Henkel TEROSON High-Performance

STRUCTURAL ADHESIVES

NEXT GENERATION SOLUTIONS FOR STIFFENING AND HEM-FLANGE BONDING

Henkel

Driving Your Future.

NEXT GENERATION HIGH-PERFORMANCE STRUCTURAL ADHESIVES FOR STIFFENING AND HEM-FLANGE BONDING

High-performance Structural Adhesives for Stiffening and Hem-flange bonding make an important contribution not only to enhance performance of the car body and closures in rigidity, durability, and sufficient level of crash-resistance, but also to give maximum protection against corrosion.

FORMULATION OPTIONS

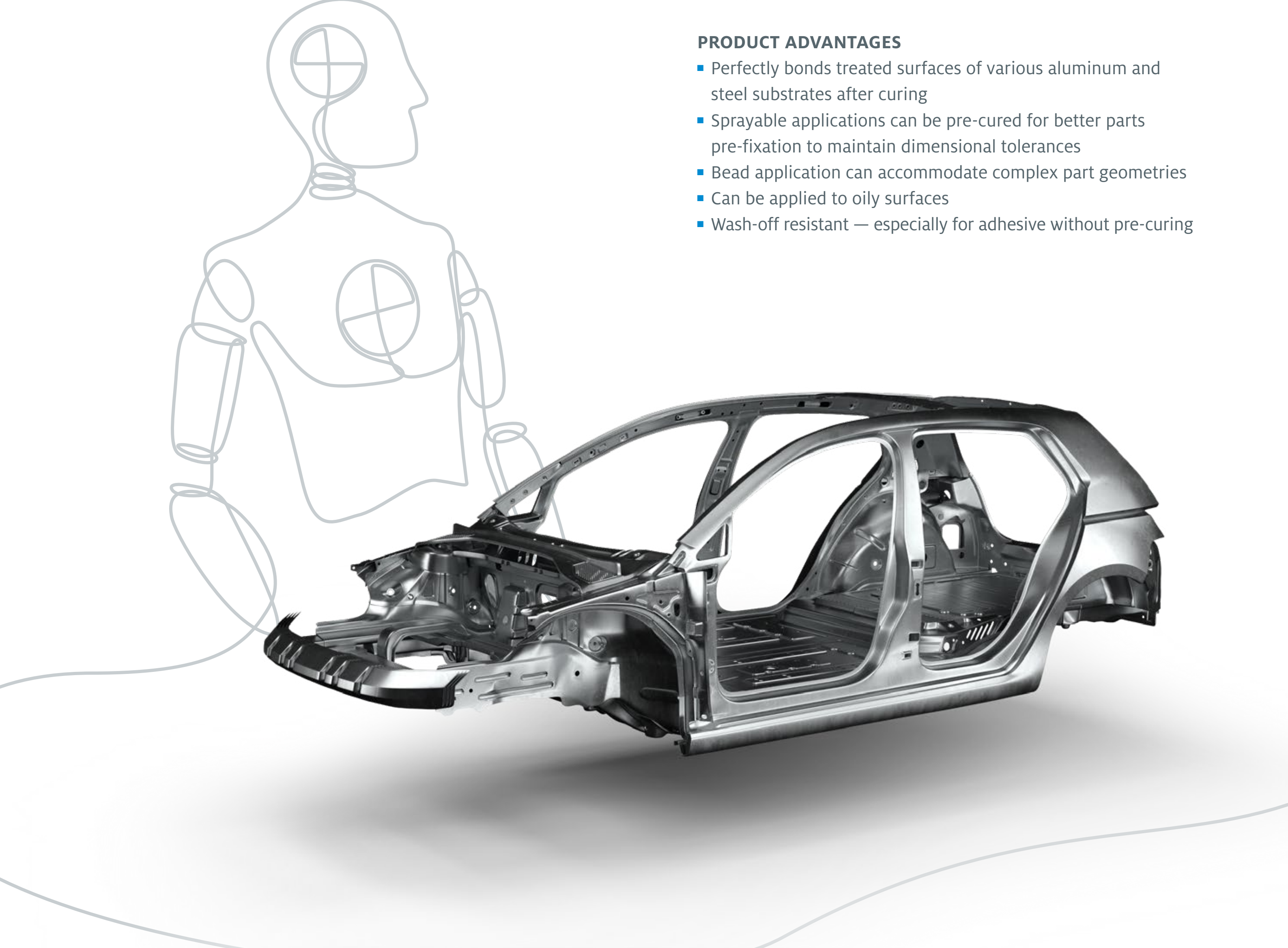
- Available in different stiffness and strength levels
- Chemistry based on epoxy, rubber, or PVC-epoxy blends

APPLICATION

- Robotically-applied in body shop prior to cleaning, surface treatment, and electrodeposition coating
- Continuous or intermittent bead pattern
- Sprayable applications available for some formulations

PRODUCT ADVANTAGES

- Perfectly bonds treated surfaces of various aluminum and steel substrates after curing
- Sprayable applications can be pre-cured for better parts pre-fixation to maintain dimensional tolerances
- Bead application can accommodate complex part geometries
- Can be applied to oily surfaces
- Wash-off resistant — especially for adhesive without pre-curing



BACKGROUND: EVOLUTION OF THE VEHICLE BODY

Car body structures are becoming lighter. And as strict regulations and demands drive lower CO_2 emissions, they are set to become lighter still in the coming years. In their efforts to make cars lighter, manufacturers are pursuing two main avenues: reducing the number of assembled parts and downgauging the thickness. Both require smart selection of high-strength materials, such as ultra- and high-strength steels (UHS and HSS), or low-density materials such as aluminum.

The areas identified as offering the greatest opportunity to reduce a car's overall weight are car body and closures. However, these need to be balanced against legal regulations related to safety — such as crash performance — as well as the need to improve stiffness and limit noise, vibration, and harshness for ride comfort and increased durability of the car body structure.

Structural adhesives play a fundamental role in lightweighting. Not only by ensuring that crash safety and battery protection requirements are met by having high fracture toughness to resist cracks, but also to carry a greater load, and to diminish impact energy. They also provide significant benefits in increasing structure stiffness for excellent ride performance. Another prominent benefit is the higher durability of bonded parts compared to punctual-jointed parts such as those utilizing rivets or spot welds, to increase the lifecycle of car body and closures.

In general, structural adhesives enable lightweighting by joining multi-material parts and allowing them to reduce part thickness. They also facilitate the manufacturing process, reducing complexity and limiting the need for heat-induced joining processes such as spot welds or mechanical joining elements such as rivets.

BIW Material Distribution

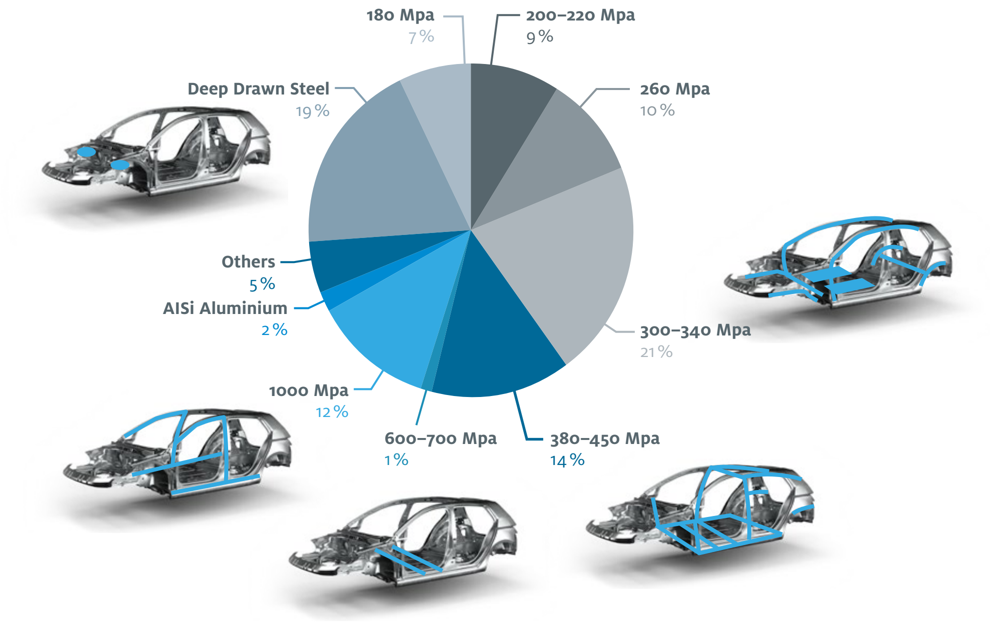
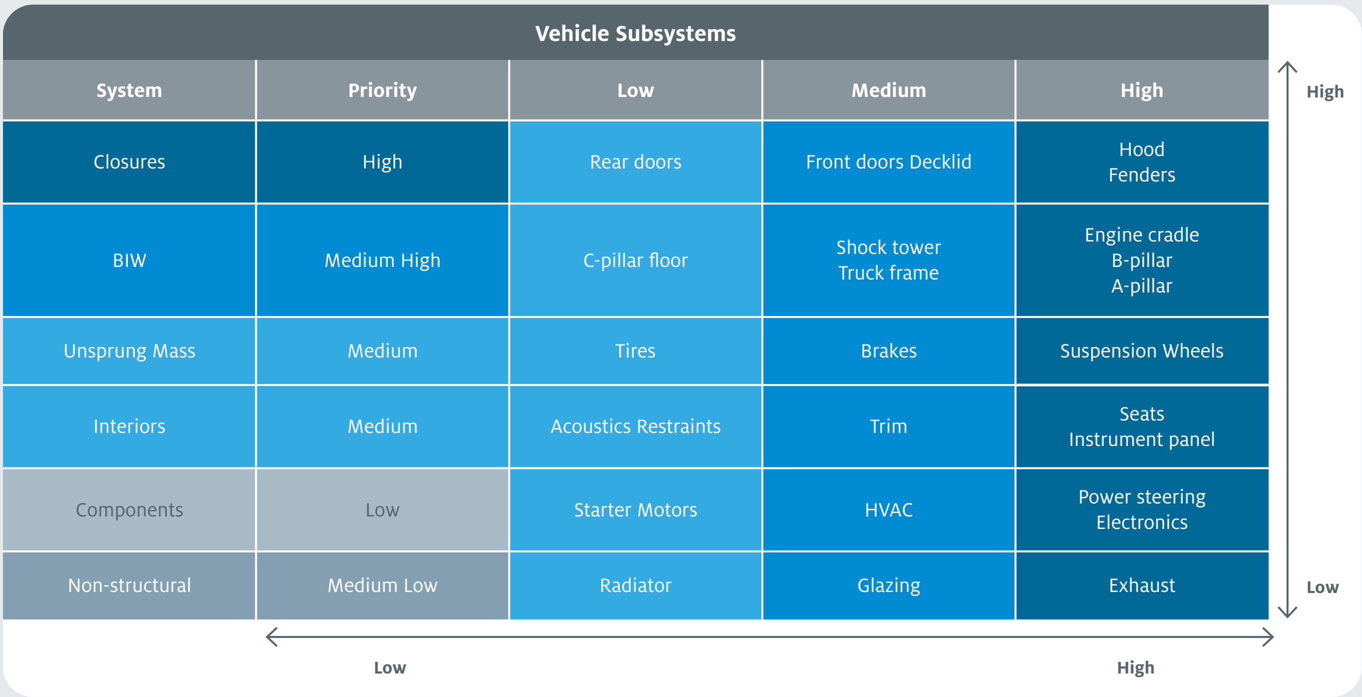


Figure 1: BIW material distribution (Baron et al. Assessing the Fleet-wide Material Technology and Costs to Lightweight Vehicles. CAR 2016)



Vehicle Subsystems				
System	**Priority**	**Low**	**Medium**	**High**
Closures	High	Rear doors	Front doors Decklid	Hood Fenders
BIW	Medium High	C-pillar floor	Shock tower Truck frame	Engine cradle B-pillar A-pillar
Unsprung Mass	Medium	Tires	Brakes	Suspension Wheels
Interiors	Medium	Acoustics Restraints	Trim	Seats Instrument panel
Components	Low	Starter Motors	HVAC	Power steering Electronics
Non-structural	Medium Low	Radiator	Glazing	Exhaust

Figure 2: Light-weighting priority of vehicle subsystem (Baron et al. Assessing the Fleet-wide Material Technology and Costs to Lightweight Vehicles. CAR 2016)

HENKEL SOLUTION

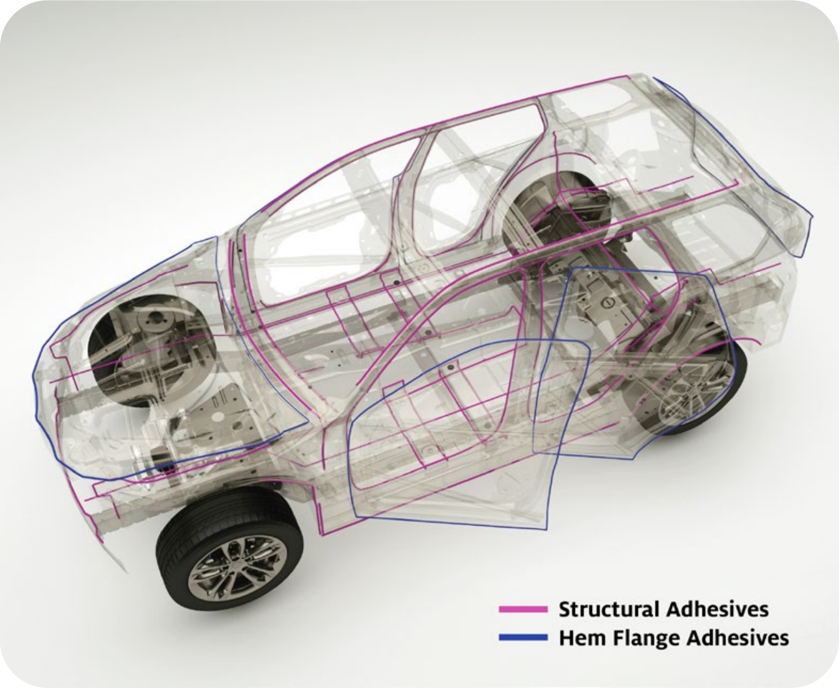


Figure 3: Typical adhesive applications on BIW and closures

HIGH-PERFORMANCE STRUCTURAL ADHESIVES FOR STIFFENING AND HEM-FLANGE APPLICATIONS

Henkel's high-performance structural adhesives in the body-in-white and closures provide a tailor-made solution to meet customer requirements. A bonded structure has evenly distributed loads through the bonded flange. Under load, the bonded flanges remain closed, while punctual joints such as spot welds or rivets tend to open. Thus, the stress peaks can be strongly reduced and the durability of bonded structure increases. Furthermore, the section rigidity during deformation can be kept at a high load level. Those are clearly beneficial in comparison to only spot-welded structures.

Henkel TEROSON High-Performance Stiffening Adhesives are applied across main structures of a car body, where section rigidity and stiffness are critical to meet the defined performance, such as pillars, roof rail, and rockers. In addition to supplying stiffness and durability, adhesives in these applications deliver improved NVH response and a cosmetically superior finished part.

Depending on customer requirements, the Henkel portfolio of high-performance stiffening adhesives consists primarily of epoxy-based formulations exhibiting high stiffness and strength with a good level of crash resistance. This chemistry ensures a stiff and rigid connection of the bonded parts. Rubber-based structural adhesives for stiffening are also available when the application requires high stiffness with medium strength and competitive cost.

Henkel TEROSON High-Performance Hem-Flange Adhesives are typically used in joining class-A surfaces such as body and closures outer panels to the inner panel, where noticeable distortions like spot welds or rivets are undesirable on visible areas. The hemming process is a separate process within the overall assembly of BIW and closures and is one of the more challenging steps in the overall manufacturing process. Hemming not only hides the raw cut edges of metal sheets — preventing injury to vehicle users — it also protects the cut edge of bare steel from corrosion and delivers a more aesthetically pleasing finished part.

In its portfolio, Henkel offers various high-performance hem-flange adhesives that are either epoxy, rubber or PVC-epoxy-blend based. The adhesive can be tailored to customer specifications and design philosophy. Thus, it can range from elastic rubber-based adhesive with high elongation at the break, up to rigid epoxy adhesives with high stiffness and strength — which are also used as stiffening adhesives.

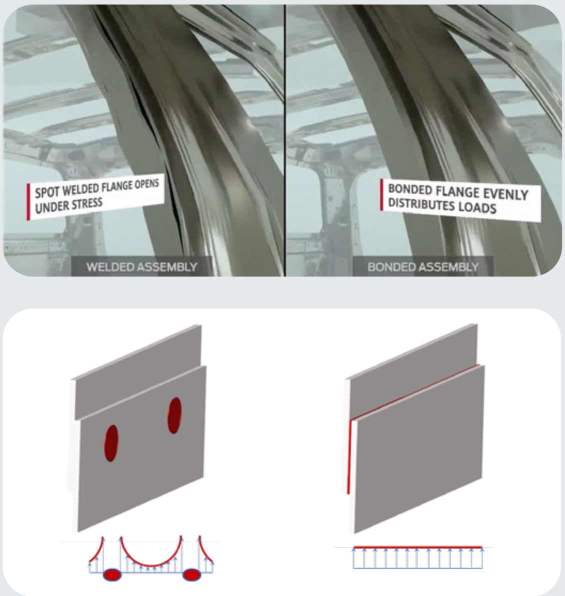


Figure 4: Evenly distributed load on bonded flange as benefit of using adhesive

High-strength **Glass Beads (GB)** can be added in both stiffening applications and, prominently, in hem-flange applications. Glass beads ensure a constant bond gap for perfect bonding, which is especially important for hem flanges. In the hemming process, glass beads act as a stopper to limit the hem-roll from further pressing the flange to zero gap. This can significantly reduce the amount of adhesive squeeze-out from the flange. Also, the glass beads can minimize spring-back of the hemmed flange. Too much spring-back can lead to air entrapments and air channels in the bond line, which is a common cause of corrosion and ultimately leads to voids in the subsequent seam sealer at the paint shop.

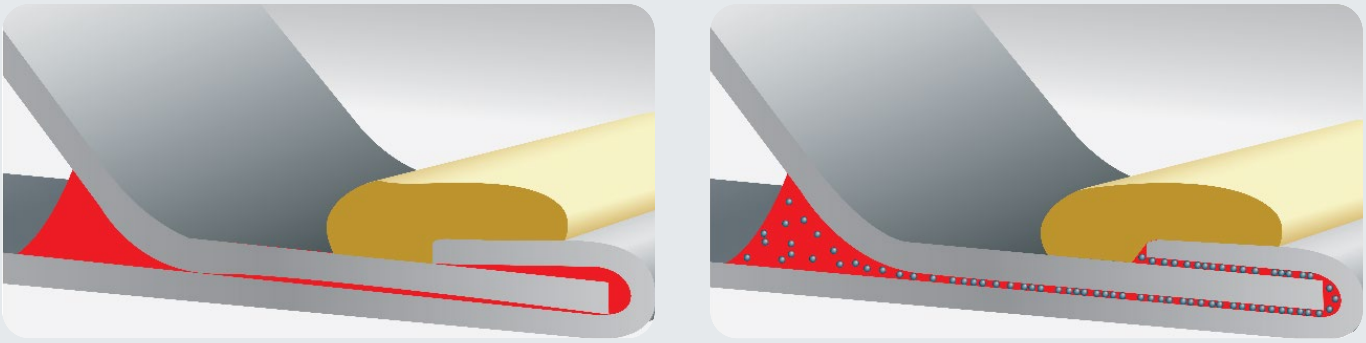


Figure 5: Hem-flange adhesive and seam sealer on the outer and inner panels of a door show an uneven, or non-constant, bond gap without Glass Beads, versus constant gap with glass beads.

HENKEL SOLUTION

To meet OEM requirements, Henkel TEROSON adhesive product development takes into consideration a range of factors:

1. Uncured properties: all aspects of the product in the before-cured state that are considered in relation to production line processes. These can be customized to OEMs' production line process requirements and constraints, such as wash-off resistance, humidity resistance, and viscosity that relate to application and the cure kinetics.

2. Cured properties: aspects of the adhesive's material chemistry that specifically affect the adhesive's final mechanical properties in the cured state, which is important for lightweight design. They are customizable 'one-formulation' adhesives for a broad range of steel and aluminum structures, compatible with the surface chemistry of the bonded substrates to ensure perfect adhesion.

3. Engineering properties: aspects that enable car manufacturers to predict and analyze the performance of the bonded structure at full-car level, with numerical simulation during the design development phase.

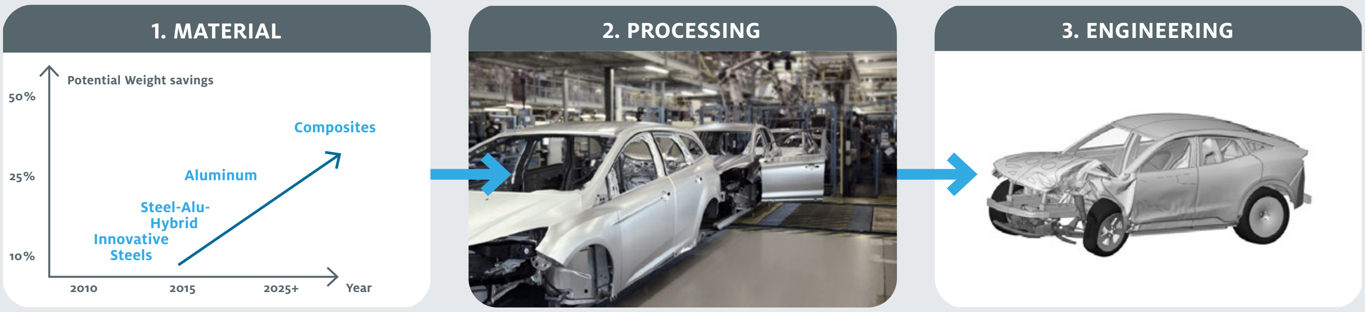


Figure 6: Development of TEROSON structural adhesives covers every trait, from material chemistry to the production process and engineering aspects

UNCURED PROPERTIES OF HIGH-PERFORMANCE STIFFENING & HEM-FLANGE ADHESIVES

Wash-off resistance is one of the most important uncured properties for an adhesive. Movement of the body-in-white in the pretreatment bath process can cause coating fluid to flow in all directions and wash the uncured adhesive bead off the flange. This washed-off adhesive contaminates the sequential bath processes of degreasing, phosphating, e-coat and so on. Furthermore, the washed-out adhesive particles can settle on the body panels and disturb the painting process. Therefore, the wash-off resistance of TEROSON structural adhesives is precisely optimized to the requirements of each car manufacturer.

Figure 7: Bathing process of car body (left picture). Rotating Immersion method use to proof the Wash-Off resistant of Henkel adhesives. These wash-off test samples show good bead stability via control over yield point and thixotropy (right picture).

Humidity resistance is the ability of a cured structural adhesive to maintain its performance after exposure to humidity in both the uncured and cured state. Production line downtime is the most typical scenario in which uncured adhesives – in an open or closed bead state – are exposed to humidity for an extended time. To ensure good adhesion after this exposure, humidity uptake must be prevented from diffusing within the uncured bead of adhesive. An adhesive having good wetting properties on oily substrates is a factor in optimizing humidity resistance.

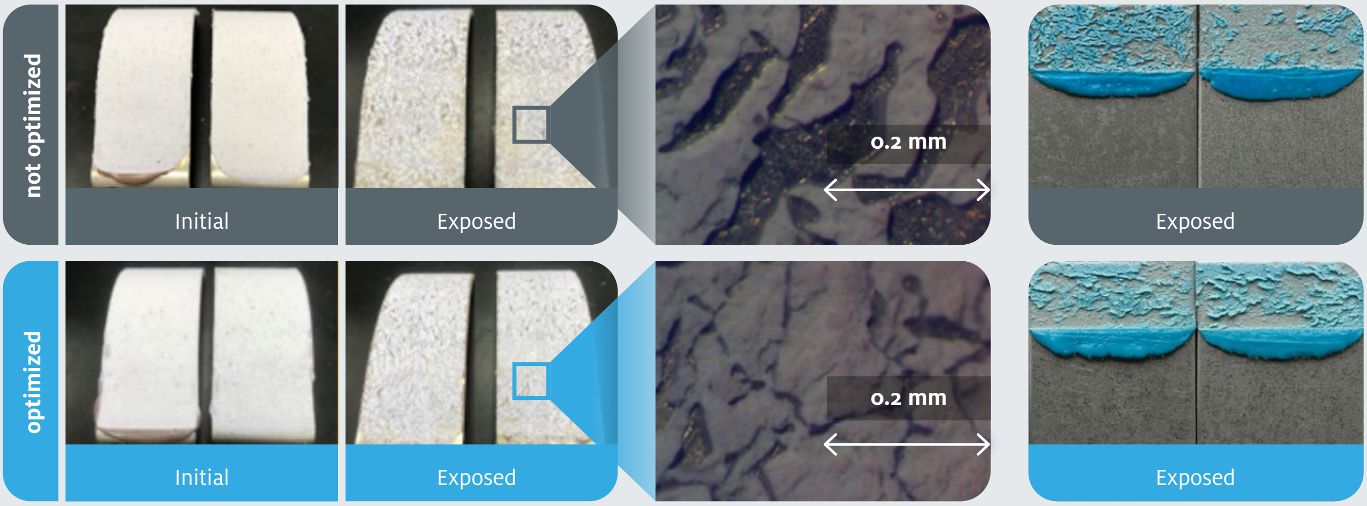
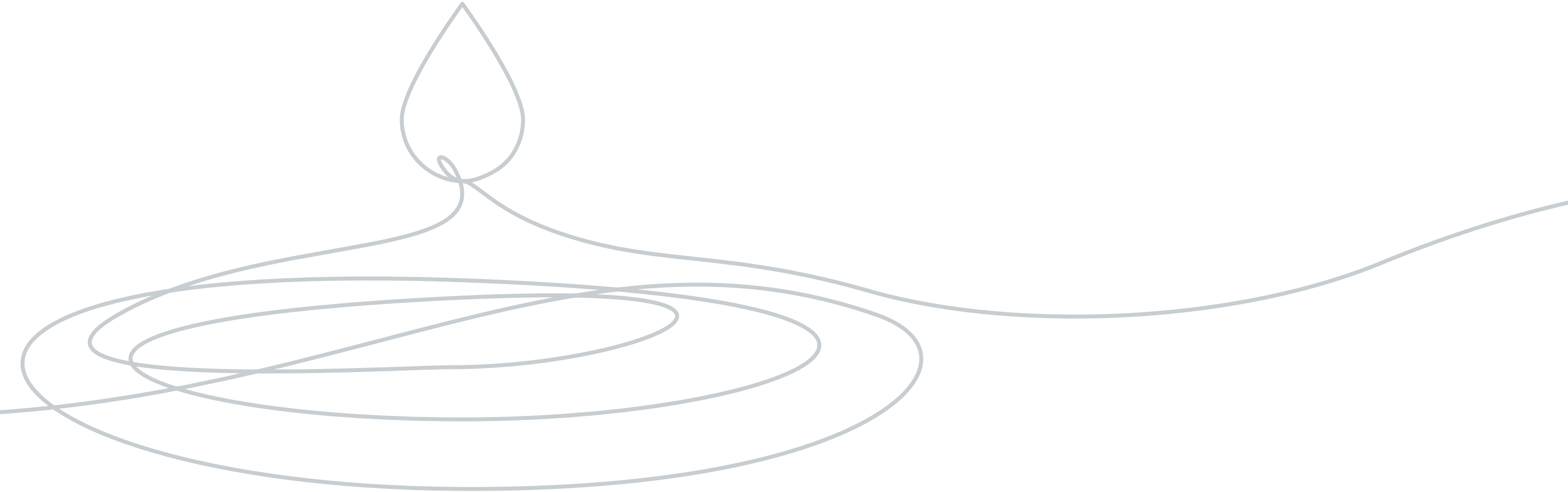


Figure 8: Failure modes after exposure of non- and optimized reduction of blistering and interfacial failure due to moisture absorption

Viscosity is one of the most important factors related to the application of adhesives on a production line. Good pumpability and short stringing are crucial properties to ensure perfect and clean adhesive application on bonded flanges. In the adhesive's development, those properties can be adjusted to meet every car manufacturer's production line requirements.

Henkel offers a range of low, medium, and high viscosity TEROSON stiffening and hem-flange structural adhesives. The low viscosity adhesives can be applied "cold", with only a heated nozzle at 30 °C to 35 °C to overcome the seasonal temperature fluctuations. Medium viscosity adhesives use heated follower plate application and a heated nozzle at 40 °C — 60 °C. Special adhesives with high viscosity require the nozzle heated up to 70 °C.

Intelligent curing kinetics are applied to each TEROSON adhesive to keep the viscosity stable over the whole adhesive shelf life. It also ensures the adhesives will fully cure within the minimum and maximum curing window defined in each car manufacturer's E-Coat oven. Again, all of those above characteristics can be tailored to the customer's individual needs.



CURED PROPERTIES OF HIGH-PERFORMANCE STIFFENING & HEM-FLANGE ADHESIVES

Modulus is a key feature, especially for stiffening adhesives. A high modulus level is required to increase and maintain the stiffness and rigidity of bonded structures.

TEROSON High-Performance stiffening adhesives are designed to achieve superior modulus customized to the individual needs of the OEM. The typical modulus of stiffening adhesives with an epoxy or rubber base ranges from 1500 MPa to 6000 MPa. Compared to only spot-welding the BIW, the use of high modulus adhesives can increase static stiffness of the car body by as much as 10 %. As well, the natural frequency responses of global bending and torsion modes of the car body can be increased up to 2 Hz. As a result, better ride handling can be achieved.

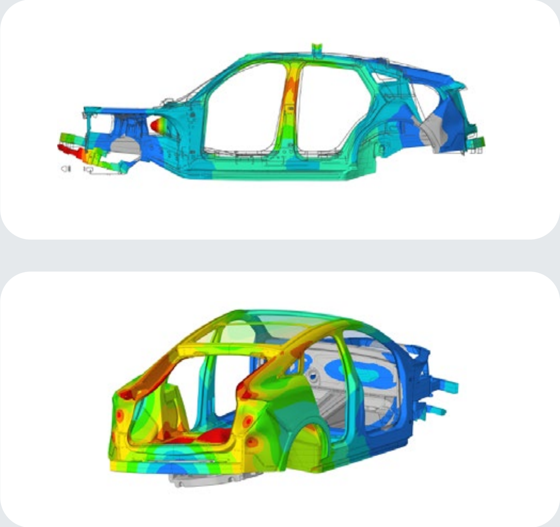


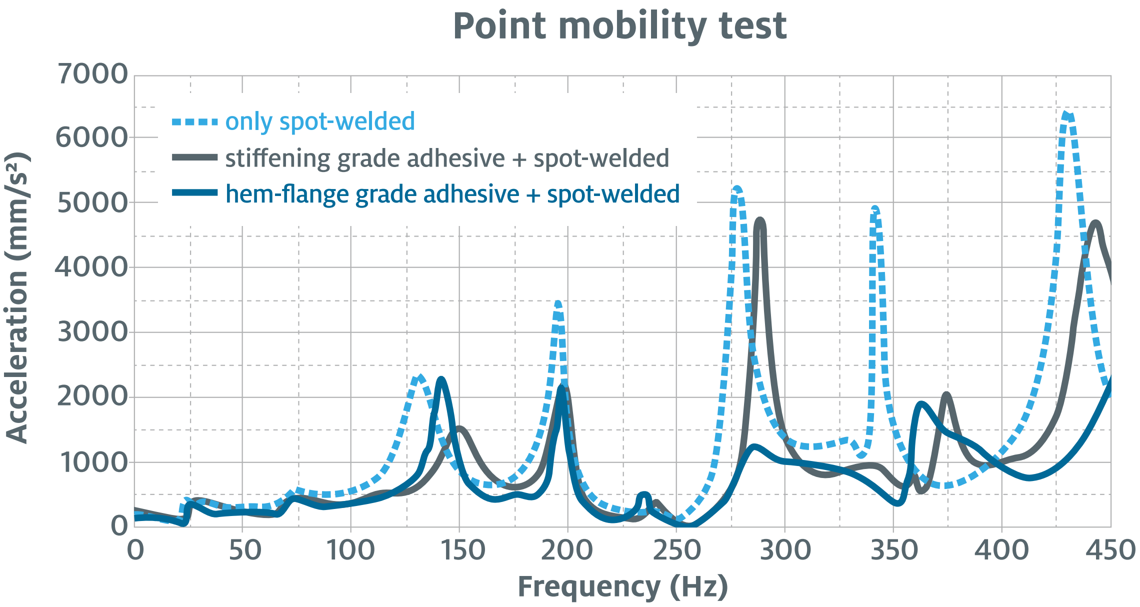
Figure 9: Absolute displacements (max=red, min=darkblue) occur in global bending and torsion modes of a BIW

For TEROSON hem-flange adhesives, the range of minimum to maximum modulus available is even larger than the stiffening adhesives. The modulus of the adhesive is not always seen as a high priority in hem-flange bonding by every car manufacturer. The individual design strategy and philosophy drive different requirements from one OEM to the next for hem-flange bonding, which ultimately determines the base chemistry of the adhesives.

Some car manufacturers focus on high modulus, using epoxy-based or high-modulus rubber-based adhesives ranging from 1500 MPa to 6000 MPa, which are similar to stiffening adhesives.

PVC/epoxy-blend-based hem-flange adhesives display medium modulus, ranging from 500 MPa to 1000 MPa. Adhesives of this type have a pre-gel ability that improves the pre-fixation of bonded parts, before fully curing in the e-coat oven. The dimensional tolerance can therefore be maintained in a more precise manner as a benefit.

For lower modulus, with a range of 50 to 500 MPa with very high elongation at break, elastic rubber-based hem-flange adhesives are the choice. The adhesive's rubber content contributes additional benefits in acoustic damping. This can help achieve better acoustic comfort through the reduction of door slam and structure-born noise.



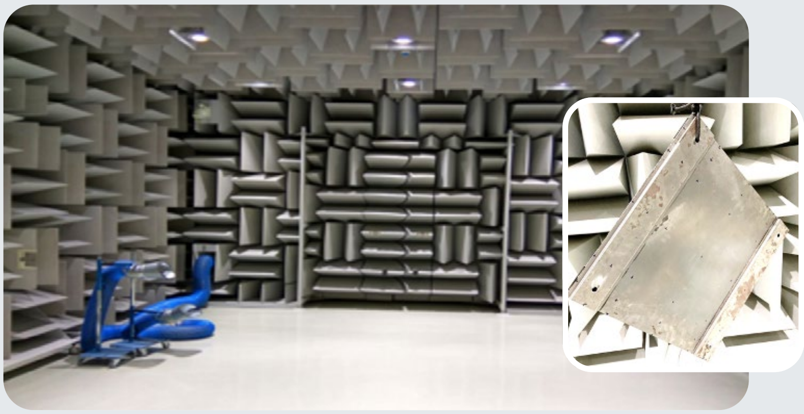


Figure 10: Point mobility test in anechoic chamber captured shifting of peaks to higher frequencies and significant reduction of amplitude responses of spot-welded and bonded floor section with elastic rubber-based hem-flange adhesive.

Strength reflects the ability of an adhesive to withstand load before failure. It is generally measured directly from bulk material through common standard uniaxial tensile testing and in-situ, through lap-shear test specimens. **The lap shear strength (LSS)** can vary depending on the substrate type and thickness. For the sake of comparable results, all TEROSON stiffening and hem-flange adhesives are uniformly tested on cold-rolled steel with 2 mm thickness.

The elongation at break from the tensile test indicates the adhesive's brittleness. Again, each car manufacturer's unique design strategy drives the required level of bond strength.

The new generation of TEROSON stiffening and hem-flange adhesives are epoxy-based and designed to reach very high strength in uniaxial tensile load up to 40 MPa with up to 3 % elongation at break. The epoxy-PVC-blend hem-flange adhesives reach up to 8 % elongation at break and exhibit medium strength up to 15 MPa and elastic rubber-based formulations can reach very high elongation — up to 20 % — before breaking.

LSS for epoxy-based formulations — both TEROSON stiffening and hem-flange adhesive — can reach greater than 20 MPa. The rubber-based formulations achieve LSS in the range of 5 MPa to 15 MPa and the epoxy-PVC-blend adhesives for hem-flange applications have LSS ranging between 10 to 20 MPa.

As structural adhesives, especially for the epoxy-based, both stiffening and hem-flange adhesives are designed to have sufficient fracture toughness. The dynamic resistance measured from impact wedge peel tests is in the range of 10 to 20 N/mm. That enables the adhesive to properly absorb energy and keep the bonded flange closed during impact deformation. Up to 10 % higher crash performance can be achieved compared to an only spot-welded structure.

If higher impact resistance is required, Henkel TEROSON high crash-resistant structural adhesive products are definitively the first choice. **Read more about in our Whitepaper for high crash-resistant structural adhesives.**

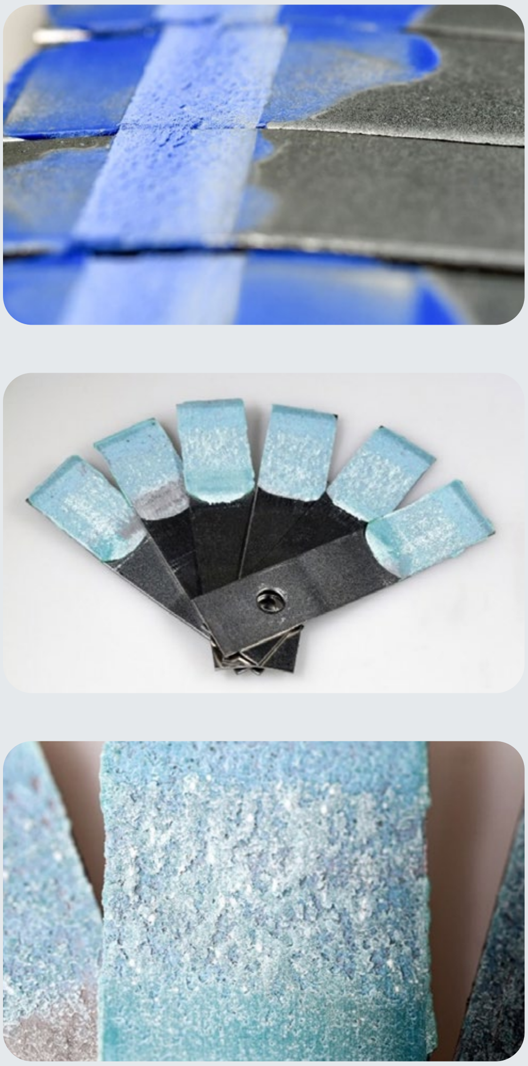
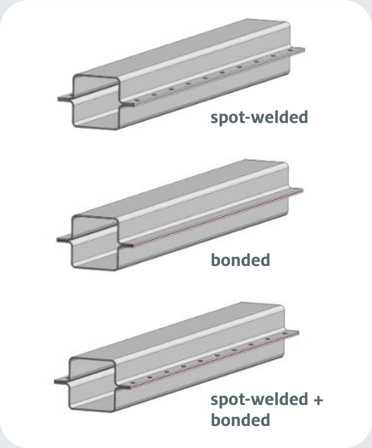


Figure 11: Lap shear and impact peel testing with Henkel TEROSON adhesives showing 100 % cohesive failure.



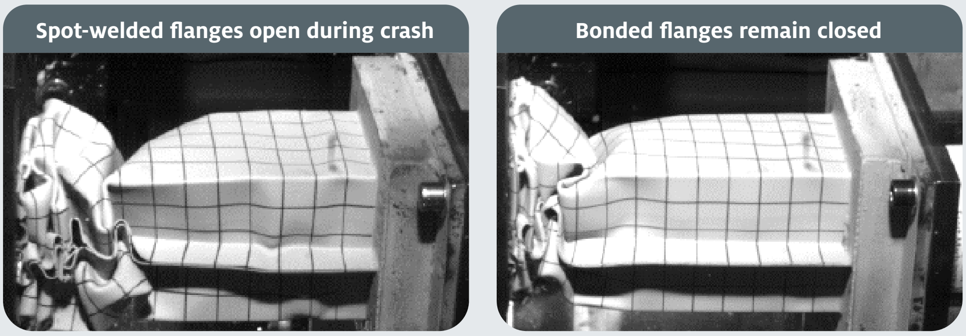
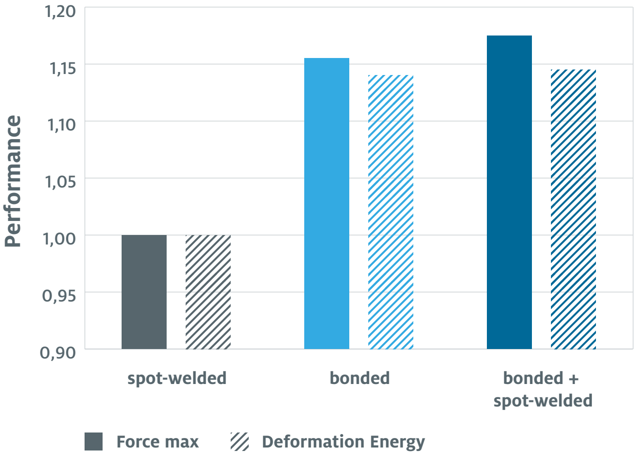
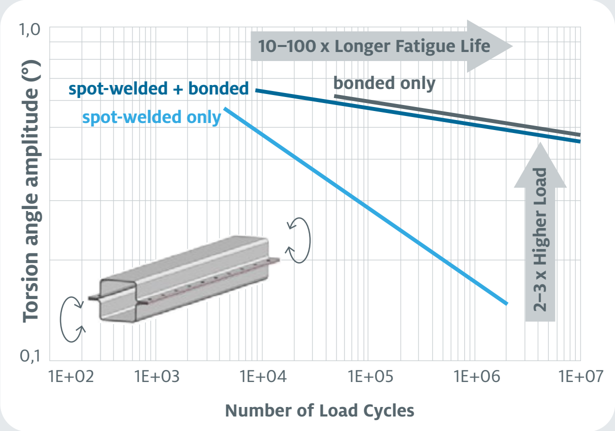


Figure 12: Under drop tower impact test the bonded flange of hat-shape profile remains closed during deformation. As the result, the profile can absorb a significantly higher impact energy and thus increases its section rigidity compared to the only spot-welded profile.



Durability or fatigue is the most prominent benefit of bonded structures. The load transfer is evenly distributed along the bonded flanges. Local high-stress peaks created by punctual joints (such as spot welds) that propagate cracks are significantly reduced. As a result, the structure demonstrates longer fatigue life by a scale of 10 to 100 times, though much higher load can easily be achieved.



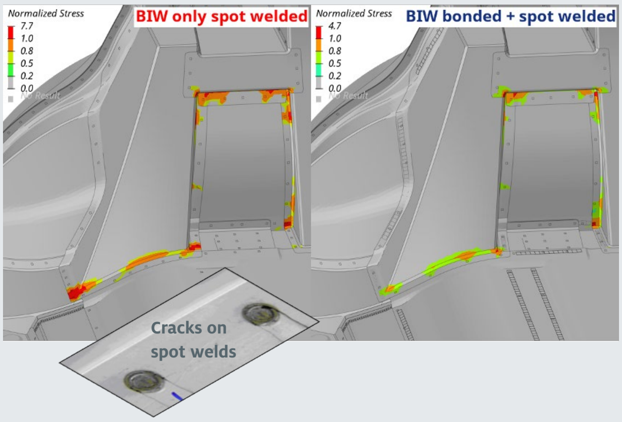


Figure 13: Increase of structure durability of bonded profile under alternating torsion load that prevent early fatigue failures (top picture). Significant reduction of stress peaks in bonded wheelhouse flange area under torsional load (bottom picture)

ENGINEERING OF HIGH-PERFORMANCE STIFFENING & HEM-FLANGE STRUCTURAL ADHESIVES

Predicting the performance of bonded structures in the full car using numerical analysis is now standard in the car development process. Numerical simulation can provide a good prediction of adhesive performance in different load cases, which increases confidence in the behavior of car structures as a whole in real situations. In the early development phase, simulation results give designers crucial information about which direction they need to take their design in.

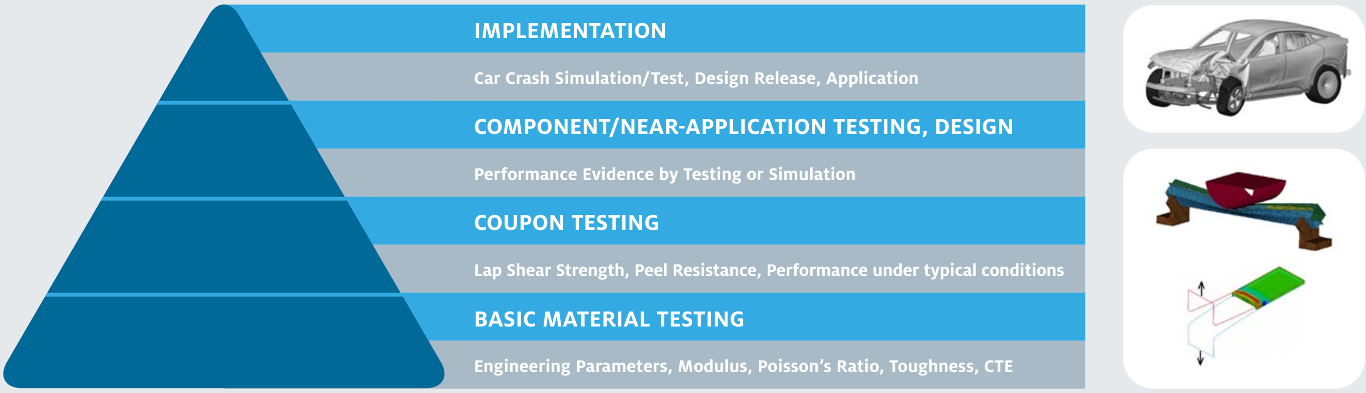


Figure 14: Engineering process from generating, validating and final implementation of simulation material data input of Henkel's structural adhesives

Henkel provides the state-of-the-art simulation material data input for TEROSON structural adhesives. Data input is validated through coupon and near-application-level testing to achieve high prediction accuracy.

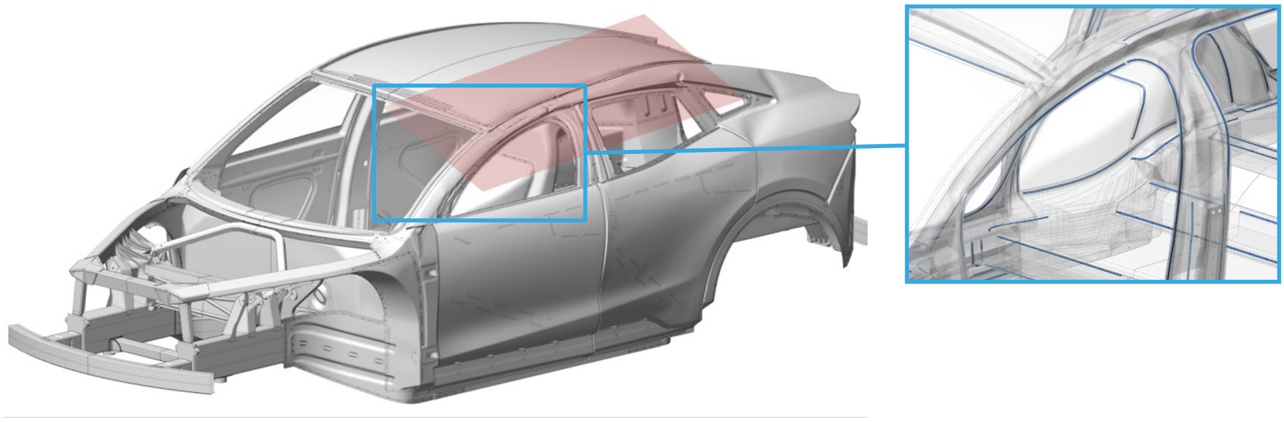


Figure 15: Prediction of performance of bonded BIW under roof crush

SELECTION FROM HENKEL PORTFOLIO OF HIGH-PERFORMANCE STIFFENING & HEM-FLANGE STRUCTURAL ADHESIVES

Henkel Product TEROSON	Base chemistry	Stiffening	Hem-flanges	Viscosity	E-Modulus (MPa) ISO 527-1	Tensile strength (MPa)	Elongation@ break (%) ISO 527-1	LSS (MPa) 2 mm DC04	Impact peel (N/mm) ISO 11343	Special Properties
EP 2400 M	epoxy	✓		medium	1380	20	3	20	8	Expandable stiffening adhesive with 40 % — 50 % expansion rate for bonding flanges with gap (not weldable)
EP 4550	epoxy	✓		medium	5000	40	1	28	5	Stiffening adhesive with high modulus and high strength
EP 4580	epoxy	✓		medium	3230	18	1	28	8	Stiffening adhesive with glass beads with high modulus and LSS strength, cured at 160°C 10 minutes
EP 4585 GB	epoxy		✓	medium	4560	35	1	28	4	Hem-flange adhesive with high modulus and strength. Use 200-300 µm glass beads
EP 8028 GB	PVC-epoxy blend		✓	low	650	14	8	16	10	Hem-flange adhesive with pre-gelling ability for good wash-off resistance, contains additional adhesion promoter for bonding Zn-Mg coated substrates.
EP 8031	PVC-epoxy blend		✓	medium	826	12	8	10	10	With higher viscosity for wash-off resistant without pre-gelling, contains glass beads 200 — 300 µm.
RB 5191 GB	rubber		✓	medium	50	6	30	6	10	Hem-flange adhesive with higher elongation and good damping property
RB 5197	rubber	✓		high	4000	14	4	14	5	Stiffening rubber-based adhesive with high viscosity for excellent wash-off resistance

We additionally offer a broad range of crash adhesives in our portfolio. And thanks to our engineering capabilities, we can support you to optimize the mix. **Read more in our Whitepaper for high crash-resistance adhesives.**

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GET IN TOUCH WITH US

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