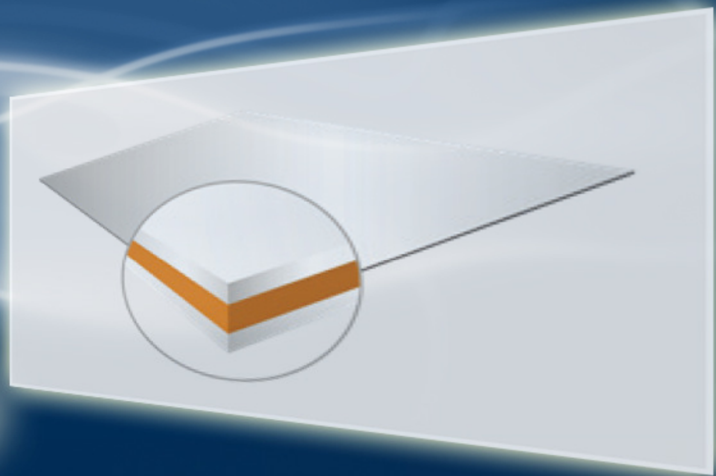
Modeling approach for steel sandwich materials in automotive crash simulations

David Pieronek, Dr. Thorsten Böger, Rolf Peter Röttger

2012-10-09, Ulm



ThyssenKrupp Steel Europe

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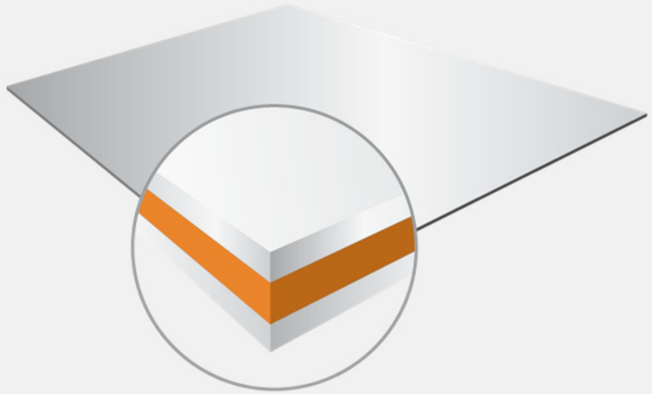
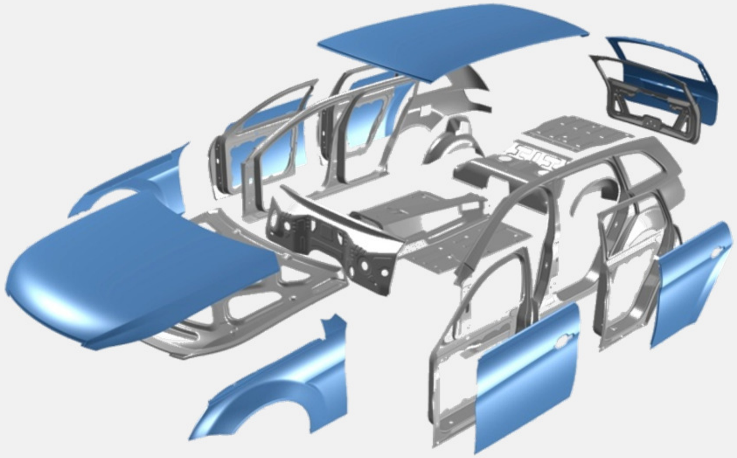
Modeling approach for steel sandwich materials in automotive crash simulations

Agenda

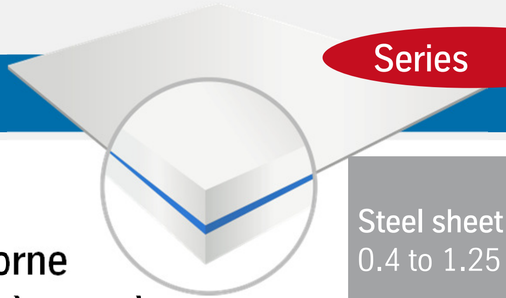


- Steel sandwich materials
- Crash CAE method
  - Approach
  - Validation and verification
- Application / InCar project
- Conclusion



Steel sandwich materials
Comparison

BONDAL® — Series



- Application: Structure-borne sound damping and sound insulation in vehicle acoustics
- Very thin, permanently visco-elastic polymer layer
- Reduced bending stiffness by vibration damping core
- Suitable for paint shop

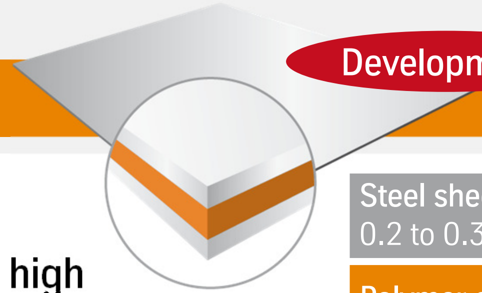
Steel sheet
0.4 to 1.25 mm

Polymer core
0.025 to 0.05 mm

Steel sheet
0.4 to 1.25 mm

➔ Focus: Acoustics, vibration damping

LITECOR® — Development



- Target: Material with high lightweight design advantage at lower costs in comparison to aluminium
- Very thin steel layers (from 0.20 mm)
- Tailor made flexural stiffness by individual sandwich configuration
- Suitable for paint shop

Steel sheet
0.2 to 0.3 mm

Polymer core
from 0.3 mm

Steel sheet
0.2 to 0.3 mm

➔ Focus: Lightweight design

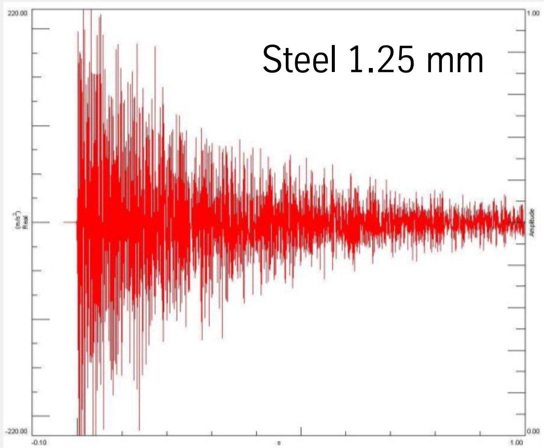
Steel sandwich materials

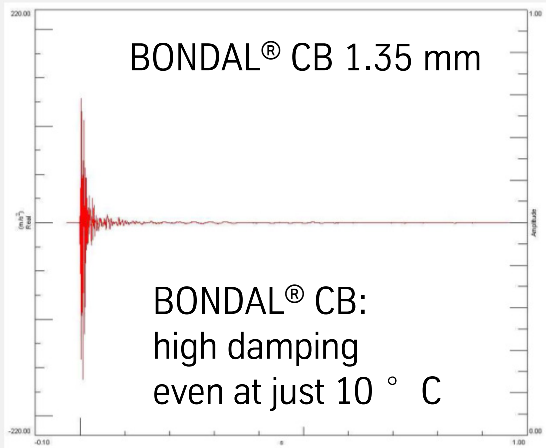
BONDAL® CB: Firewall Mercedes A- and B-Class

- Two firewalls in comparison
  - Solid steel sheet
  - BONDAL® CB

Test temperature
10 ° C

- Damping behavior of vibrations (frequency response analysis)





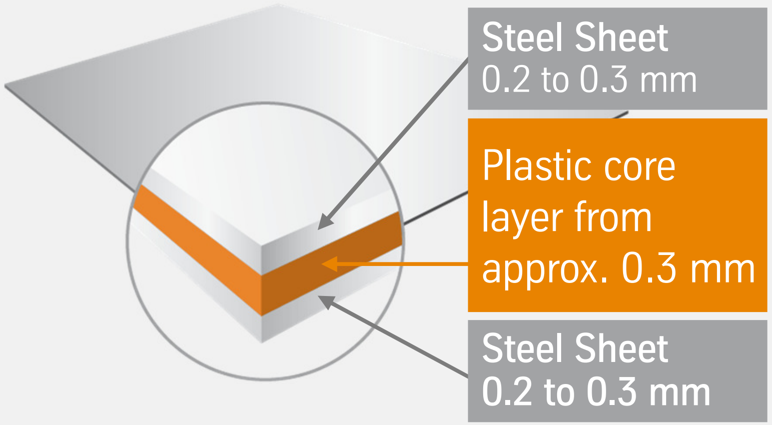
➔ Mass savings and increased constructed size by reduction of damping insulation

Steel sandwich materials

Innovative composite material for automotive lightweight engineering

LITECOR®

- Composite material consisting of thin steel cover sheets and thermoplastic interlayer
- Combines the high strength of steel with the low weight of plastic
- Very high flexural stiffness – tailor made by individual layer design
- Asymmetric sandwich structure possible, tailored adjustment of grades & material thickness
- Integration into BiW: suitable for paint shop
- Production starts with inner parts, development target is outer panel quality

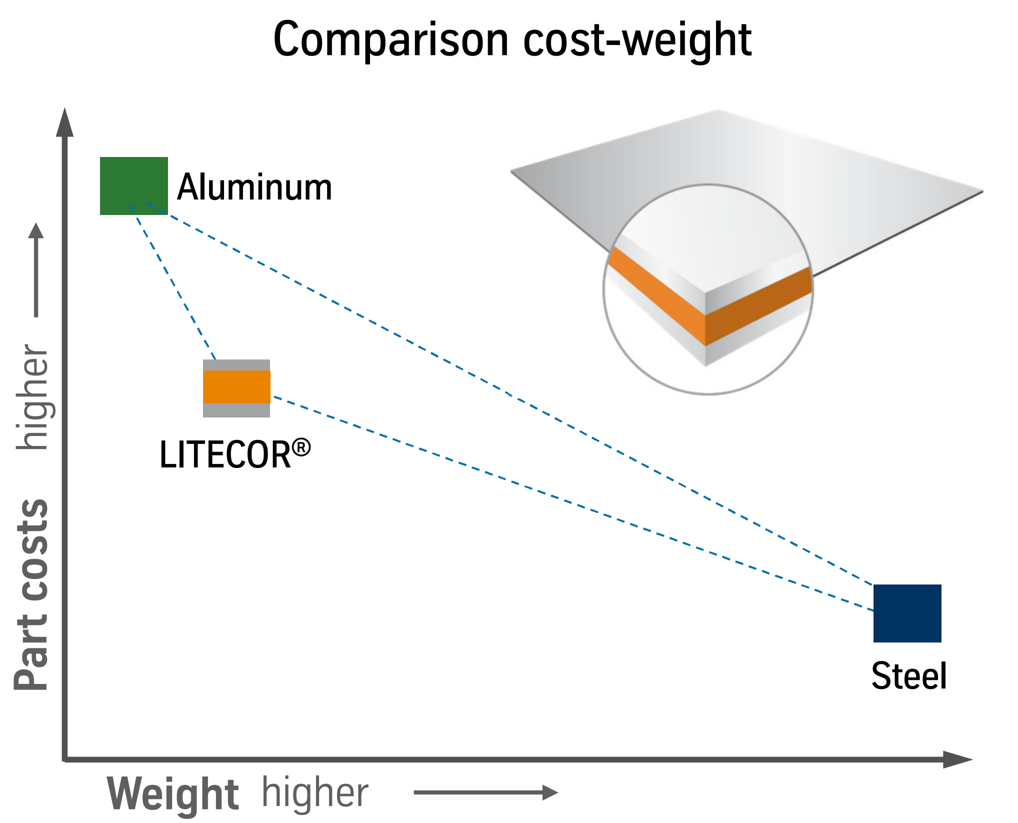


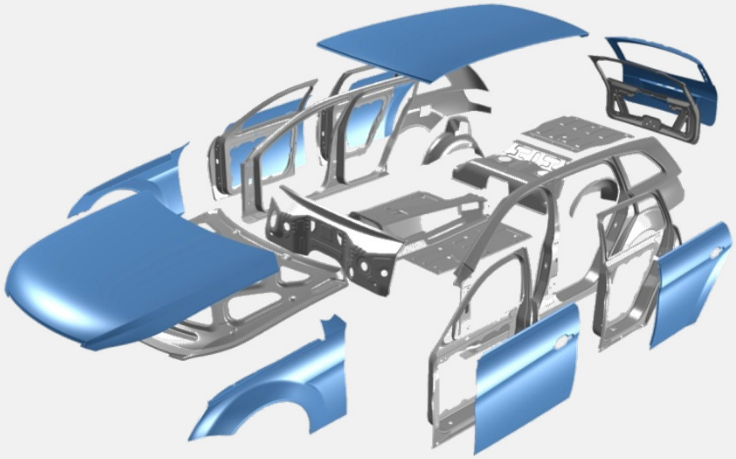
LITECOR®

➔ The economical alternative to aluminum for all large-scale parts

Steel sandwich materials

LITECOR®: Material for large-scale outer and inner car body panels





Outer panel parts
Inner panel parts

➔ Optimal solution for car classes with high cost pressure

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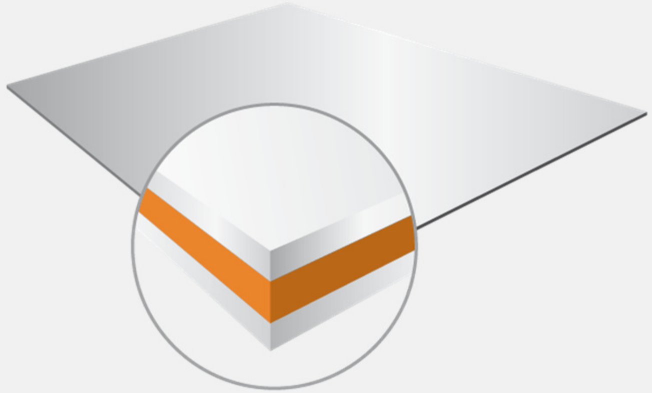

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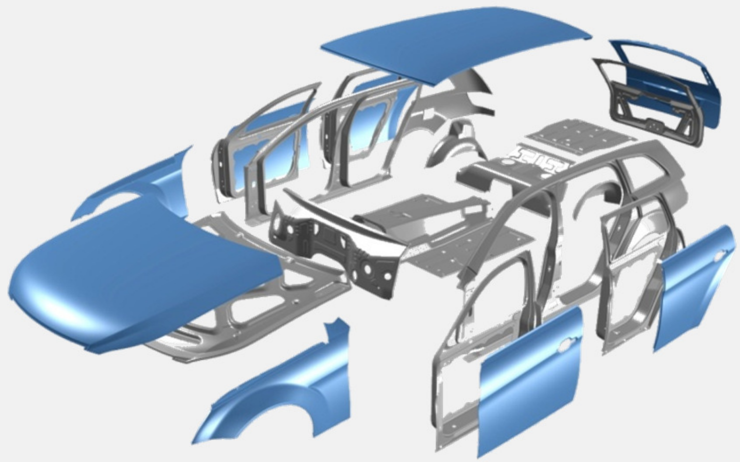
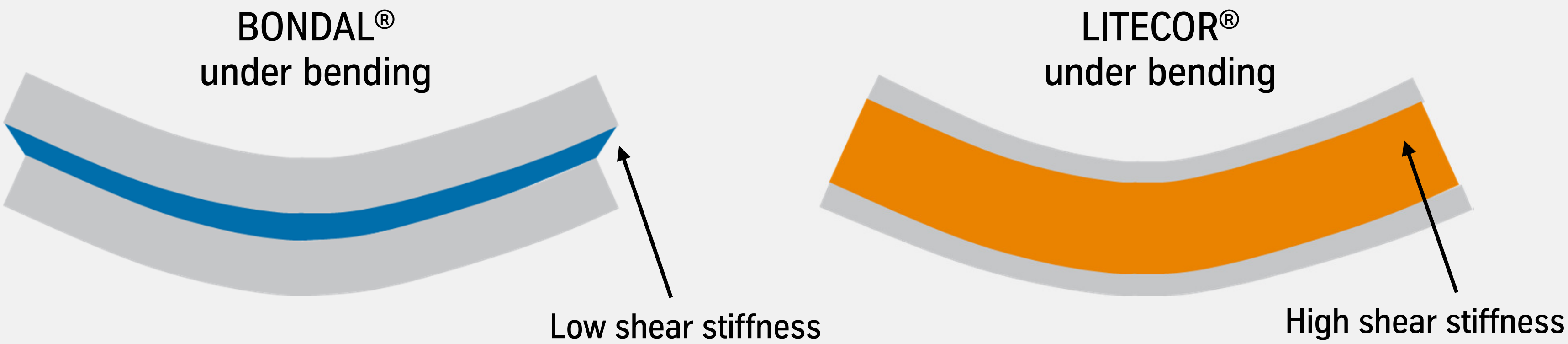


Crash CAE method

Steel sandwich material properties

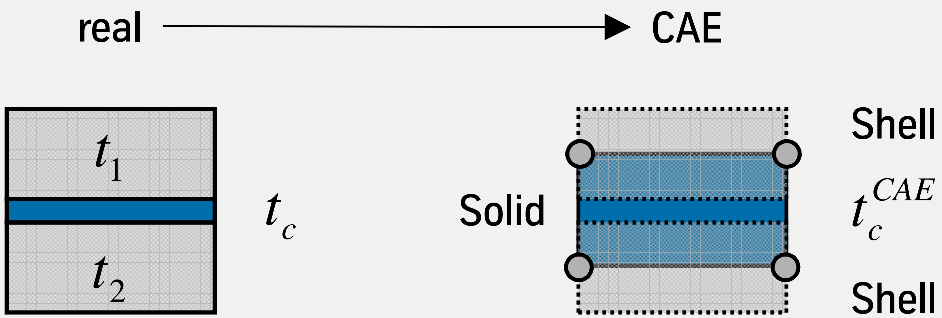
* Plate flexural stiffness based on 1,780 x 1,688mm²/analytical calculation

Material	Configuration / Thickness	Membrane Stiffness*	Bending Stiffness*
Steel (Reference)	0.75 mm	100 %	100 %
BONDAL®	0.4 / 0.05 / 0.4 mm → 0.85 mm	106 %	30 %
LITECOR®	0.2 / 0.4 / 0.2 mm → 0.8 mm	53 %	106 %



Crash CAE method

BONDAL®: Shell-Solid-Shell Approach



Real core Material Properties (Index c)

- Material model: ELASTIC
- Ec Elasticity module (dynamic) = 5,0 MPa
- ρc Density = 1,0 e-9 t/mm³
- Poisson Coefficient = 0,48

Steel Sheet Properties: Mild Steel

Plastic Material Model with strain rate dependent flow curves

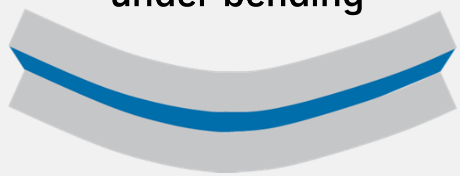
Scaling of core properties

$$t_c^{CAE} = t_c + 0{,}5 \cdot (t_1 + t_2)$$

$$\rho_c^{CAE} = \rho_c \cdot \frac{t_c}{t_c^{CAE}}$$

$$E_c^{CAE} = E_c \cdot \frac{t_c^{CAE}}{t_c}$$

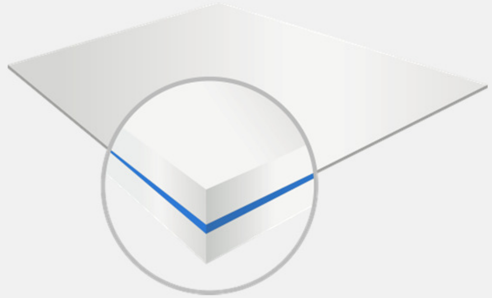
BONDAL®
under bending



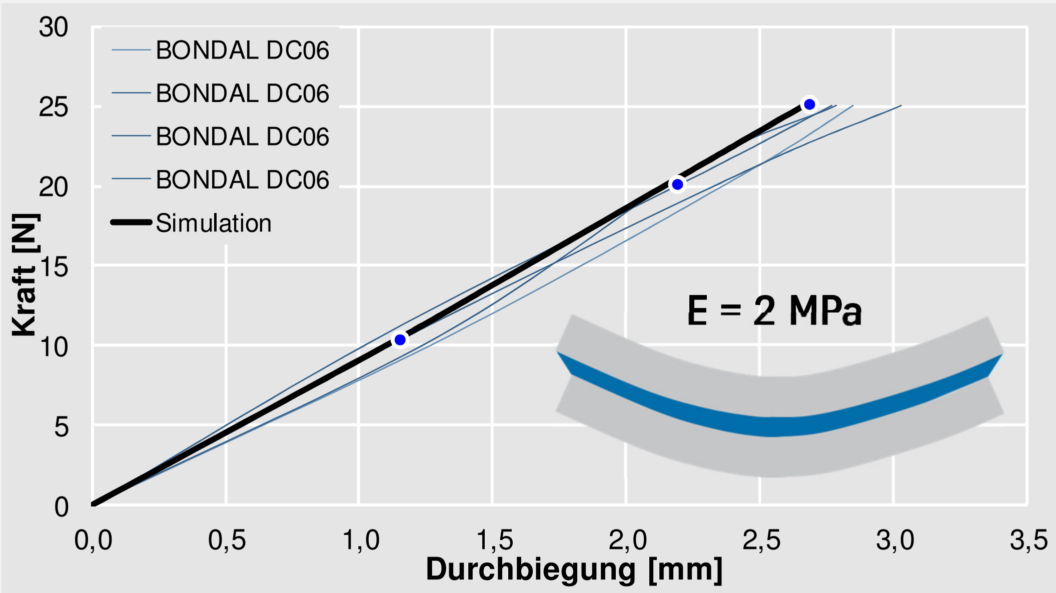
➔ Simulation model: relative displacement of steel sheets under bending is possible

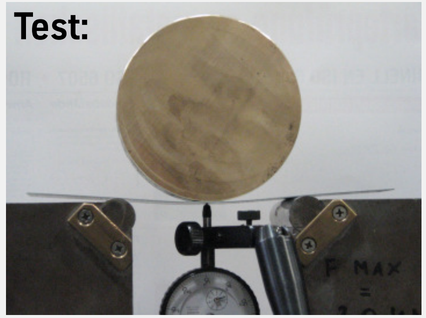
Crash CAE method

BONDAL®: Validation

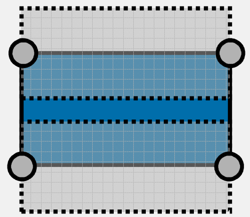


- Three-point bending test with BONDAL®
  - Load by weights (3 levels)
  - Evaluation of deformation after defined holding time





Shell/solid/Shell

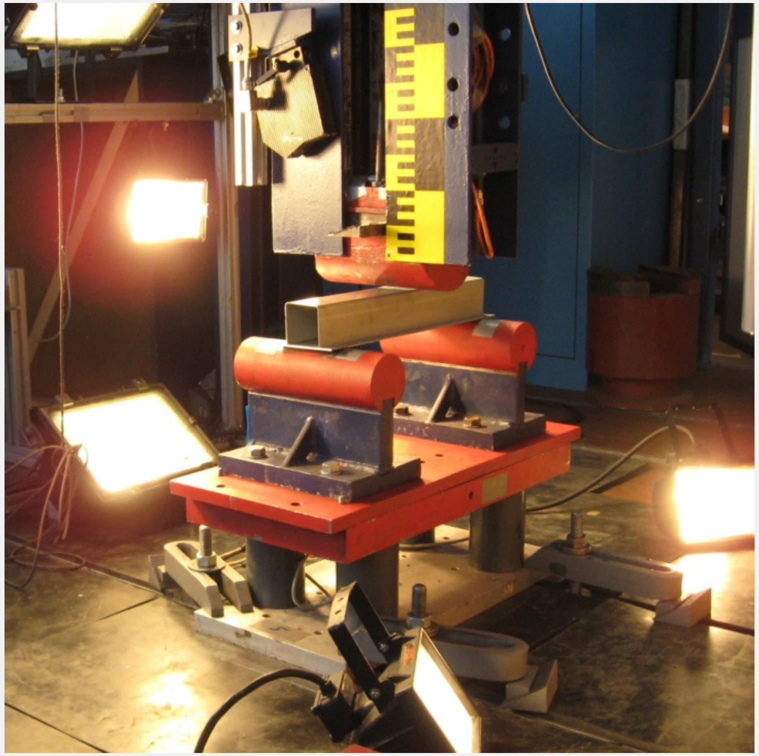


→ Identification of static elastic core module by reverse engineering

Crash CAE method

BONDAL®: Validation (Three-point bending test)

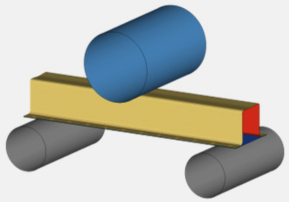
- Test setup
  - Impactor: mass 25 kg, radius 62.5 mm
  - Support: distance 350 mm, radius 30 mm
- Test series 1 (solid sheet metal DX56)
  - Energy 250 J, drop height h 1.0 m (4.6 m/s)
  - Energy 350 J, drop height h 1.4 m (7.1 m/s)
- Test series 2 (BONDAL® CB DC06)
  - Energy 150 J, drop height h 0.6 m (3.4 m/s)
  - Energy 250 J, drop height h 1.0 m (4.6 m/s)
- Test evaluation
  - Displacement: laser measuring system
  - Force: acceleration at the impactor

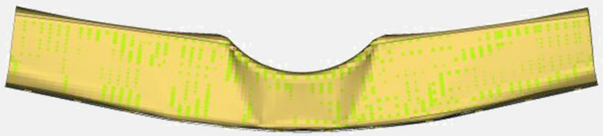


Three-point bending crash performance

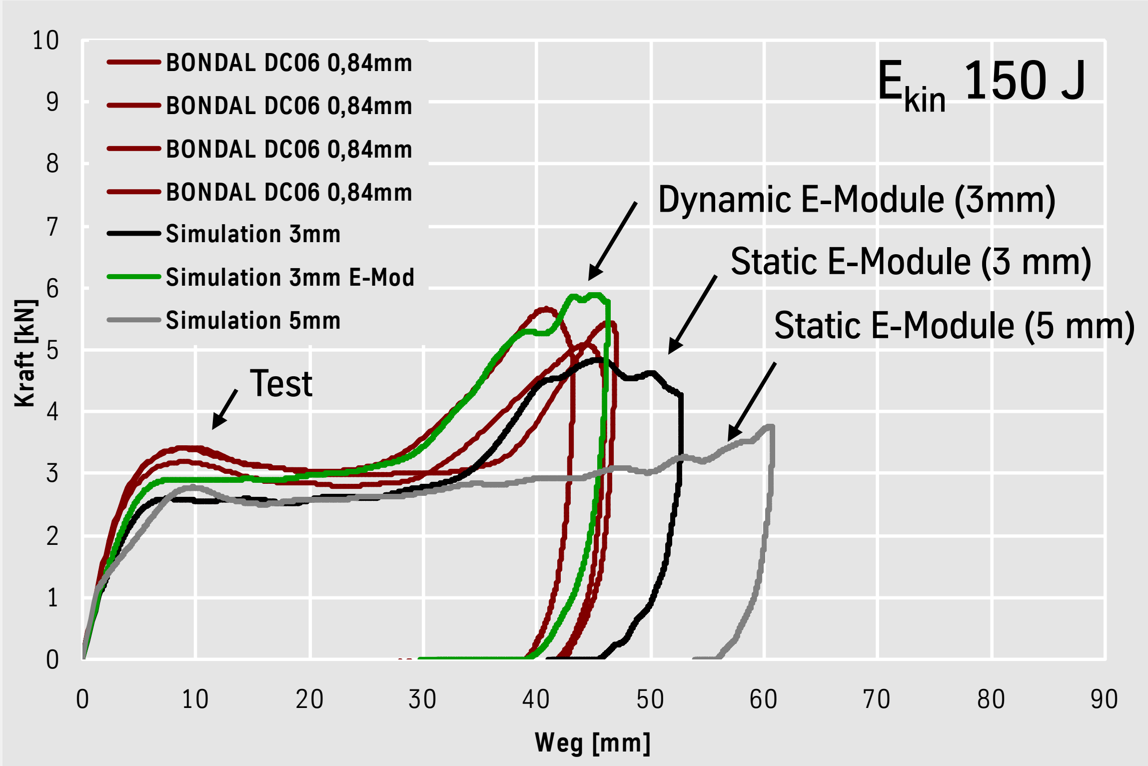
Crash CAE method

BONDAL®: Validation (Three-point bending test)





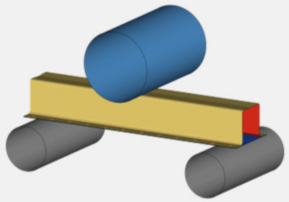
Simulation

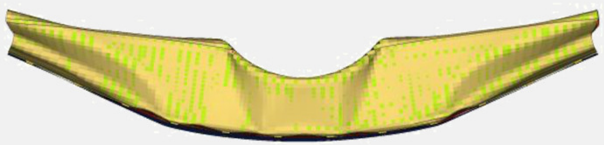


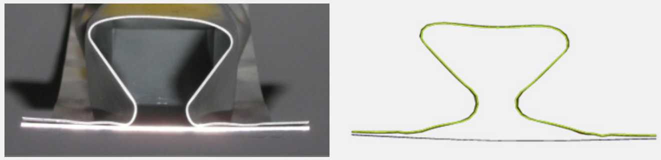
➔ Good agreement between test and simulation is achieved

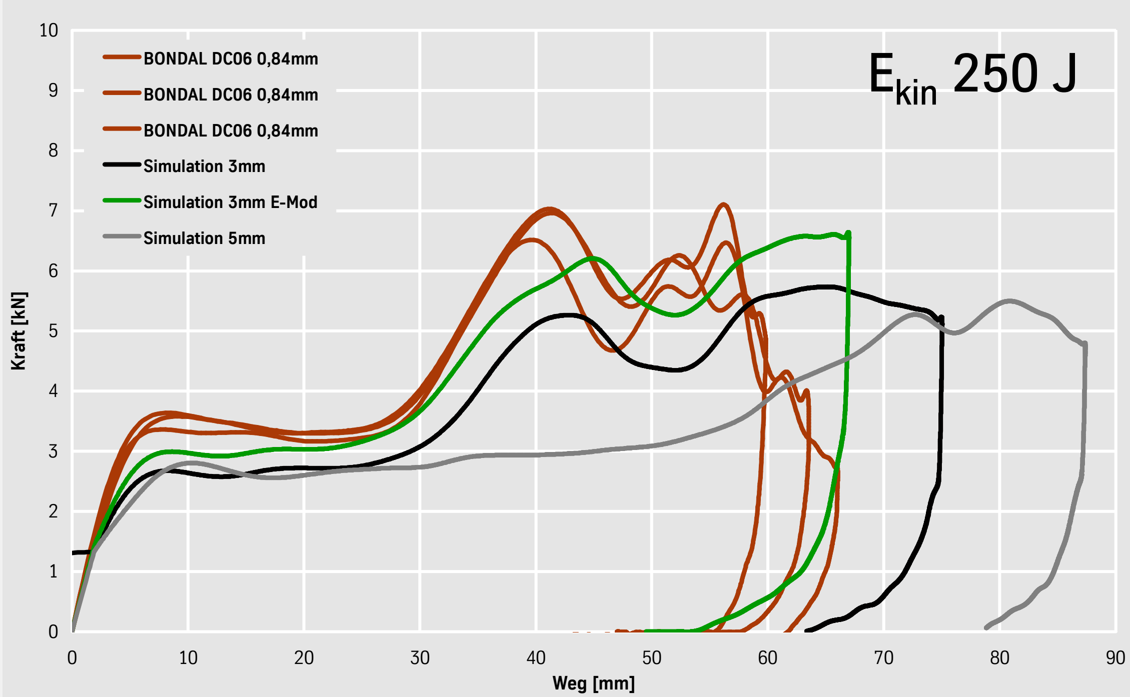
Crash CAE method

BONDAL®: Validation (Three-point bending test)









→ Good agreement between test and simulation also for higher energy input

Crash CAE method

BONDAL®: Verification (Axial crushing)

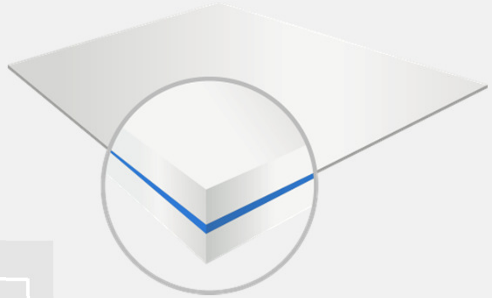
- Test setup
  - Impactor: mass 30 kg, level
  - Absorption: solid plate with milled groove
- Test series (BONDAL® DC06, solid sheet metal)
  - Energy 800 J, drop height h 2.7 m (7.1 m/s)
- Test evaluation
  - Displacement: laser measuring system
  - Force: acceleration at the impactor (acceleration signal SAE 1000 filter)

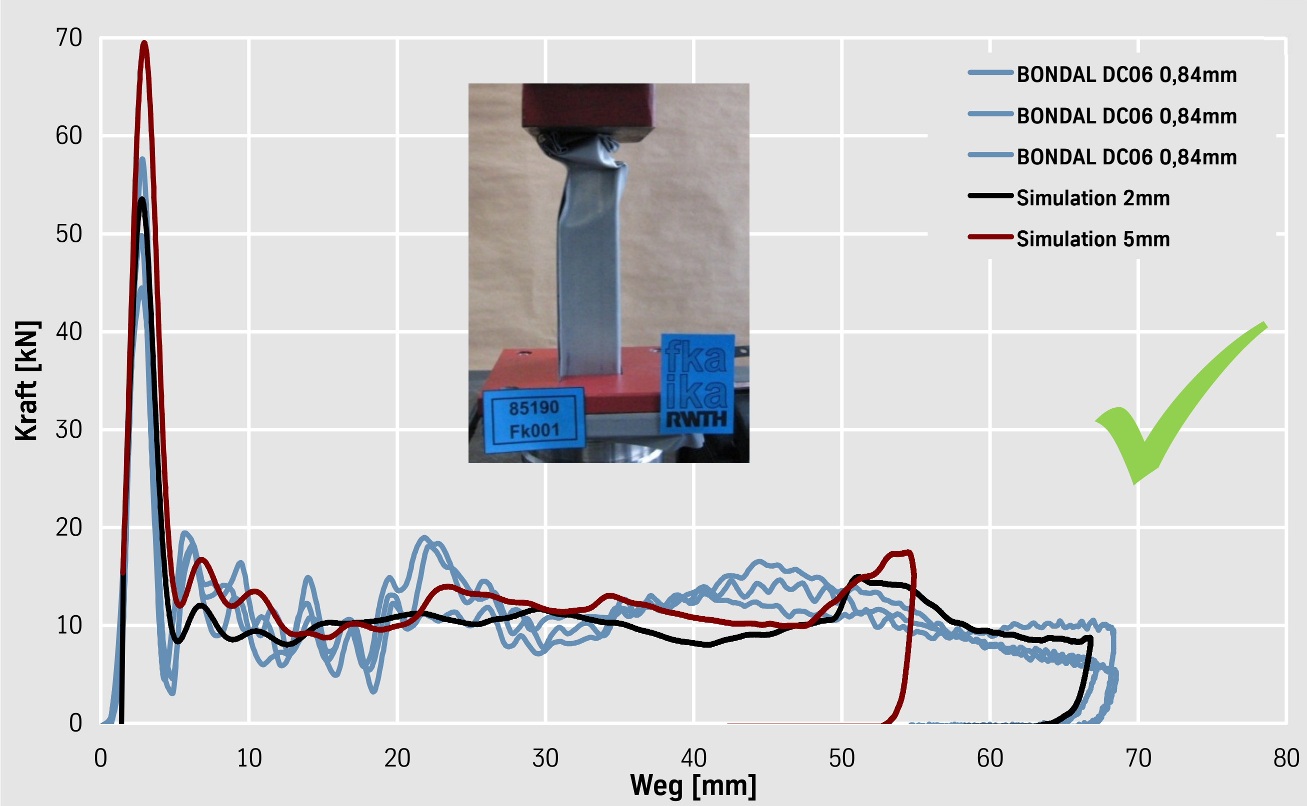
Test setup: axial crash performance

→ Evaluation of simulation model quality by additional crash load case

Crash CAE method

BONDAL®: Verification (Axial crushing)





Test

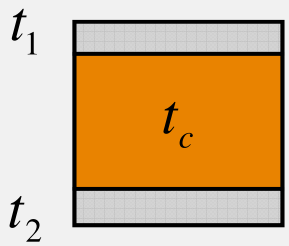
Simulation

→ Successful verification of simulation technique for BONDAL ®

Crash CAE method

LITECOR®: Multi-Layered-Shell-Approach

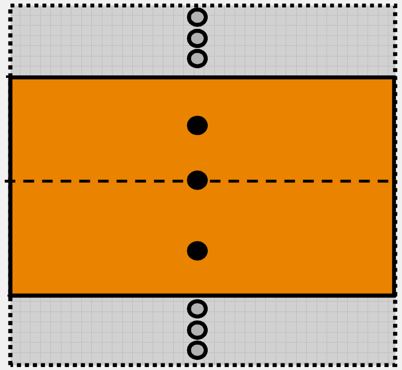
real → CAE



CAE

Multi-Layered-Shell

Material properties are defined per integration points

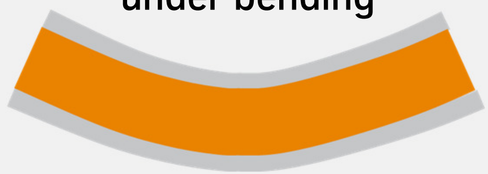


Shell midsurface

Core Material Properties (Index c)

- Material model: ELASTIC / PLASTIC
- Elasticity modulus (dynamic) = 980 MPa
- Density = 1,0 e-9 t/mm^3
- Poisson Coefficient = 0,38

LITECOR® under bending



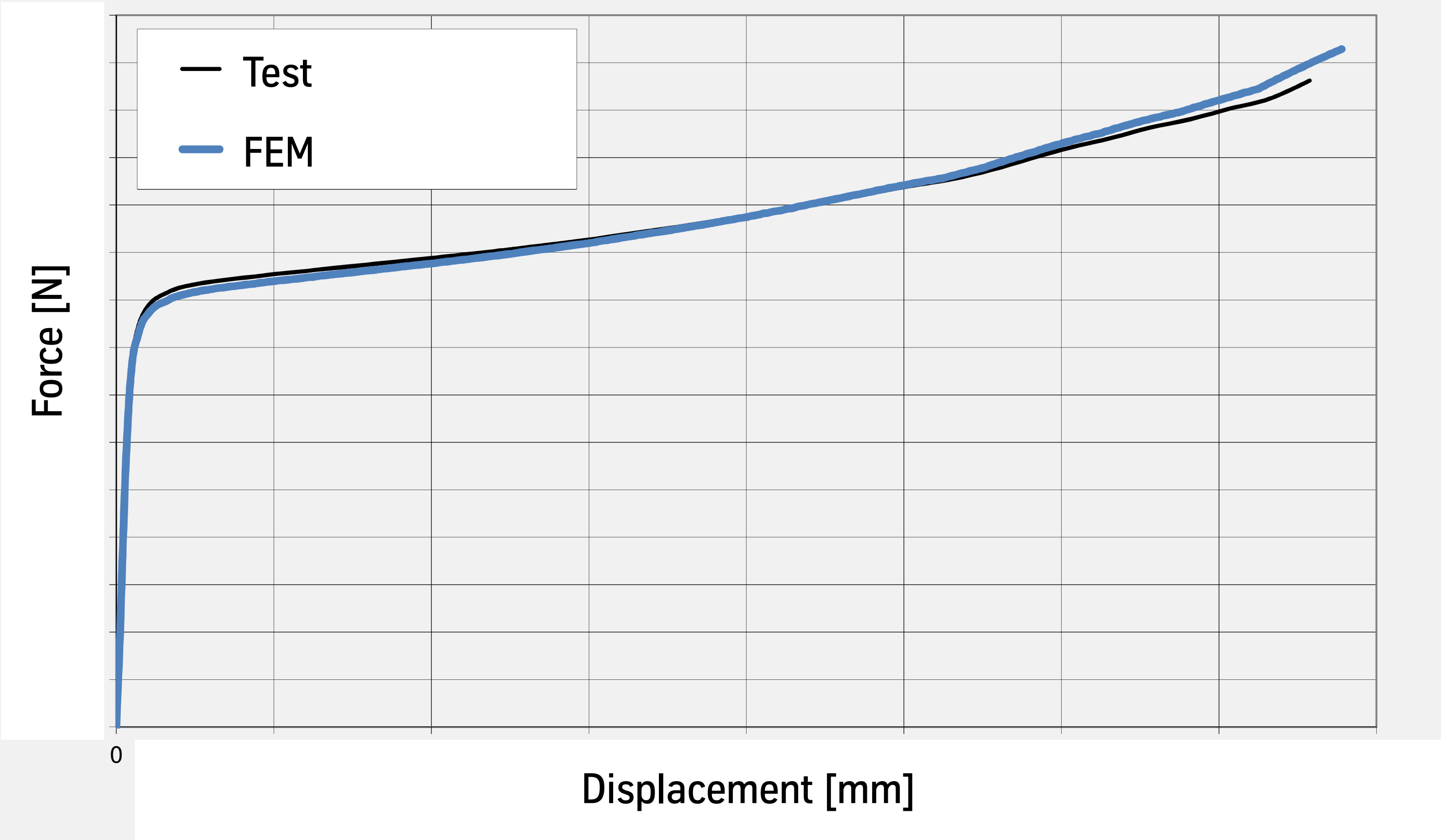
Steel Sheet Properties: Mild Steel and Dual-Phase-Steel

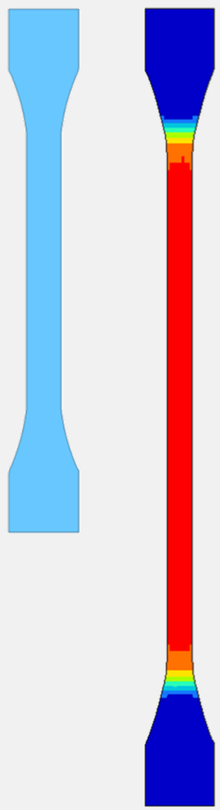
Plastic Material Model with strain rate dependent flow curves

→ Steel layers dominate mechanical properties

Crash CAE method

LITECOR®: Core material characterisation under tensile loading

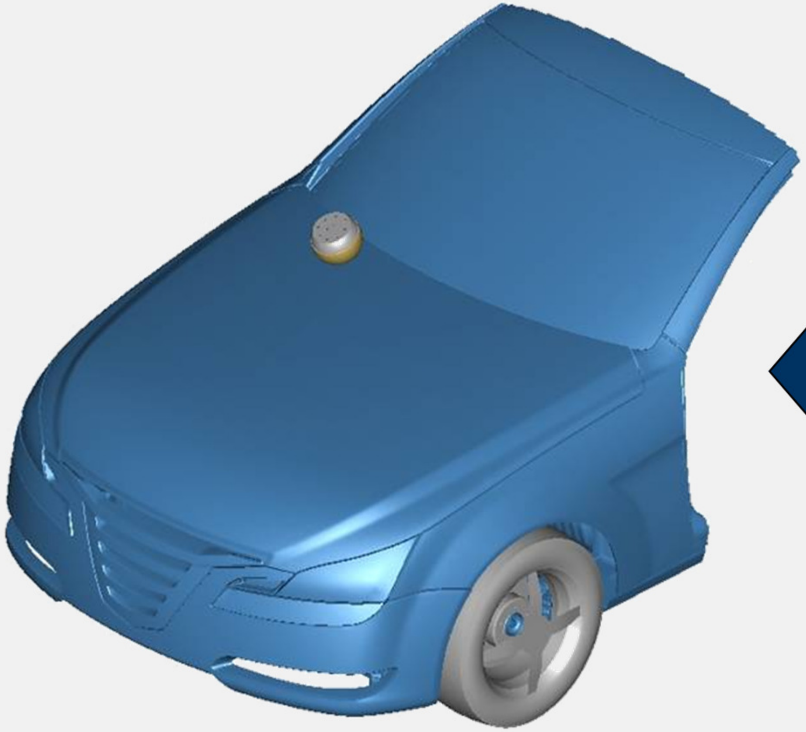




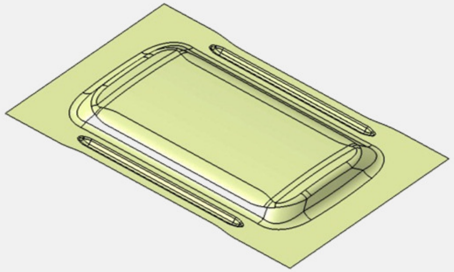
➔ Identification of plastic core material behaviour under static loading conditions

Crash CAE method

LITECOR®: Verification (pedestrian safety)



Simplified sub-model

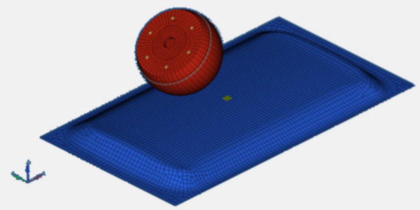


cassette specimen with typical outer panel deep drawing conditions (phi 2 - 3 %)

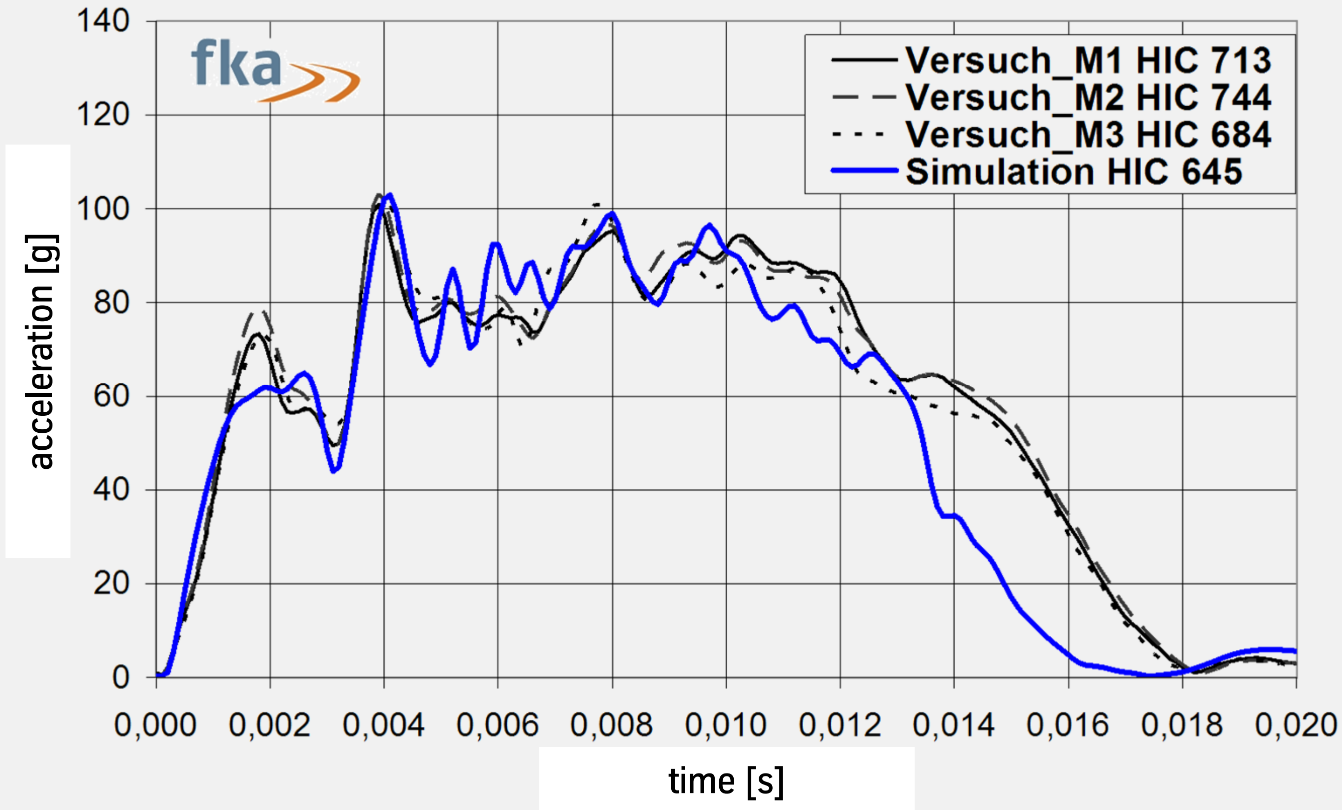
➔ Pedestrian safety concerns are transferred to a simplified sub-model

Crash CAE method

LITECOR®: Verification (pedestrian safety)

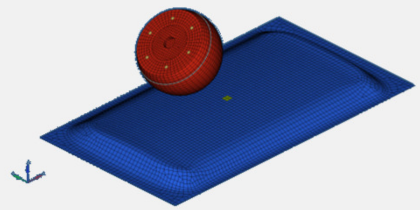


Results for monolithic steel H180 0,7 mm

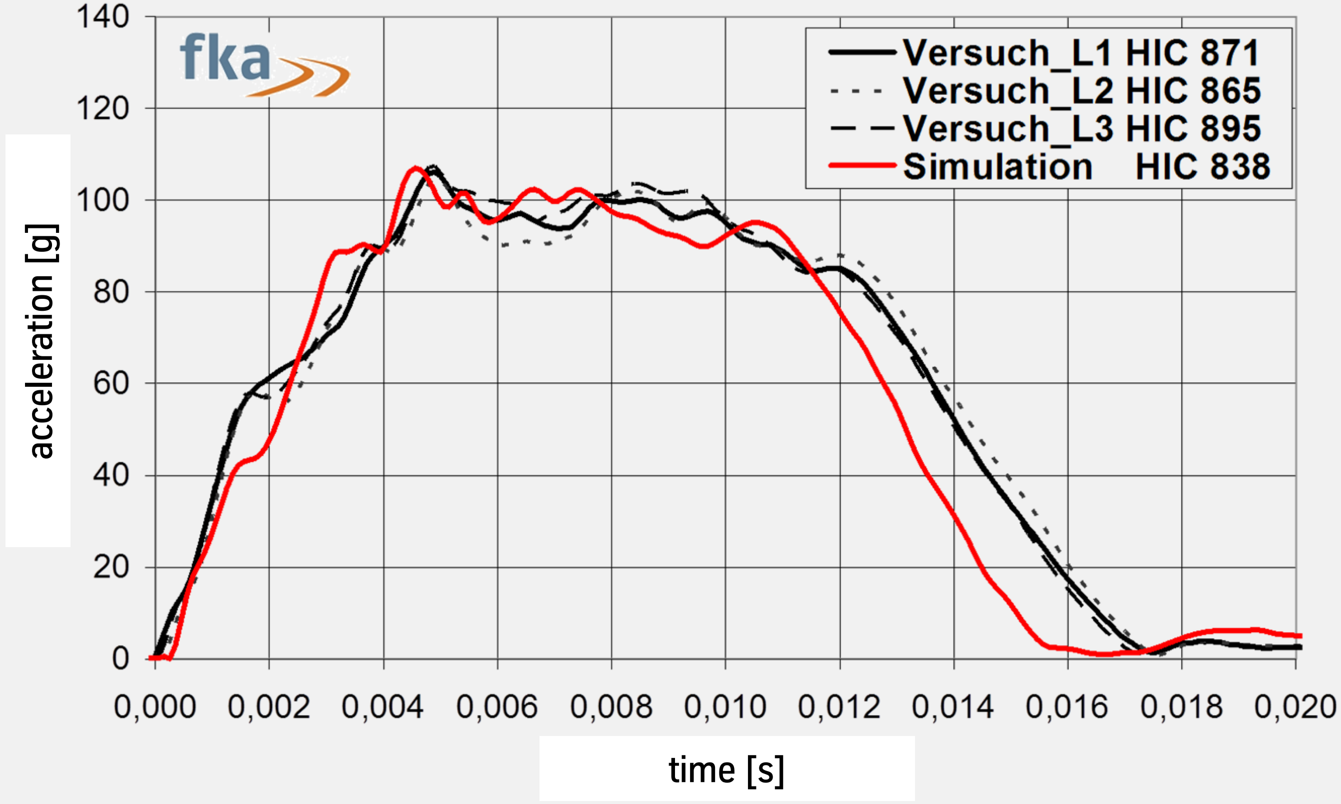


Crash CAE method

LITECOR®: Verification (pedestrian safety)

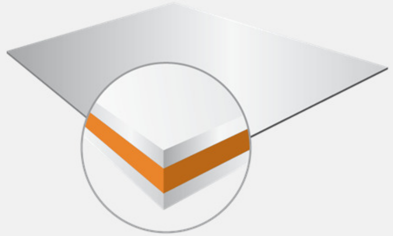


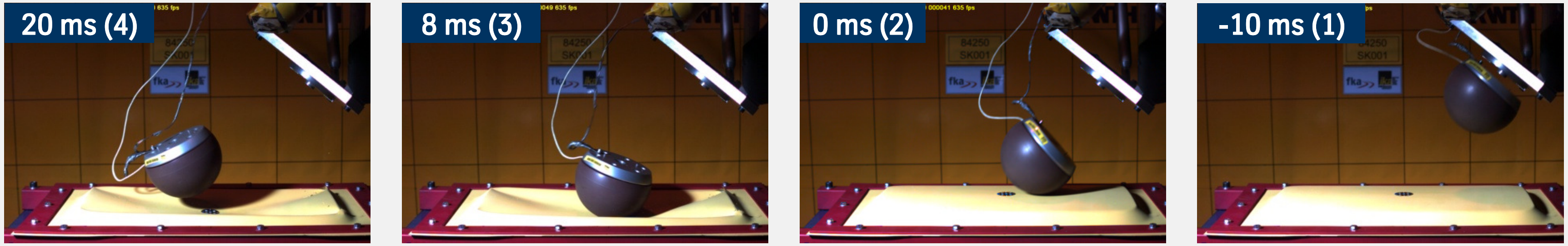
Results for LITECOR® (0,25 mm / 0,6 mm / 0,2 mm)



Crash CAE method

LITECOR®: Verification (pedestrian safety)



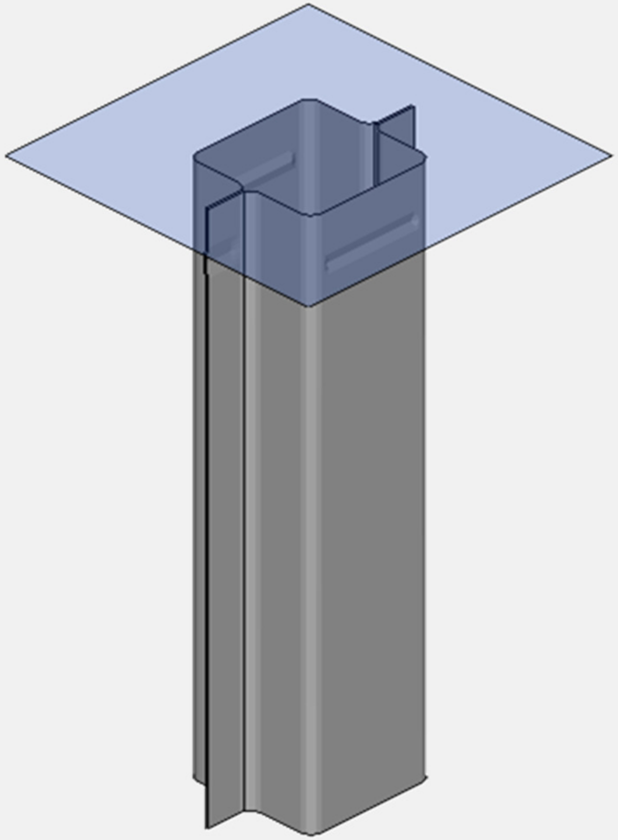


Test run: impact phase of ACEA impactor 3,5 kg

➔ Good agreement between test and simulation is achieved

Crash CAE method

LITECOR®: Verification (Axial crushing)



- **Impactor:**
  - m = 60 kg, h = 3,7 m, E = 2200 J
- **Specimen:**
  - Dim: 60 mm x 60 mm x 250 mm
  - Joining: Bonding
  - LITECOR® new material:
    - Variant: 0,25 / 0,40 / 0,25
    - DP 500 / PE-PA / DP 500
- **Evaluation:**
  - Deformation: Impactor displacement
  - Load: Acceleration from sensor within impactor (filter SAE 180)
  - Stability of folding
  - Delamination and Fracture

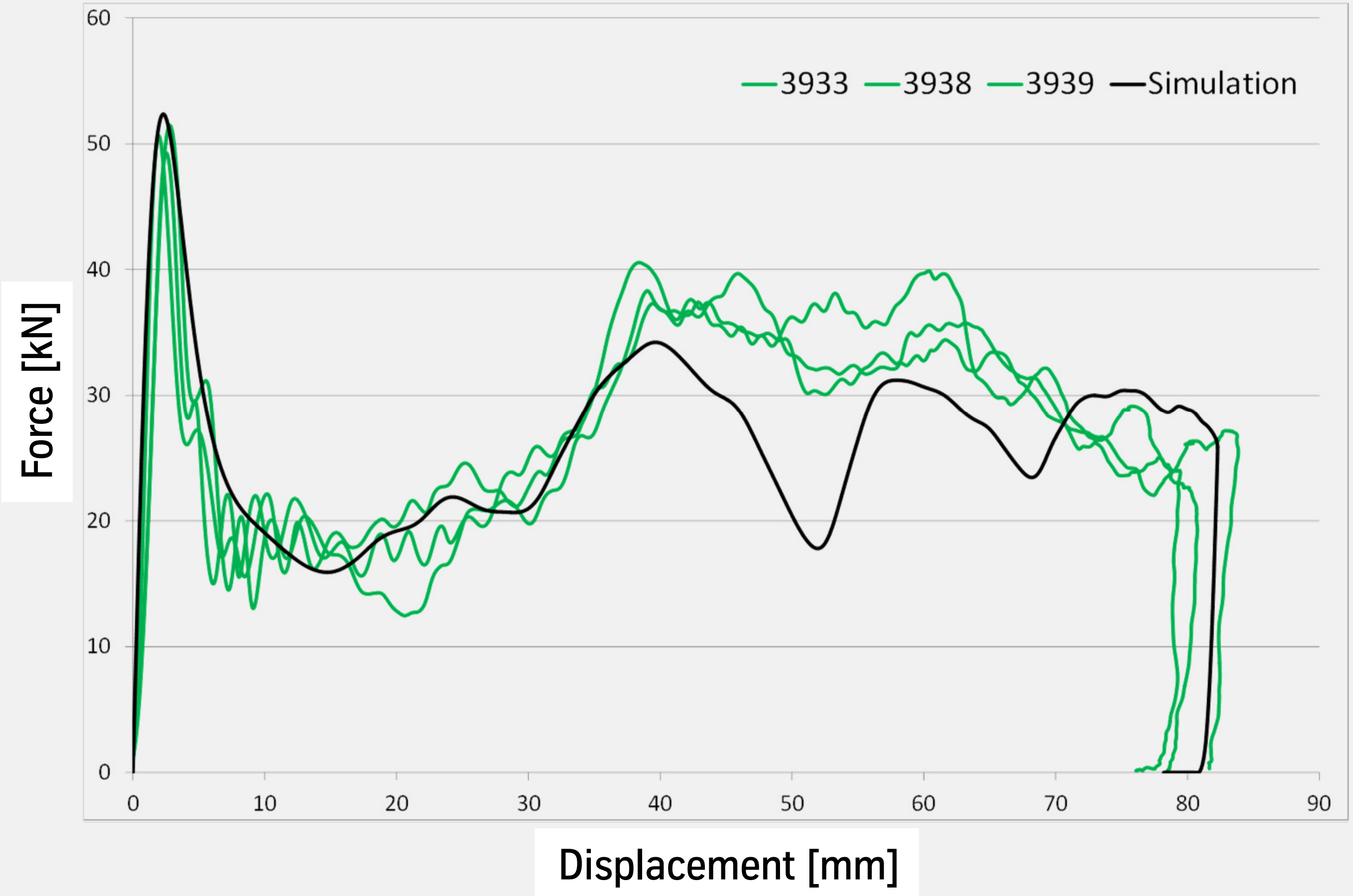
Crash CAE method

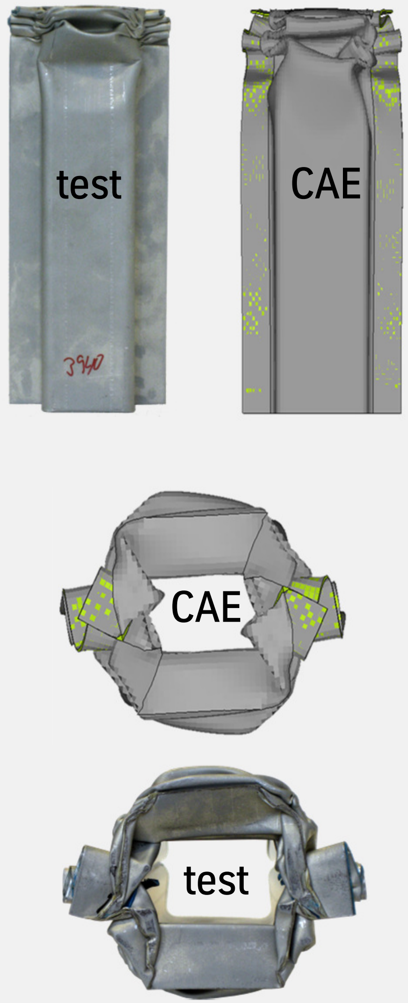
LITECOR®: Verification (Axial crushing)

➔ Stable folding without delamination and fracture

Crash CAE method

LITECOR®: Verification (Axial crushing)





→ Successful verification of simulation technique for LITECOR®

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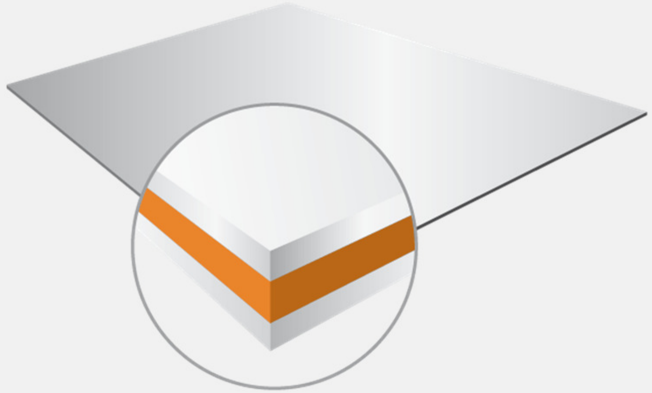

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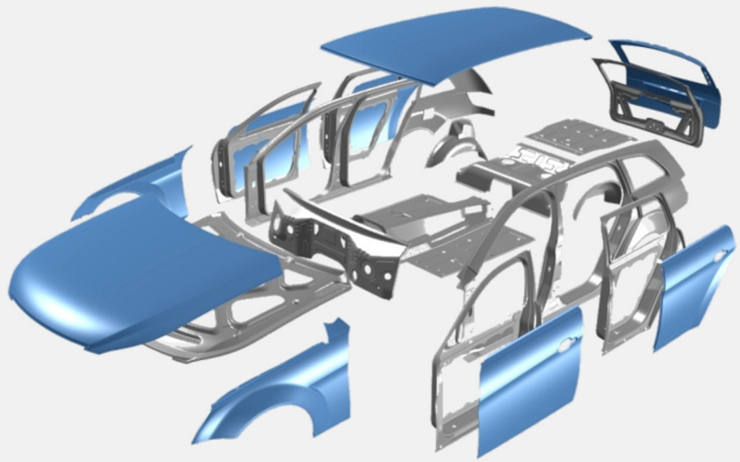
- **Application / InCar project**
- Conclusion

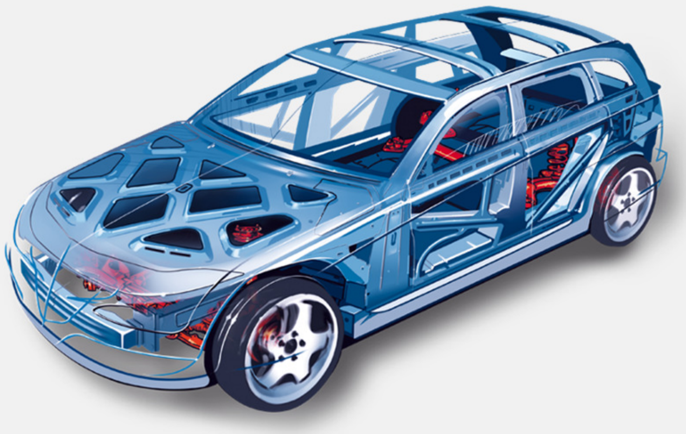


InCar® – the modular solution kit for the automotive industry

Individual solutions to different customer requirements

- Innovative modular system with more than 30 solutions for body, chassis and powertrain
- Developments focused on key auto industry requirements: weight, costs, functionality and CO_2 emissions
- Manufacturer-independent reference structure
- Integrated lifecycle assessment shows CO_2 reduction potential for all solutions
- More than 70% of the solutions are directly available, production readiness of all developments by 2014 targeted

InCar®



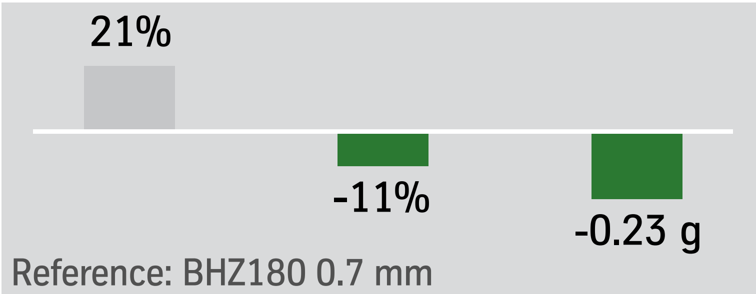
➔ Bringing innovations "InCar" together with customers

Application / InCar project

Highlights: Solutions with steel sandwich materials

LITECOR®
0.25 / 0.40 / 0.25 mm

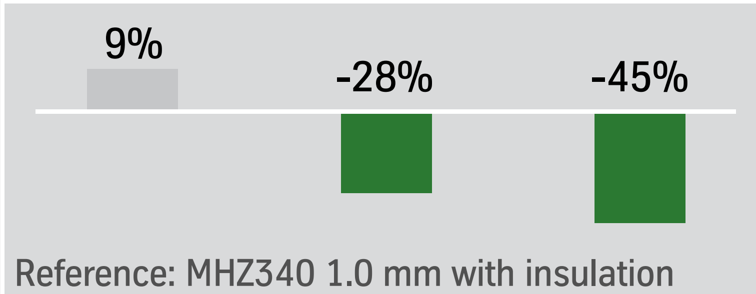
Costs	Weight	CO_2/km



Serie 2010 2011 2012 2013

BONDAL®
0.50 / 0.50 / 0.50 mm

Costs	Weight	Package



Serie 2010 2011 2012 2013

Modeling approach for steel sandwich materials in automotive crash simulations

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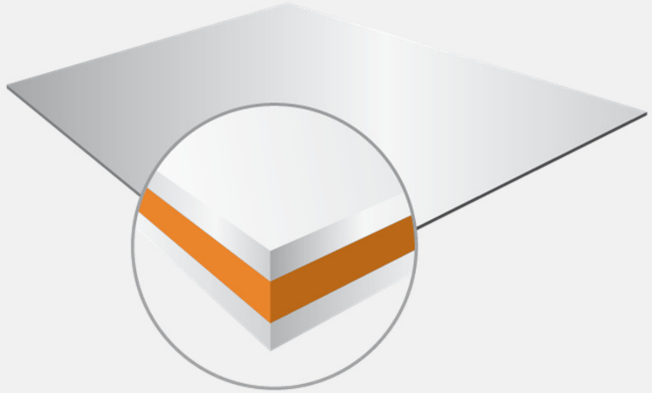

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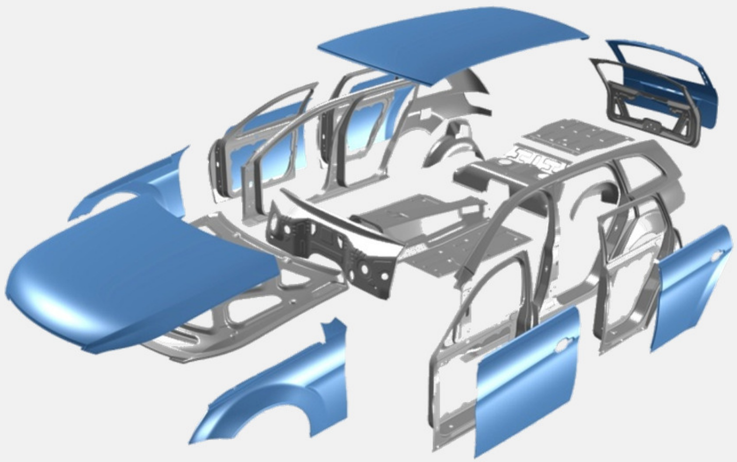

Modeling approach for steel sandwich materials in automotive crash simulations

Conclusion

- Presentation of two innovative steel composite materials for cost-effective automotive lightweight engineering.
- General crash simulation method for BONDAL® and LITECOR® in automotive crash simulations verified (LS-Dyna).
- Change of steel cover material and thickness can be considered by CAE-approach and easily adjusted.
- Application of developed simulation models to InCar project. Several benefiting steel sandwich material solutions were developed.
- Model migration to different crash software codes possible

Thank you for your attention !

ThyssenKrupp Steel Europe