ENABLING LIGHTWEIGHT DESIGN WITH **HENKEL TEROSON® HIGH-PERFORMANCE STRUCTURAL INSERTS**

EXECUTIVE SUMMARY

This white paper explores the need for lightweighted EV designs. Henkel structural insert reinforcements offer the ideal solution.

Henkel structural inserts increase stiffness and section rigidity. At the same time, they provide valuable energy absorption in crash events. Their light weight allows designers to downgauge body panel thickness and reduce parts count. Yet assemblies still reliably meet stringent structural and crash performance requirements.

Test and performance outcomes are optimized when Henkel engineers collaborate with OEMs. This can occur at virtually every stage of project development. However, doing it early in the design process can save time, money and headaches later.

Henkel Adhesive Technologies

BACKGROUND

Driven by the ongoing growth of EVs, automobile design lightweighting is more important than ever. It was first proven to improve fuel efficiency in ICE vehicles. For EVs, offsetting the battery system mass makes it even more vital to extending range. Extended range to ICE vehicle levels is a vital component of EV acceptance with buyers.

Reducing vehicle mass has primary and secondary benefits. Primarily, mass reduction allows the vehicle to expend less energy to reach the same performance and range levels. An equivalent battery size and configuration will accelerate faster and go further in a lightweighted vehicle than in a heavier one.

Secondarily, weight optimization enhances braking system and suspension performance. It also improves driving confidence.

UNIQUE EV CHALLENGES

Compared to conventional ICE car design, added battery mass in an EV leads to different weight distribution. This requires different load path management to protect the passenger compartment and battery. In response, designers may be tempted to add metal reinforcements to body pillars and rocker panels. But to achieve lightweighting goals, it also becomes necessary to reduce metal sheet thickness and parts count. These opposing design challenges require fresh solutions that combine design flexibility, material performance, cost-effectiveness and sustainability.

THE HENKEL TEROSON® HIGH-PERFORMANCE STRUCTURAL INSERT ASSEMBLY

Henkel TEROSON structural inserts are a three-dimensional, engineered hybrid solution. Created by injection molding two main components to create the final assembly, they consist of:

1. **The Carrier** – This structural foundation is made from thermoplastic polyamide PA6 or PA66. It contains 30% to 60% glass fiber content. The composite material can also contain a metal structure to accommodate design or performance requirements.
2. **Structural Foam** – Made from epoxy-based, heat-curing, expanding structural adhesive, this is the bonding component of the insert assembly. It fills gaps inside the metal cavities where the assembly is placed. During crashes, it enhances load distribution and energy absorption.

Figure 1 Henkel structural inserts for stiffness and crash applications.

WORKING PRINCIPLE

Henkel structural inserts are easily secured in the body-in-white cavity with clips or by spot welding an embedded metal tab. Prior to heat curing, there is a slight gap between the installed insert and the metal cavity in which it is secured. This allows anti-corrosion coatings to flow around the cavity interior without interference during metal pretreatment in the body shop. Later, during curing in the e-coat oven, the heat causes the structural foam to expand and fill the gap between the metal cavity walls and the insert carrier.

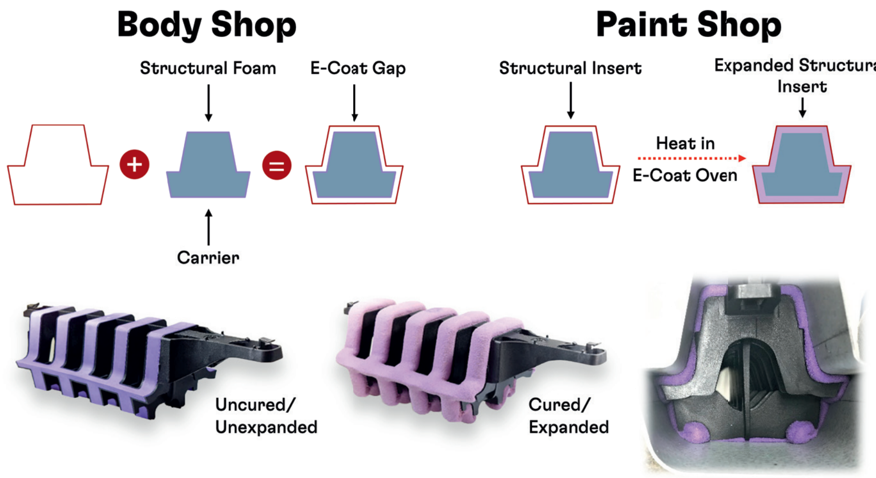


Figure 2 Working principle of structural insert.

Once cured, Henkel's structural foam creates a high-strength, three-dimensional bond between the structural carrier and the surrounding metal cavity. This yields improved local section integrity. It also offers better load path distribution. In addition, the insert enhances body stiffness, rigidity and durability. When used together with Henkel's acoustic products, NVH performance and passenger comfort can also be improved.

For passenger safety and battery protection in crash events, Henkel TEROSON structural inserts can be specified to absorb impact energy. The weight distribution and center of gravity of conventional ICE vehicles with front-mounted engines is vastly different from an EV. The heavy battery and its location under the floor make it more critical for an EV to withstand roof crush loads in the A- and B-pillars. In a side collision or pole crash, the rocker area must be able to protect the battery compartment.

In short, Henkel's TEROSON structural inserts can help vehicle manufacturers improve ICE or EV vehicle performance and safety while also enabling designers to:

- Potentially downgauge sheet metal thickness
- Reduce weld spots or increase the pitch of weld spots
- Eliminate existing metal reinforcements
- Improve NVH performance
- Realize cost-saving opportunities
- Discover greater design flexibility

For best results, structural inserts should be considered during the earliest vehicle design stages. In one of Henkel's design studies, engineers integrated an array of structural solutions – including structural inserts – into a BEV concept. It resulted in a potential weight reduction of the BIW and closures of up to 10 percent. In addition, the structural inserts achieved the same performance requirements as the original design under various crash and stiffness load simulations.

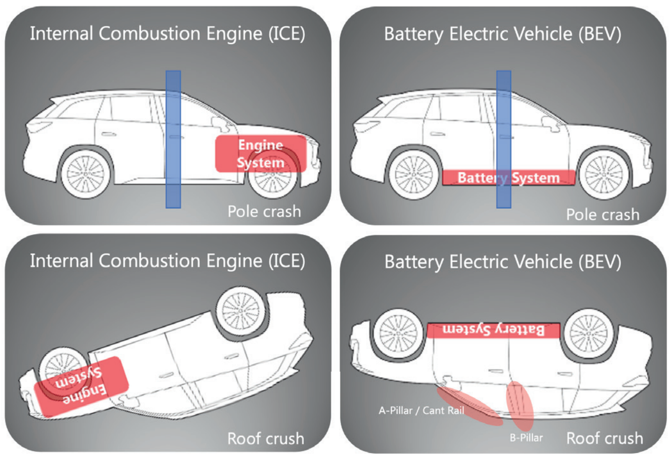


Figure 3 Different weight distribution and center of gravity of EVs leads to new requirements for reinforcement and lightweighting solutions.

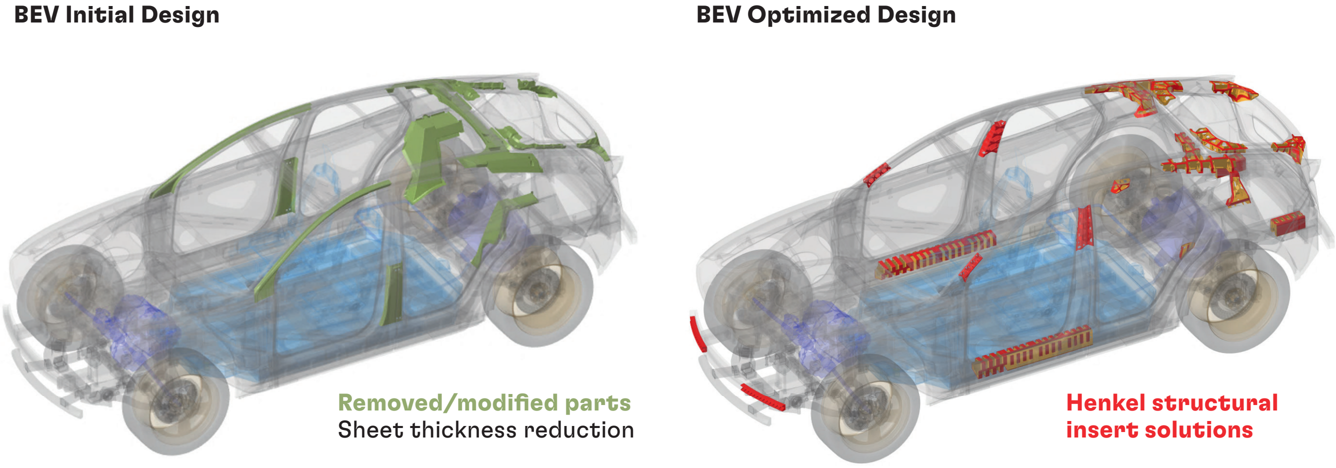


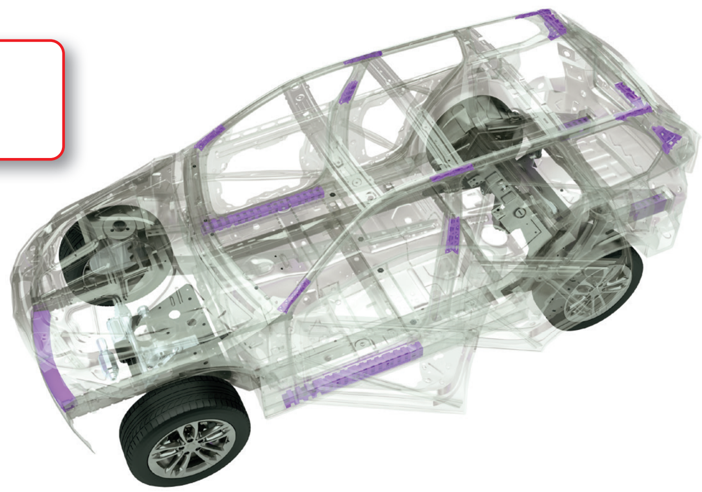
Figure 4 Henkel study on lightweighting a BIW and closures of a BEV.

HENKEL STRUCTURAL INSERT APPLICATION AREAS

Structural insert application locations vary depending on the load type and path. Typical load cases for these applications are:

- Roof crush
- Side crash, e.g., side pole, MDB
- Frontal crash, e.g., SORB ODB, full rigid wall crash
- Torsional and bending stiffness
- Rigidity and durability
- NVH improvements

ROOF CRUSH
A-/B-pillars
Roof rail



TORSIONAL AND BENDING STIFFNESS
Pillar junctions
Liftgate
Doors
Rocker

REAR CRASH
Longitudinal rear

FRONTAL OFFSET CRASH
Bumper, longitudinal front
Shotgun
A-pillar, rocker front

Figure 5 Structural insert application location to accommodate various load cases.

SIDE AND POLE CRASH
B-pillar
Rocker
Transversal beam

KEY PERFORMANCE MEASURES

There are two primary performance considerations for structural inserts:

1. The Material
2. The Design

1. The Material: Light and Strong.

To meet OEMs' weight, strength and stiffness requirements, the Henkel structural insert assembly combines expanding structural foam and a nylon PA6 or PA66 carrier. The carrier is reinforced with glass fiber. There are multiple structural foam formulations available to help fine-tune performance. These varying characteristics allow customizing a solution to meet unique application requirements:

- Expansion rates of up to 300% are available. This allows the foam to fill gap sizes from medium to extreme. It also reduces the amount of required material
- Strength specifications can be met by tailoring structural foam to specific crash performance requirements
- BIW stiffness and NVH characteristics can be enhanced by specifying a structural foam that reduces vibration and optimizes driving stability

Engineered Henkel Structural Foams

Henkel's TEROSON structural foams are optimized to absorb crash impact absorption while providing rigidity. During material development, Henkel uses state-of-the-art methods to create and validate the most effective formulas. These methods include virtual testing, reverse engineering and machine learning. Over time, Henkel's research engineers have generated vast libraries of virtual material data. This allows them to capitalize on machine learning to help define potential solutions the fit the requirements. Once defined, solutions are tested virtually under real-world load scenarios. Based on testing outcomes, Henkel uses reverse engineering to set appropriate material properties targets. This leads to obtaining the final recommendations.

Henkel's structural foam morphology can be virtually designed, validated and parameterized. This can be performed at both ends of the macroscale and microscale spectrum. The expanding material database allows ever-increasing accuracy in predicting final material properties by machine learning. Henkel's already-reliable predictive modeling process continues improving with each new test scenario.

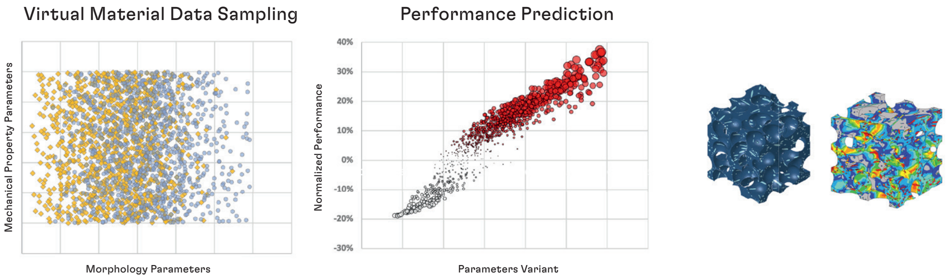


Figure 6 Data sampling for machine learning prediction for a specified performance using microscale model of structural foam.

Structural Foam Material for Structural Inserts

HENKEL PRODUCT	TEROSON EP 1475	TEROSON EP 1465
Density after curing	<0.5 g/cm³	<0.5 g/cm³
Expansion rate (free)	Up to 300%	Up to 200%
Compression strength	>15MPa	>12MPa
Young's modulus	>700MPa	>700MPa
Curing temperature (minimum)	>140°C (10 min.)	>150°C (15 min.)
Benefits and performance	ADCA-free Superior compression strength for high crash performance High expansion rate Low curability Reduced vibration and increased driving stability due to improved BIW stiffness	ADCA-free Good crash performance for common body cavity locations Medium expansion rate Broad bakeability Good stiffening performance for improved vehicle ride and handling

2. The Design: Achieving Maximum Performance.

Lightweighting is the core objective. But the design plays a role nearly as significant as the material selection to achieve optimum safety performance.

For example, Henkel structural insert solutions offer an advantageous, weight-saving replacement for traditional aluminum extruded structural insert. In Battery Electric Vehicle (BEV) application, every gram matters. The Henkel structural insert solution for one BEV application replaced an extruded aluminum battery shield. To save weight, Henkel devised a design solution of TEROSON EP1475, in combination with a carrier reinforced with PA66 glass fiber fixed into a steel cavity subassembly. The outcome was a weight savings of 0.35kg per side on the vehicle.

This solution also offers cost efficiency at the same performance. In addition, it eliminates the previous design's inherent aluminum-to-steel contact corrosion risk.

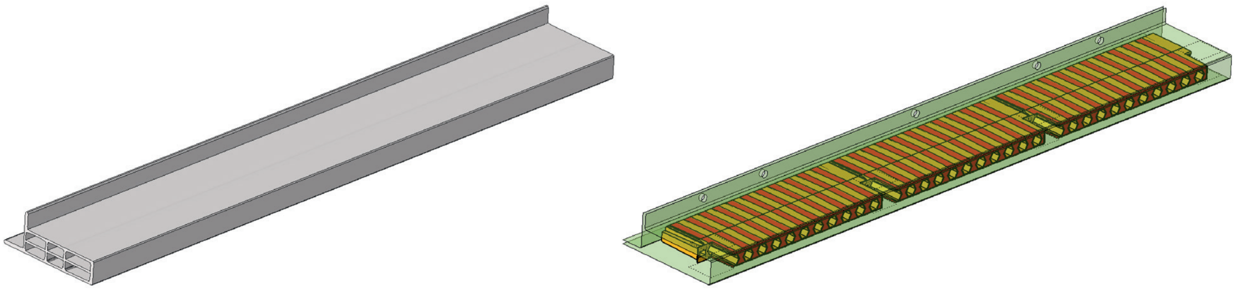


Figure 7 Battery protection extruded aluminum insert (left) compared with a Henkel structural insert solution as assembly in a steel cavity (right).

Early Design Optimization Is Key

Collaborating with Henkel during the early vehicle design stage is the best route for an OEM to achieve their vision for BIW performance outcomes. It is the quickest, most reliable and most cost-effective approach. Partnering together, Henkel engineering teams work directly with OEM design engineers. This allows leveraging Henkel's extensive structural foam testing performance database. It also capitalizes on Henkel's extensive expertise in effective structural carrier design.

Henkel has already invested significant effort in studying various structural insert configurations. This helps engineers to understand formats that work well in most applications.

Figure 8 illustrates load-dependent structural insert design examples. All are designed to fit the same BIW cavity of a BEV. Each has varying responses and performances under defined crash-load direction. Rather than starting "from scratch," the results help engineers to start with a design that considers specific load paths. This helps to reduce part development time.

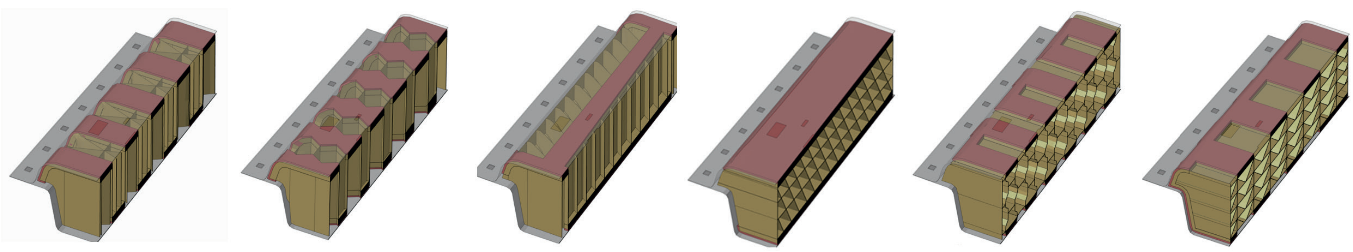
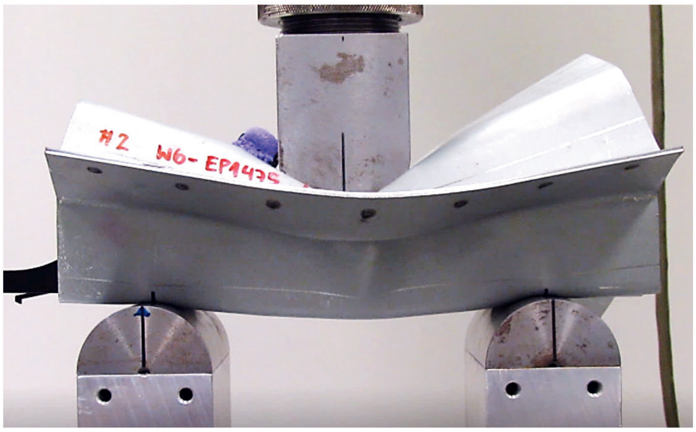


Figure 8 Examples of crash load-dependent structural insert design variants in a BIW cavity cross-section cut.

Proof-of-Concept Validation

Henkel's virtual testing models are proven realistic in numerous customer-specific design scenarios. To assist in the decision-making process, Henkel is able to conduct proof of concept testing at the component or sub-assembly level. It provides the OEM with confidence that completed virtual simulations are valid. This value-added process measures the performance. Part of that performance measurement shows the correlation between the actual part and the virtually developed part. The following part level three-point bend testing examples demonstrate excellent correlation between physical and simulated results at various impact speeds:

- Quasi-static represents a low-speed applied load such as roof crush behavior during a vehicle rollover event. The stiffness of the insert design plays a significant role in the performance



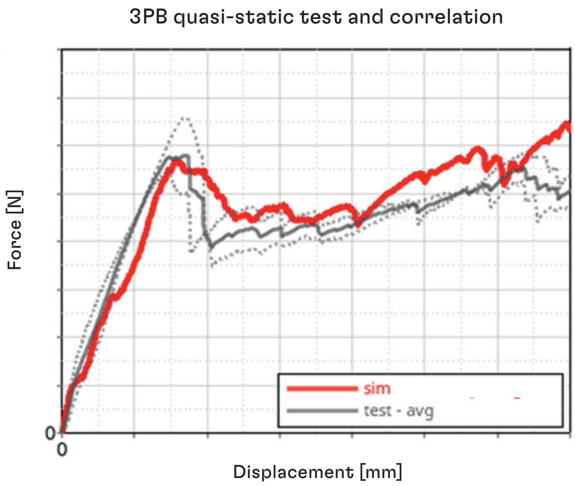
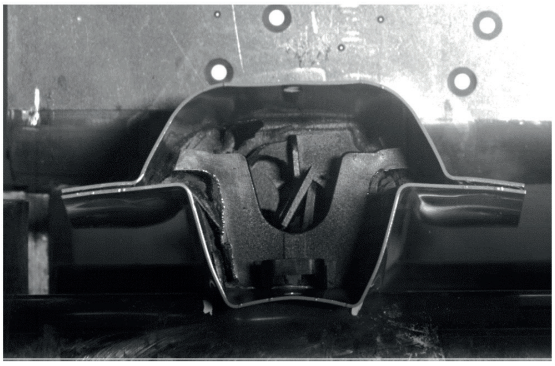


Figure 9 Quasi-static three-point bend testing and the correlation between physical and simulation results.

- High-speed drop tower impact test represents a crash event on a car body section structure. How the structural insert absorbs impact energy illustrates design key performance



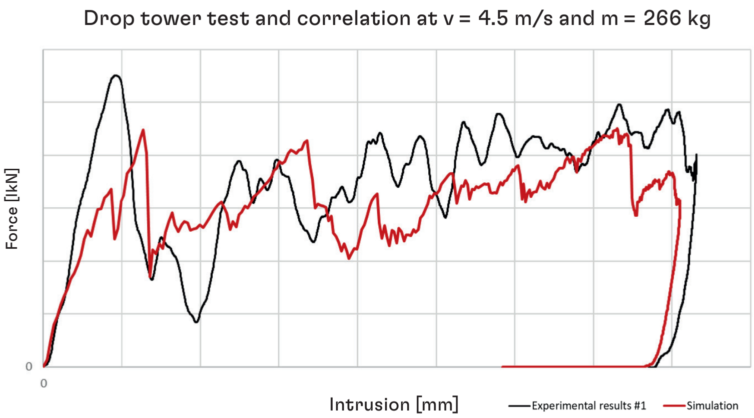


Figure 10 Structural insert under drop tower test using three-point bending configuration and the correlation between physical and simulation results.

STRENGTH WITH SUSTAINABILITY

Innovative Henkel structural insert solutions with integral steel reinforcements can help OEMs meet their sustainability targets. This is accomplished by reducing structural component weights up to 20% compared to conventional all-metal components. OEMs can also be confident that Henkel structural inserts are produced efficiently, generating just 37.7 kg CO_2e per insert.

kg CO_2 eq/Part	HENKEL STRUCTURAL INSERT + STEEL
Formulation	28.0
Packaging	4.4
Production	0.6
Upstream Transportation	4.7
Total	**37.7**

Figure 11 CO_2 emission footprint of Henkel structural insert and steel, 43% (TEROSON EP1450 + PA666GF30) + 57% Steel, e.g., for battery protection).

CO_2 Footprint Percentage Per Insert[1]

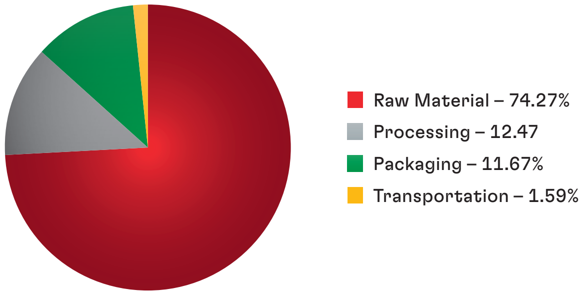


Figure 12 Visual representation of Henkel structural insert CO_2 emission footprint.

Manufacturers can also specify recycled nylon in their structural insert designs to reduce upstream CO_2 emissions. Replacing virgin nylon with recycled alternatives can significantly reduce CO_2 emissions that nylon manufacturing generates.[2]

CONCLUSION

Henkel structural inserts offer OEMs a wide array of benefits for product planning, design and performance. Integrating them early in the design phase allows OEMs to take advantage of Henkel's material science expertise. Henkel structural design experience can also be leveraged to streamline testing and validation time from the start. Further benefits can also be reaped further downstream in the process, including:

- Downgauging or eliminating existing metal reinforcements
- Meeting or exceeding strength-to-weight ratio standards
- Enhancing BIW stiffness and boosting driving stability
- Improving NVH performance for increased passenger comfort when used together with Henkel acoustic products
- Leveraging low-cure capabilities that set the stage for lower paint shop oven temperatures
- Saving material with high-expansion TEROSON structural foam products
- Improving crash performance in critical areas of the BIW

WHAT STRUCTURAL CHALLENGE ARE YOU FACING? START YOUR JOURNEY TOWARD A SOLUTION TODAY.

Visit:
www.next.henkel-adhesives.com

Or contact us directly at:
automotiveoem.marketing@henkel.com

Henkel

[1] Henkel calculates carbon footprint for selected Henkel products. Customers may use product carbon footprint as provided by Henkel only for calculating carbon footprints of their own products when produced using Henkel products. Disclosure and/or distribution of Henkel's data with third parties is prohibited except under the following cumulative conditions: (1) Henkel data cannot be traced, either by extracting it from the customer's environmental data or by any direct correlation between the customer's environmental information and the underlying Henkel product. (2) Any disclosures of Henkel data or other information contained herein requires prior written Henkel consent in each individual case. Henkel data reflect the situation at the time of data collection and have not been verified by an external representative study. Henkel will not provide updates of submitted information. Updates must be requested by the customer and may be provided in Henkel's sole discretion to the extent available. Any calculated data are given to the best of Henkel's knowledge at the time of disclosure. Any information, including any other verbal and/or written statements in connection with carbon footprint data shall not, however, as far as legally permissible, create any guarantee or representation of any kind or any liability of Henkel and shall not relieve the user from undertaking its own investigations and tests. In particular, to the extent legally permissible, Henkel does not assume any representation or warranty for the suitability of Henkel products for customers' individual purposes including but not limited to the achievement of any sustainability effects of customer's products.

[2] Based on recycled nylon raw material supplier estimates.