50 years. Our integrated production system, statistical process control, and highly efficient reactor dynamics combine to make an exceptionally pure pyrogenic silica that offers high performance. HDK® is made by hydrolysis of chlorosilane in an oxyhydrogen flame. The process yields highly branched aggregates, which are the basic building block of our pyrogenic silica. These form weakly bound agglomerates upon cooling. HDK® made in the flame reactor is hydrophilic. By post-treatment in a second reactor, we are able to offer hydrophobic HDK® grades, which are key to rheology control in polar systems.

How HDK® Works

HDK® has an exceptionally high surface-area-to-mass ratio. This enables many particle interactions in liquid formulations and helps build a three-dimensional physical network. This network is the basis for the rheology control HDK® provides. Obtaining optimal rheology for your adhesive depends on getting the specific surface area just right and selecting the correct hydrophilic or hydrophobic HDK® grade. Our broad portfolio provides the ideal solution for nearly any formula.

Properties of HDK®:

- Synthetic, inert inorganic additive
- Neutral in color
- Migration-resistant
- Thermally stable
- Non-hazardous

Benefits of HDK® in Adhesives:

- Highly effective rheology control
- Stable viscosity during storage
- Controlled anti-sag behavior
- Chemical inertness in various reactive systems
- Effective tuning of mechanical properties



What HDK® grades will yield the best results in your formulation? Just get in touch with us, and we will gladly advise you.

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OPTIMIZE PERFORMANCE

Superior Rheology Control in Adhesives

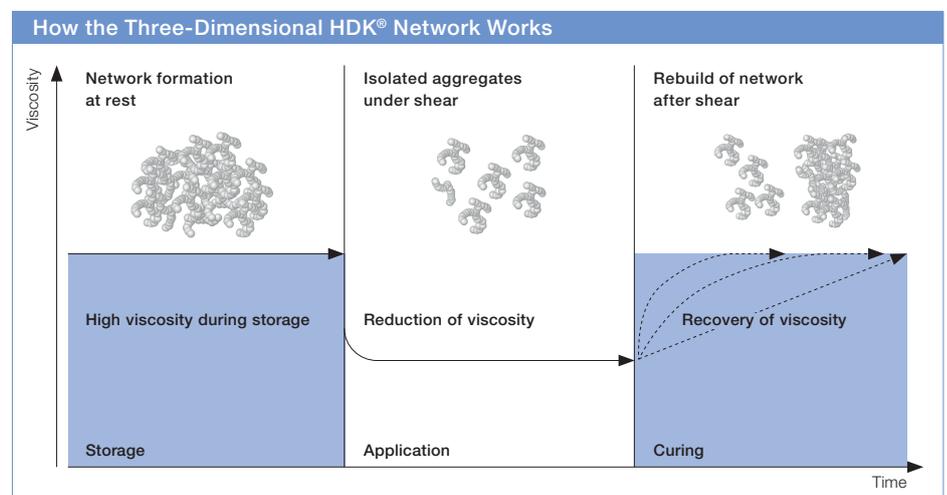
Adhesives require good rheology control during manufacture, storage, and processing. The rheological properties of adhesives can be adjusted using suitable HDK[®] grades. Adding HDK[®] to an adhesive formulation increases the viscosity of the liquid phase, influencing shear thinning and thixotropic flow behavior. In general, HDK[®] grades with a larger specific surface area yield more pronounced rheological effects, while grades with a smaller specific surface area are easier to disperse. Hydrophobic HDK[®] grades are typically used for polar adhesives formulations. The chemical inertness of hydrophobic HDK[®] in polar, reactive resins allows for excellent storage stability. Hydrophilic HDK[®], on the other hand, enables excellent rheology control of non-polar adhesives formulations and is often suitable for use even under high pH value conditions.

Suitable Viscosity during Processing, Storage, and Application

Once incorporated and dispersed in an adhesive formula, the interacting HDK[®] aggregate particles form a shear-sensitive three-dimensional network. During storage, the network formation increases the formulation's viscosity and prevents

components from settling. The viscosity at rest is influenced by the grade and amount of the added silica. When shear forces are applied during the processing of the adhesive, the branched network breaks up and the viscosity decreases (shear thinning). This allows for easy processing of the adhesive. After the

adhesive has been applied to a substrate, the HDK[®] network reforms (thixotropy). This leads to a fast recovery of viscosity, effectively avoids sagging, and ensures your adhesive will stay where you want it while curing.



A KEY COMPONENT: HDK® IN ADHESIVES

Rheology Control in Bonding Pastes

Wind turbine bonding pastes based on epoxy and vinyl ester resins are applied in thick beads onto rotor blade half shells. Adding HDK® to bonding paste formulas enables optimal rheology control in order to meet the demanding requirements for sag resistance. The pronounced thixotropy and shear-thinning effect provided by HDK® allows easy processing of the adhesives components even at high silica loading levels. Moreover, HDK® increases the viscosity of adhesives components during storage and prevents ingredients from settling.



Composition of Bonding Paste

Component 1

| | |
|---------------------------|--------------------------------------|
| Resin | Bisphenol A/F-based |
| Reactive diluent | Glycidylether-based |
| Filler | Mineral filler, others |
| Aspirator (if applicable) | Foam-breaking polymers/polysiloxanes |
| Toughener | e.g. GENIOPERL® P52 |
| Rheology additive | HDK® H18, HDK® H21, HDK® H17 |

Component 2

| | |
|-------------------|------------------------------------|
| Amine hardener | Polyaminoamide/IPDA/polyetheramine |
| Rheology additive | HDK® N20 |

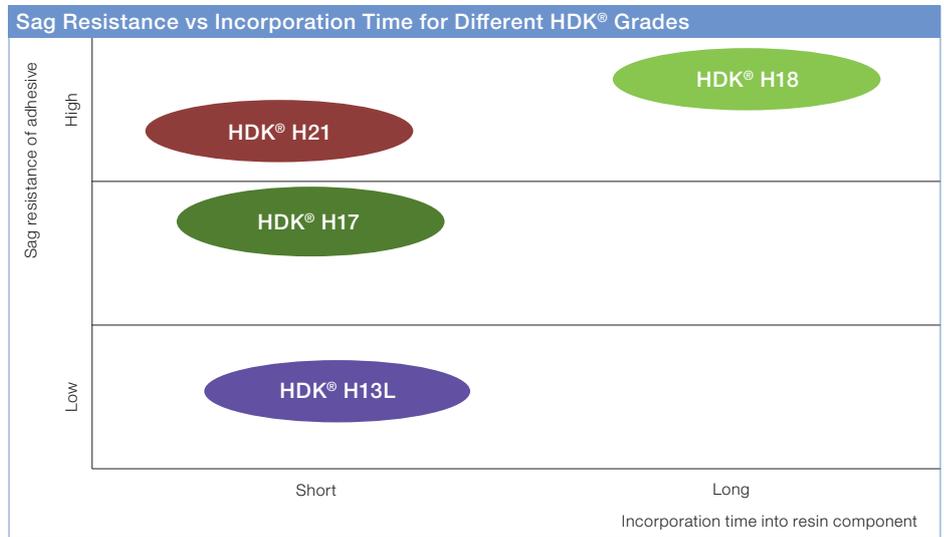
TIP

Add the highly hydrophobic grade HDK® H18 to epoxy adhesives for high rheological impact and excellent storage stability. Typically, the concentration level of HDK® in resin components should be 8–10% by weight. HDK® H21 and HDK® H17 are excellent alternatives and are even easier to incorporate.



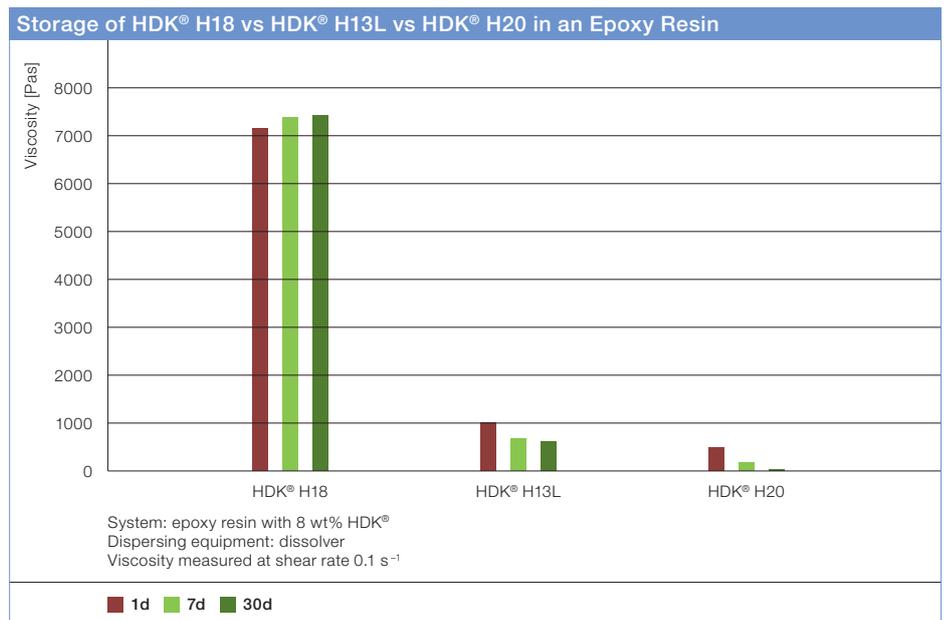
Properties of HDK® Grades in Epoxy-Based Systems

Depending on your individual requirements, WACKER offers various grades of HDK® that perform differently in epoxy-based systems. Due to its high degree of surface modification, HDK® H18 provides the highest storage stability and sag resistance to polar adhesives. HDK® H21 combines excellent anti-sag properties with short incorporation times into resin components. HDK® H17 displays well balanced features and is particularly easy to disperse.



Sag resistance properties and incorporation time of HDK® in epoxy-based formulations

Hydrophobic HDK® grades ensure low viscosity during application, high viscosity and sag resistance at rest, and anti-settling during storage.



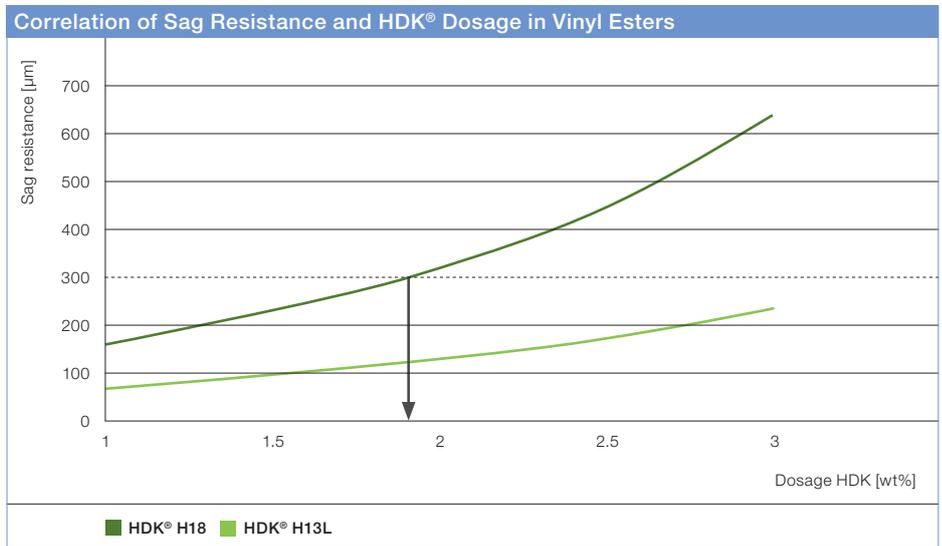
HDK® H18 has a very high degree of surface modification. Compared to less hydrophobic silica grades HDK® H18 combines excellent thickening performance and storage stability in epoxy-based formulas.

HDK® H18 for Maximal Sag Resistance

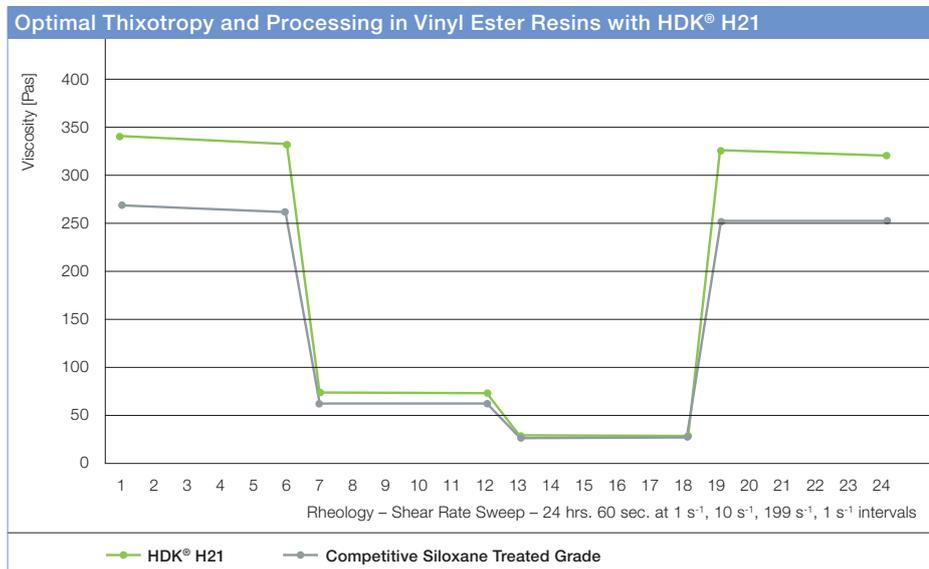
HDK® H18 achieves high viscosity in vinyl esters at low dosages. At the same time, the high hydrophobicity as well as the large particle surface area provide good thixotropy. These characteristics make HDK® H18 a superior choice over less hydrophobic products when high sag resistance is a deciding requirement.

HDK® H21 for Easy Dispersion

HDK® H21 is a silica for use in highly polar systems including vinyl ester resins. The polysiloxane treated product displays superior processing and performance properties and has been designed to provide easy dispersion and excellent rheology control.



HDK® H18 outperforms less hydrophobic silicas based on smaller particle surfaces with regard to the sag resistance of vinyl esters.



HDK® H21 exhibits superior rheological properties, a very high thixotropic effect, and is easy to incorporate.



HDK® Pyrogenic Silica for Chemical Anchors

Chemical anchor fasteners based on vinyl esters and two-component epoxy formulas are polar adhesives that secure mechanical anchors such as bolts, rods, and dowels in concrete and masonry construction, and help support heavy loads. As a rheology additive to chemical anchor formulations, HDK® prevents sagging in the uncured adhesive so it does not flow out of the drilled hole.

Optimal Rheology Control with HDK®
Highly hydrophobic and chemically inert grades, such as HDK® H18, HDK® H21, and HDK® H17, provide excellent thixotropy and effectively enable easy processing and maximal sag resistance. HDK® is very stable in polar systems, ensuring extended product shelf life.

Vinyl-Ester-Based Adhesive

| | |
|-----------------------|------------------------------|
| Resin | Vinyl ester |
| Rheology additive | HDK® H18, HDK® H21 |
| Filler | Quartz sand/cement |
| Adhesion promotor | Functional alkoxyalkylsilane |
| Peroxide curing agent | e.g. MEKP |

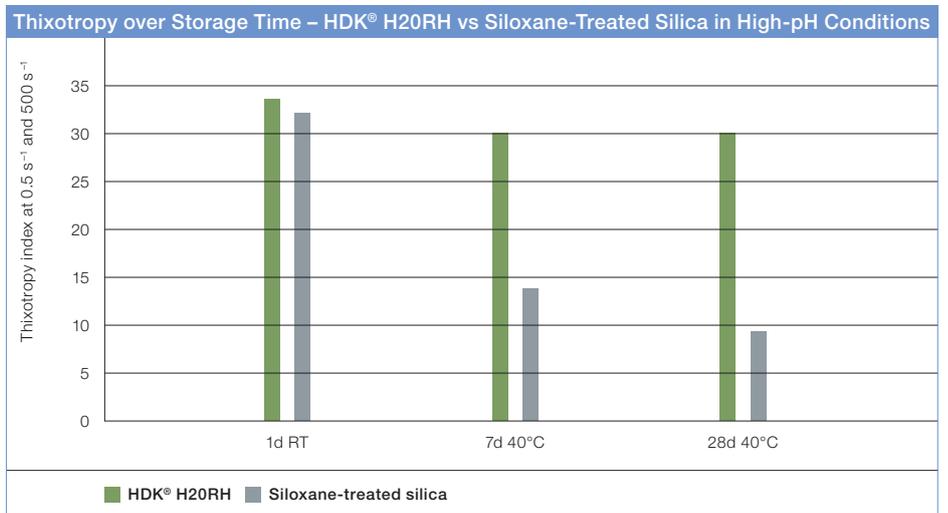


TIP

Use HDK® H21 if the dispersion of other polydimethylsiloxane-treated silica grades is challenging.

Stability in High-pH Conditions

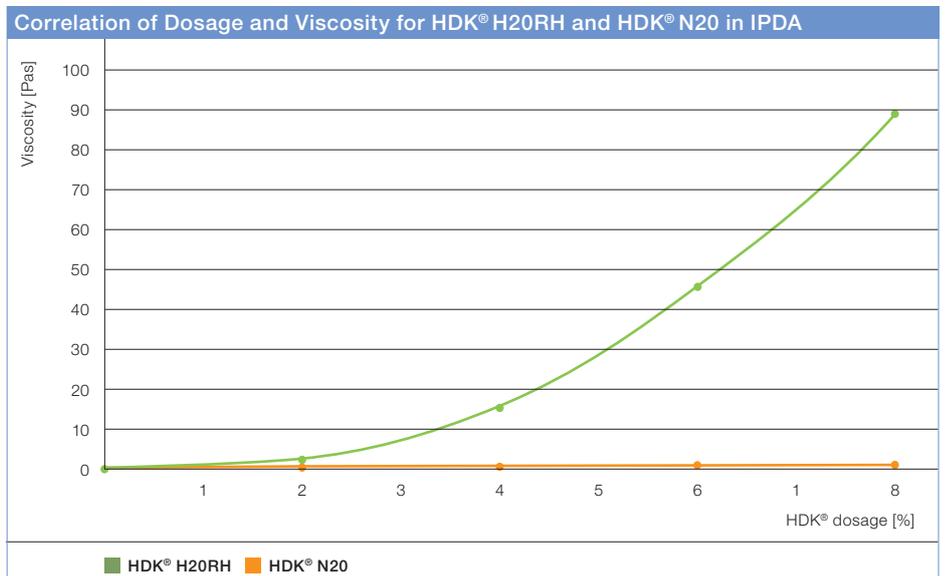
Hydrophilic silica such as HDK® N20 is used to develop a good rheological profile in amine components of epoxy adhesives, but it often requires high silica loadings. Depending on the formula's polarity, hydrophobic siloxane-treated silicas may give a better rheological impact but are not sufficiently stable in high-pH conditions. HDK® H20RH has an alkylsilane-modified particle surface which is stable in the amine component and leads to a pronounced thixotropy, even at lower silica loadings.



With HDK® H20RH, the thixotropic behavior of an amine mixture can be maintained during storage, whereas siloxane-treated grades are less suitable for high-pH value formulations.

TIP

Use HDK® H20RH in the amine component for better thixotropy at lower dosages as an alternative to a hydrophilic silica. In contrast to siloxane-treated silicas, HDK® H20RH is stable in high-pH conditions.



HDK® H20RH allows for reduced dosages in medium to high polar amines such as isophorone diamine.

Rheology Control in Structural Adhesives

Structural adhesives are used in the construction of transport vehicles, for weight reduction purposes, improved crash performance, and durability. Applications include the bonding of parts that are difficult to access, bonding materials that are non-weldable and/or heat-sensitive, and joining metallic with plastic surfaces. Epoxy adhesives are well known for their excellent mechanical properties, durability over a wide temperature range, and adhesion to many materials. Two-component polyurethane adhesives are excellent for joining composite materials. They combine strength and stiffness at high elongation values.

Adjusting the rheology of structural adhesive components with hydrophobic HDK® plays a decisive role in terms of processability, anti-sag properties, and storage stability.

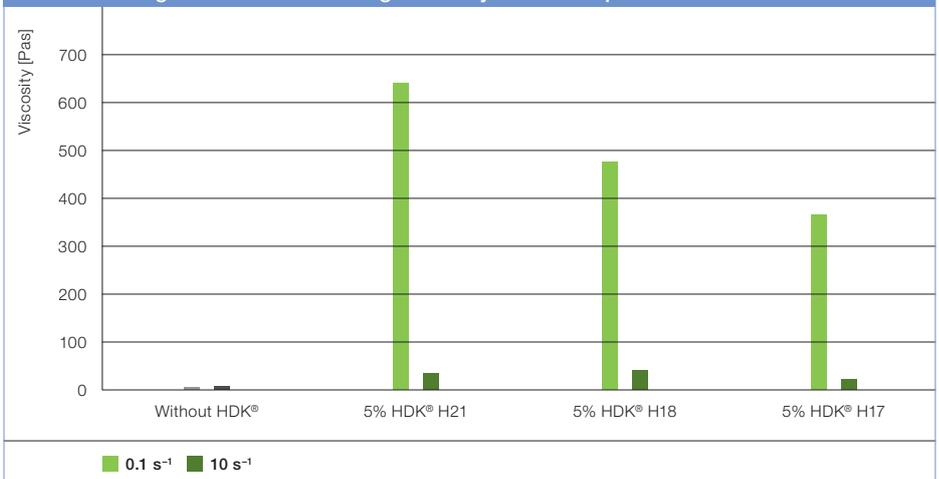


Hydrophobic HDK® grades such as HDK® H18 and HDK® H21 ensure highest sag resistance in epoxy-based adhesives where standard hydrophobic grades fail.

TIP

Efficient rheology control of isocyanates requires hydrophobic HDK®. Suitable grades are HDK® H21, HDK® H18, and HDK® H17. For most pronounced thixotropy and shortest incorporation time, HDK® H21 is recommended, while HDK® H18 achieves maximal storage stability.

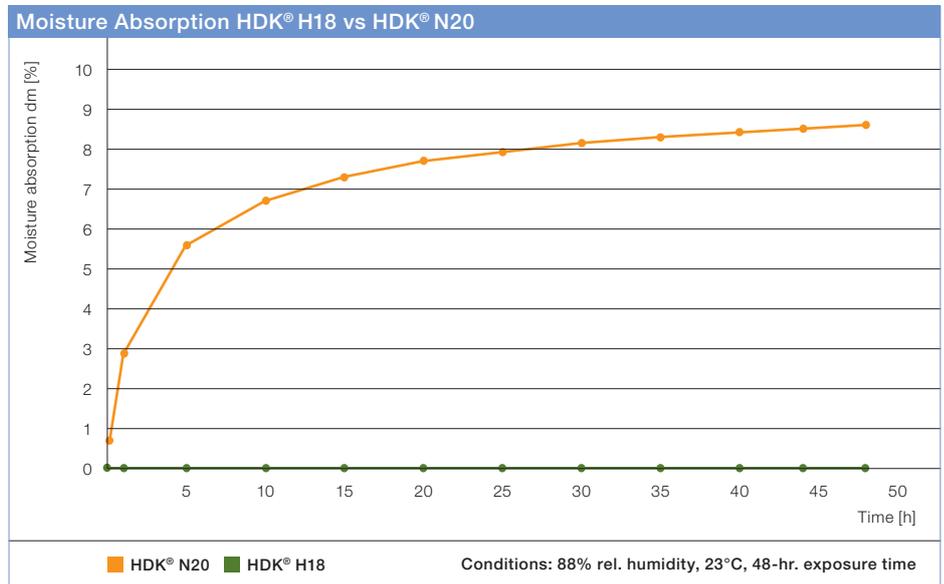
Shear Thinning with 5% HDK® Dosage in Isocyanate Component



HDK® H21 provides superior rheological properties in an aromatic isocyanate component at 5% dosage.

HDK® Pyrogenic Silica for Wood Adhesives

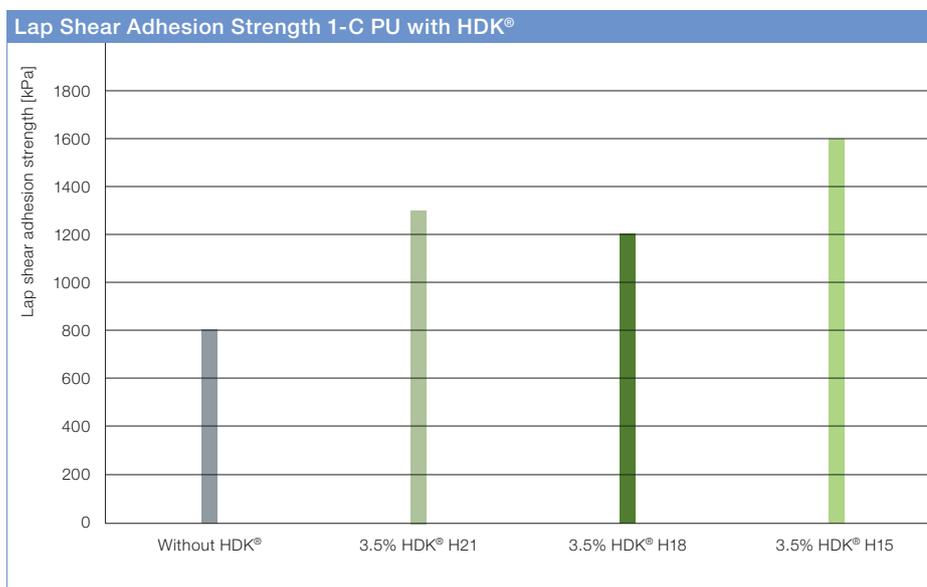
One-component polyurethane adhesives are widely used in applications requiring increased strength and flexibility. They provide high water and temperature resistance, and are particularly suitable for adhesion to wood, ceramics, stone, and metal. One-component moisture cure polyurethanes require the absence of moisture during storage. Highly hydrophobic HDK® grades do not absorb moisture and ensure good stability as well as a long shelf life of the adhesive. The highly hydrophobic grades HDK® H21, HDK® H18, and HDK® H17 achieve the strongest rheological effect in one-component polyurethane adhesives. Less hydrophobic grades, such as HDK® H15, improve lap shear strength.



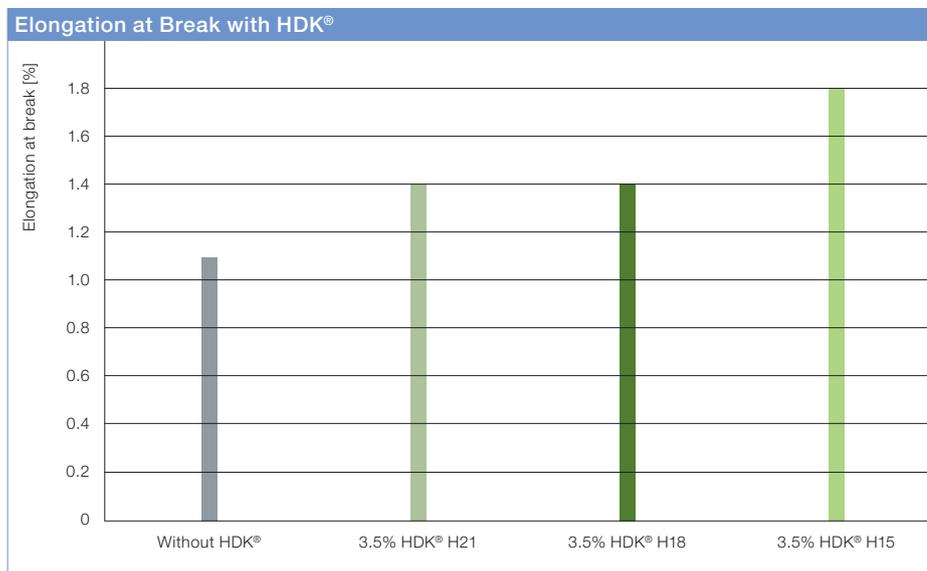
The highly hydrophobic grade HDK® H18 does not absorb significant amounts of moisture, even in high-humidity environments and during long exposure times.



Superior Strength and Flexibility



In one-component polyurethane adhesives, HDK® may increase lap shear strength (wood adhesion). Most pronounced effects are achieved with the semi-hydrophobic grade HDK® H15.



Adding HDK® to one-component polyurethane formulas increases the elongation at break.

TIP

Add hydrophobic grades such as HDK® H15 and HDK® H20 to one-component adhesive formulations to achieve the highest lap shear strength at high elongation values.

HDK® Pyrogenic Silica for Transparent Adhesives

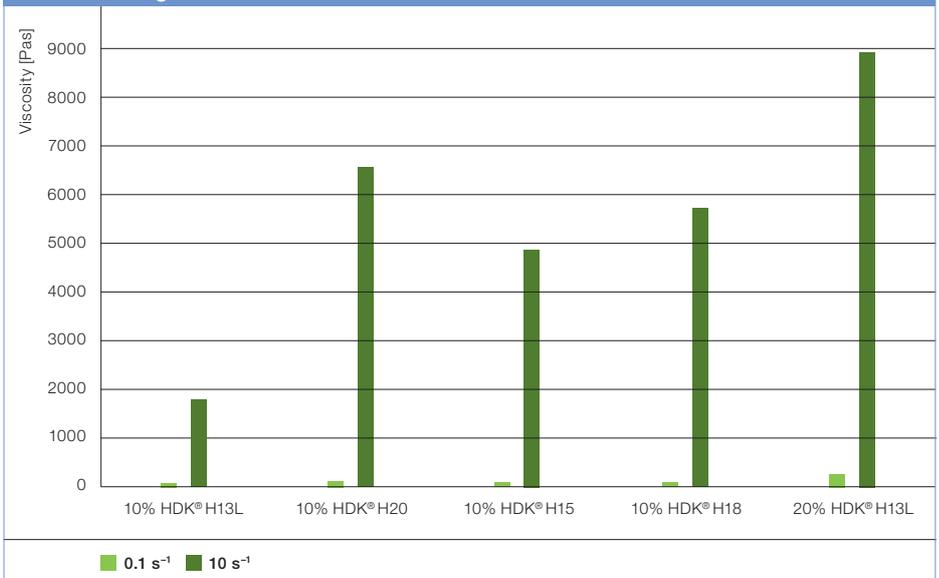
Transparency is a key feature of many silane terminated polyether-based adhesives and sealants. Besides optimizing rheological properties, HDK® also improves mechanical properties in the cured formulas. Since other bulking and reinforcing fillers are not used in these clear formulas, it is important to find the right HDK® dosage for an optimal balance between the desired rheological impact and mechanical properties.

Hydrophobic HDK® grades based on large surface areas such as HDK® H18 and HDK® H20 achieve strong thixotropy even at lower dosages. In contrast, the smaller particle surface area products HDK® H13L and HDK® H15 allow for highest loading levels, improving the physical properties of the cured formula.

STP-E30-Based Formula

| | |
|--------------------|-------------------|
| Polymer | GENIOSIL® STP-E30 |
| Rheology additive | Hydrophobic HDK® |
| Moisture scavenger | GENIOSIL® XL10 |
| Plasticizer | Hexamoll® DINCH |
| Adhesion promotor | GENIOSIL® GF96 |

Shear Thinning with HDK® in STP-E30



HDK® H20 and H18 cause the strongest rheological impact in a GENIOSIL® STP-E30-based formula at a loading level of 10%. Even higher loading levels could be easily achieved with less hydrophobic grades, particularly HDK® H13L.

TIP

Use HDK® H13L to realize high silica loading levels and excellent mechanical properties of your cured transparent formula.



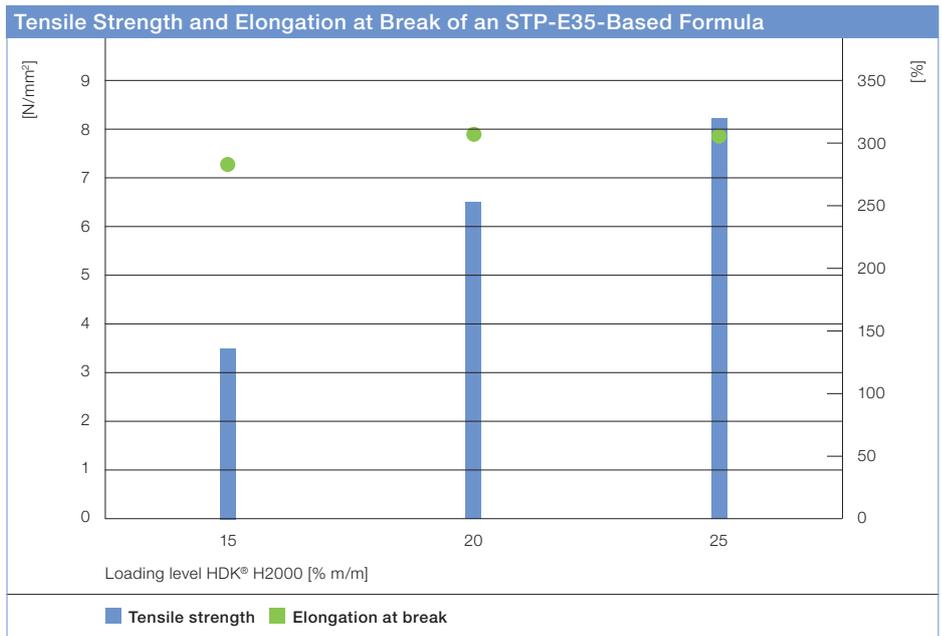
HDK® H2000 for Transparent STP-E Formulas

HDK® H2000 is a high-density silica grade that has very low rheological impact in spite of its highly hydrophobic nature. This allows for HDK® loading levels exceeding 25% in transparent STP-E formulas for outstanding tensile strength while maintaining good elongation at break. Additionally, HDK® H2000 disperses easily and contributes to transparency.

Benefits:

- Highly hydrophobic
- High bulk density
- Easy to disperse
- Allows for high loading levels
- Improves tensile strength
- Enables highest transparency

| STP-E35-Based Formula | |
|-----------------------|-------------------|
| Polymer | GENIOSIL® STP-E35 |
| Rheology additive | HDK® H2000 |
| Moisture scavenger | GENIOSIL® XL10 |
| Plasticizer | PPG 2000 |
| Adhesion promotor | GENIOSIL® GF91 |
| Catalyst | TIB KAT® 216 |



The tensile strength of STP-E-based formulas increases significantly with the HDK® H2000 loading level while elongation at break is not much affected by the HDK® concentration.



BRINGING SUPERIOR SERVICE CLOSER TO YOU

Expanding our Global Presence

New Capacity in North America

WACKER's state-of-the-art facilities in Europe and China produce a variety of pyrogenic silica grades, including nutritional and pharmaceutical products. Furthermore, our newest production plant is set to go on-stream in Charleston, TN, USA, in 2019. With an annual capacity of about 13,000 metric tons, the new facility will be a key component of the Charleston site, which produces polysilicon for the solar and semiconductor sectors. By integrating the polysilicon and HDK® production systems, WACKER can achieve maximum flexibility, less waste, and enhanced efficiency. This facility will open up new avenues for customers seeking an on-shore supplier in North America.

Optimal Packaging, Optimal Performance

In order to ensure maximum effectiveness of your products and formulations, we offer various forms of packaging to suit your logistics and workflow requirements. Packaging size, effective moisture protection, and your specific requirements are important factors in determining the optimal HDK® packaging for your productivity.

Pallets with Paper Bags

HDK® is available in multilayer, valved paper bags, which can accommodate 5 to 20 kg of product, depending on bulk density. The bags are delivered on pallets that are shrink-wrapped with a polyethylene film for moisture protection. If the shrink film is damaged accidentally or

single bags are removed, it is advisable to protect the remaining or individual bags either by wrapping them in plastic or adopting other appropriate measures.

Big Bags

The big bag solution is available for most HDK® grades. Big bags are made of woven polypropylene and are suitable for 150 to 200 kg of product, depending on bulk density. Big bags are delivered on pallets, shrink-wrapped with a polyethylene film as a safeguard against moisture.

We also provide advice on how to handle the material and, in particular, how to fluidize and unload big bags.

Please contact us for further information.



Pallets with paper bags



Big bag

EXPERTISE AND SERVICE NETWORK ON FIVE CONTINENTS



WACKER is one of the world's leading and most research-intensive chemical companies, with total sales of €4.92 billion. Products range from silicones, binders and polymer additives for diverse industrial sectors to bioengineered pharmaceutical actives and hyperpure silicon for semiconductor and solar applications. As a technology leader focusing on sustainability, WACKER promotes products and ideas that offer a high value-added potential to ensure that current and future generations enjoy a better quality of life based on energy efficiency and protection of the climate and environment.

Spanning the globe with 4 business divisions, we offer our customers highly-specialized products and comprehensive service via 23 production sites, 21 technical competence centers, 13 WACKER ACADEMY training centers and 50 sales offices in Europe, North and South America, and Asia – including a presence in China. With a workforce of some 13,800, we see ourselves as a reliable innovation partner that develops trailblazing solutions for, and in collaboration with, our customers. We also help them boost their own success. Our technical centers employ local specialists who assist customers world-

wide in the development of products tailored to regional demands, supporting them during every stage of their complex production processes, if required. WACKER e-solutions are online services provided via our customer portal and as integrated process solutions. Our customers and business partners thus benefit from comprehensive information and reliable service to enable projects and orders to be handled fast, reliably and highly efficiently. Visit us anywhere, anytime around the world at: www.wacker.com

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