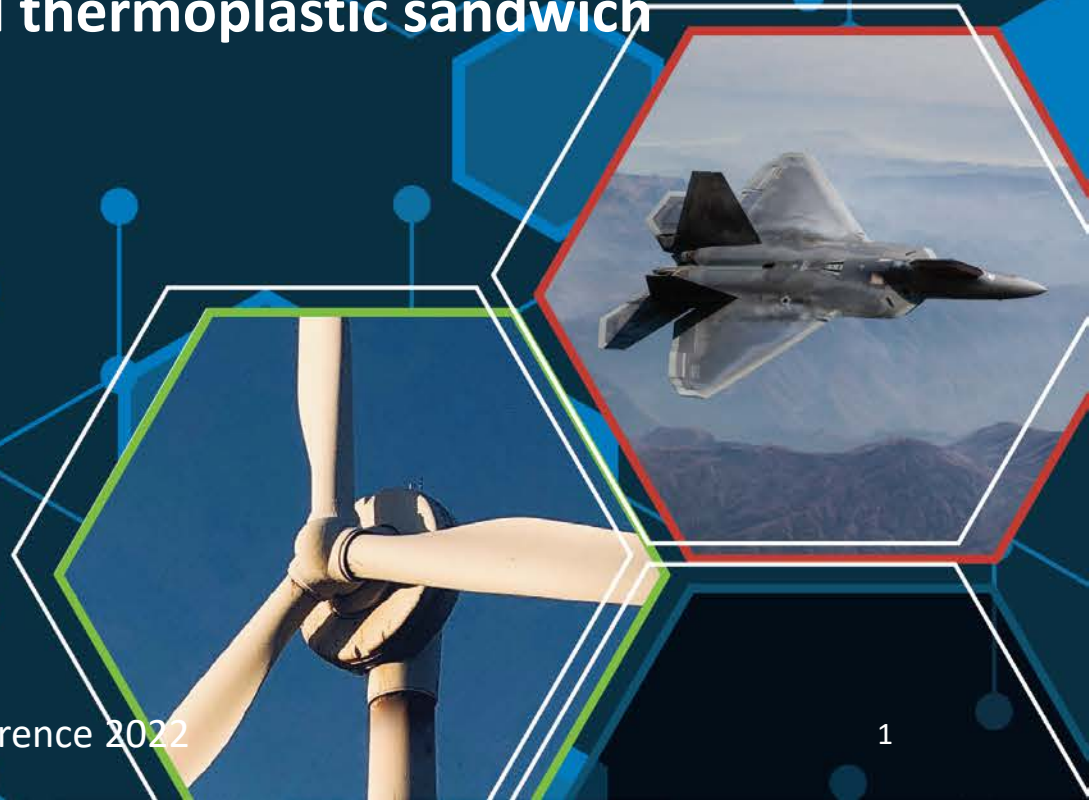


Using r-PET for innovative recyclable foam cored thermoplastic sandwich structures

Stefan Reuterlov

Armacell



Using r-PET for innovative recyclable foam cored thermoplastic sandwich structures

- ① ABOUT ARMACELL
- ② ARMACELL r-PET FOAM SOLUTIONS
- ③ HIGH DENSITY r-PET VS END GRAIN BALSA (EGB)
- ④ Q&A

// ARMACELL AT A GLANCE

3,135 employees worldwide

A global leader and the inventor of flexible elastomeric foams for equipment insulation

2 main businesses: Advanced Insulation and Engineered Foams

HQ in Luxembourg with regional head offices around the globe



24 production facilities in 16 countries on 4 continents

6 destination markets:
Commercial Equipment / Residential Equipment / Energy / Industrial / Transport / Sports & Leisure

A multi-material and multi-product company

€ 644,4 m total **net sales** in 2019

// Two business divisions



ADVANCED INSULATION

Flexible foams for the insulation of technical equipment utilised for the transport of energy

- Heating, Ventilation & Air Conditioning (HVAC)
- Plumbing
- Refrigeration
- Oil & Gas
- Commercial & Residential Equipment



ENGINEERED FOAMS

High-performance foams for the use in a broad range of end markets, **including r-PET foam cores**

- Wind Energy
- Automotive
- Transport
- Sports & Leisure

€ 502m
Net Sales



€ 142m
Net Sales



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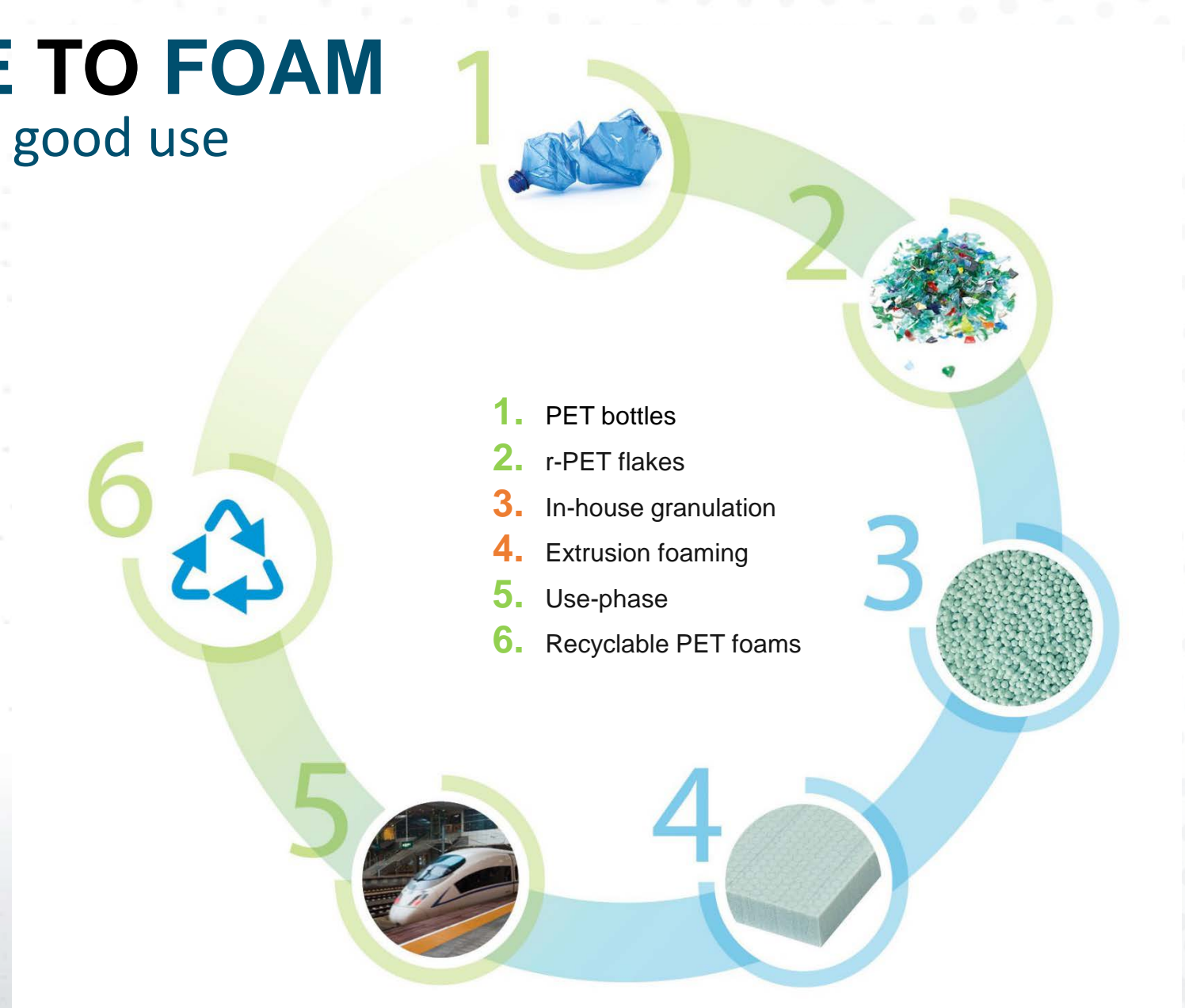
- 1 ABOUT ARMACELL
- 2 ARMACELL r-PET FOAM SOLUTIONS
- 3 HIGH DENSITY r-PET VS END GRAIN Balsa (EGB)
- 4 Q&A

// FROM BOTTLE TO FOAM

- Putting plastic waste to good use

At Armacell we constantly innovate, improve and rethink what we are doing and are focused on sustainable, profitable growth through the development and manufacturing of our products to ensure a positive impact on our community.

Our unique ArmaPET products meet the stringent technical requirements of today's composite core materials and follow the circular economy guidelines to preserve our environment.



// FROM BOTTLE TO FOAM

- Putting plastic waste to good use

Since 2010, Armacell's rPET facilities have reused over 1,500,000,000 PET bottles and saved more than 67,000 metric tonnes of CO₂ emissions in the process. That is equivalent to the emissions of ...

19,774 cars



Mid-sized car running 20,000 km per year: Medium consumption of 6.0 l / 100 km, diesel oil



26,598 cruises

10 days cruise: Cruise liner, 1 passenger



71,020 flights

Brussels - New York: One way, Economy, approx. 5,900 km, 1 traveller

169,560 trips



Route 66 trip by motorbike: >500 ccm, 1 passenger, Chicago to Santa Monica (approx. 3945 km)



1,500,000,000

RECYCLED BOTTLES USED IN OUR PRODUCTION

// ARMAPET PRODUCT SOLUTIONS

We offer **sustainable product solutions** that enhance efficiency throughout the manufacturing process and **elevate the life cycle performance** of your composite structure.

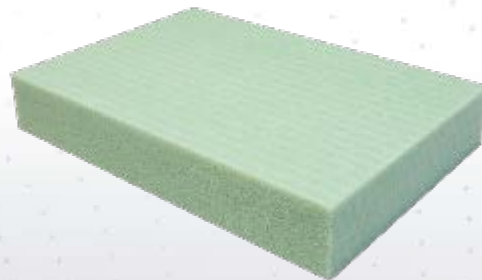
ArmaPET Struct

r-PET welded core is the versatile and durable solution for structural sandwich applications, with a more environmentally responsible approach.



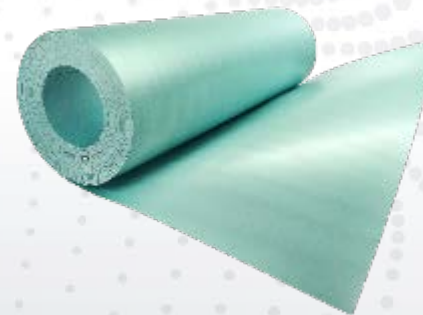
ArmaPET Eco

r-PET direct extruded combines insulation and structural integrity, ensuring energy and emission efficiency for decades of use.



ArmaPET Curve

r-PET foil is designed for recyclable thermo-formable micro sandwich solutions produced in continuous manufacturing processes.



ArmaPET Shape

r-PET particle foam offers maximum design flexibility to produce lightweight rigid 3D foam parts using innovative fusion technology.



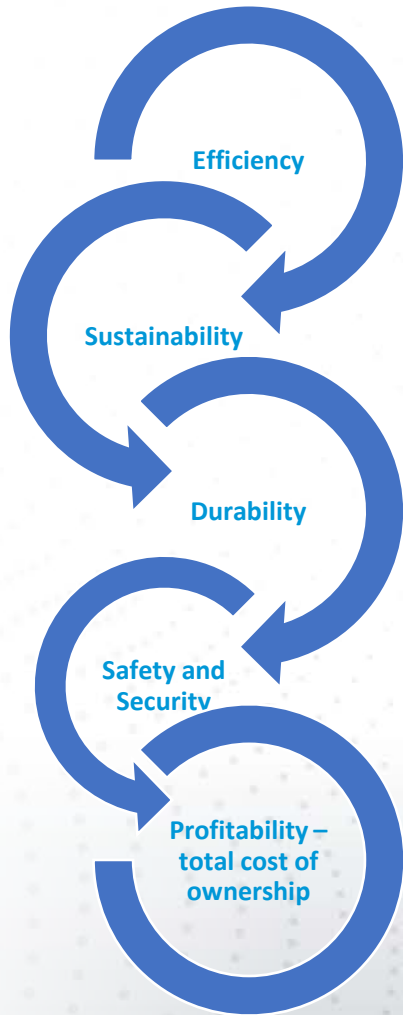
BODY STRUCTURE

Penso's *Blue Ocean Home Delivery Pods* are made of ArmaPET Struct.



// CASE STUDY: PENSO TRUCKS

• OPTIMIZE TRANSPORT EFFICIENCY



EFFICIENCY

- **Weight** reduction
- Aerodynamic optimisation
- **Fuel** savings -> £2,400 per vehicle/year
- Long-term **thermal insulation**

SUSTAINABILITY

- Reducing **CO2 emissions** -> 6.3 tons per vehicle/year
- **Recycling** of Core + Skin
 - Carbon is recycling using pyrolysis process
 - PET Core can be re-granulated and recycled

SAFETY & SECURITY

- Design optimized for **fewer accidents**, better **access** and **safe operations**

DURABILITY

- Equivalent material tested on train door:
 - Core passes 1 Mio **durability** cycles and **pressure** testing with loads up to 7000N
- All structural load-cases proven for **10 year warranty** and 1250 kg **payload**
- Easy **repair**



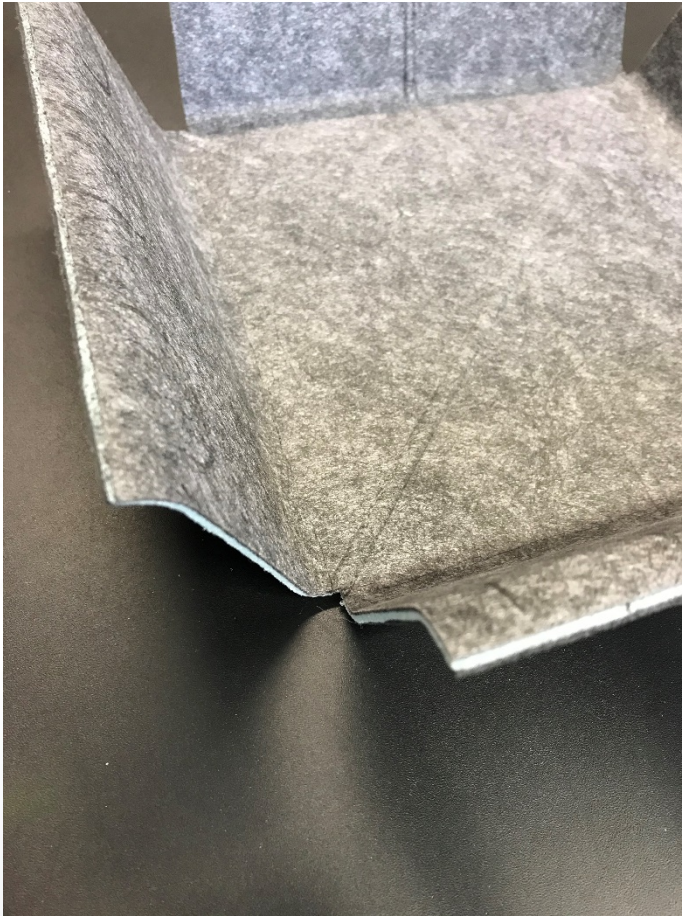
PROFITABILITY

- Optimized **Payload** (33%) and **operating efficiency**
- Fleet Savings
- Reduced **Total Cost of Ownership** by £6,700 per vehicle/year



// EXAMPLES: THERMOPLASTIC SANDWICH STRUCTURES

• FULLY THERMOPLASTIC SANDWICH STRUCTURE



PET + PET

- PET Core + PET Fleece
- **Thermal lamination** possible during **thermoforming** process due to material compatibility without intermediate layer, **cycle times** comparable to PP
- → **no adhesive needed, no additional process** steps required
- Fully **recyclable**

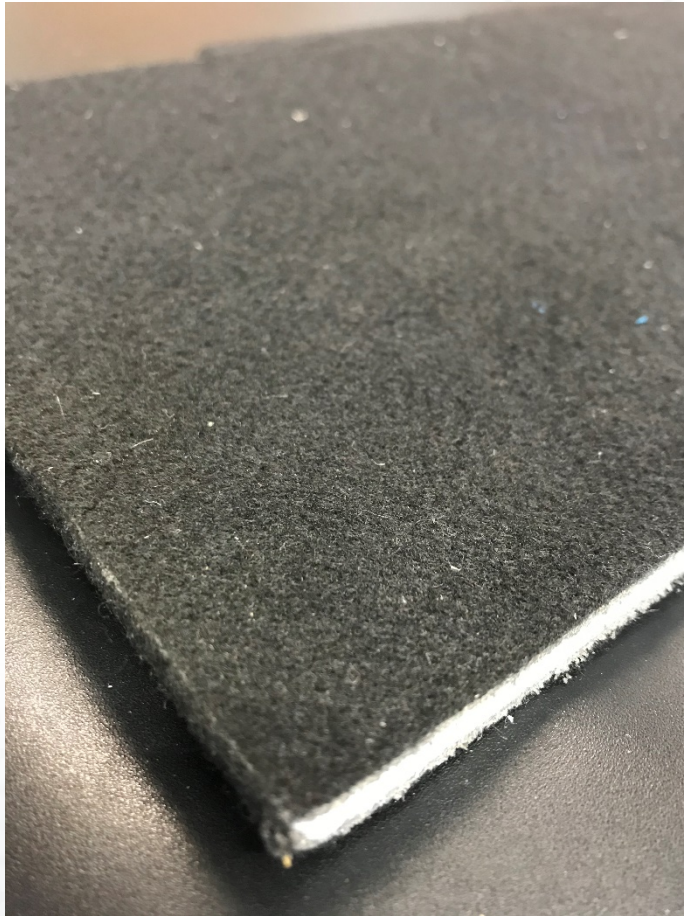


PET + natural fibre PP mix

- PET Foil Core + needled natural fibre PP mix
- can be produced in **large rolls**
- Easy **thermoforming** without any additional adhesive layer
- for **micro sandwich applications**

// EXAMPLES: THERMOPLASTIC SANDWICH STRUCTURES

• FULLY THERMOPLASTIC SANDWICH STRUCTURE



PET + PP

- PET Foam + PP Skin
- **Sandwich** structure by **thermal lamination**
- The **cell structure** of the surface allows welding of the compatible materials
- → **no adhesive** needed, **no additional process** steps required -> increased **labour productivity**
- Easily **recyclable**



PET + Glass PP

- **Automotive** part for backpanel
- PET Foam + Glass PP
- Skin is combined with **hotmelt adhesive** layer for easy processing

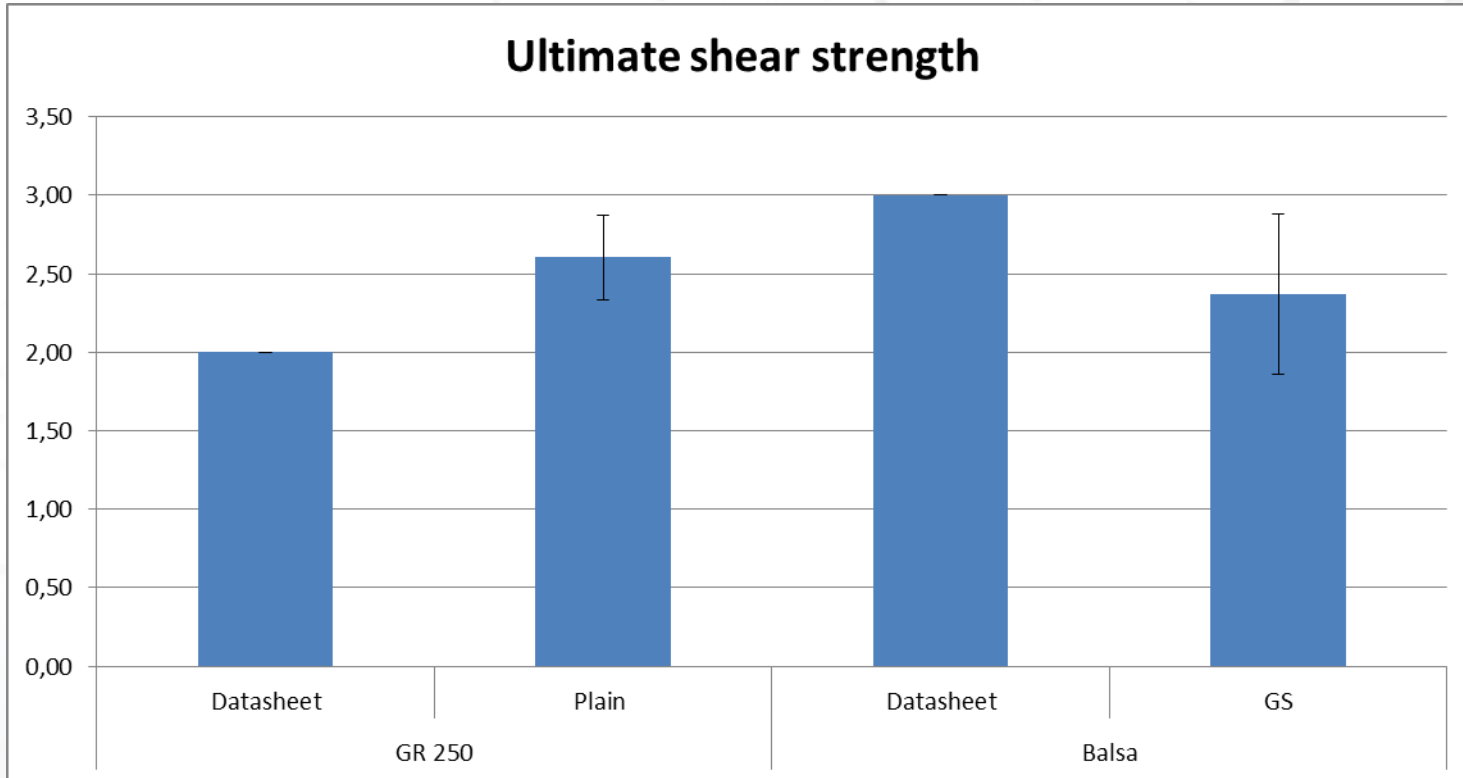


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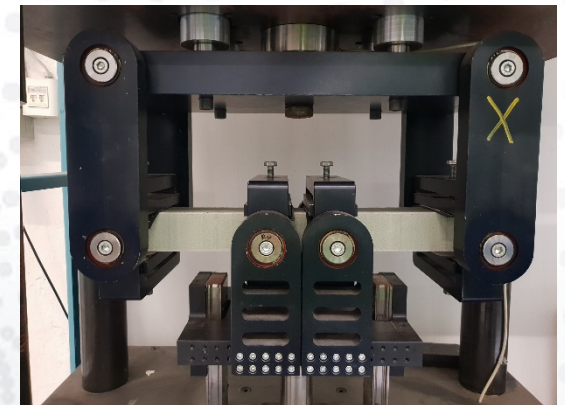
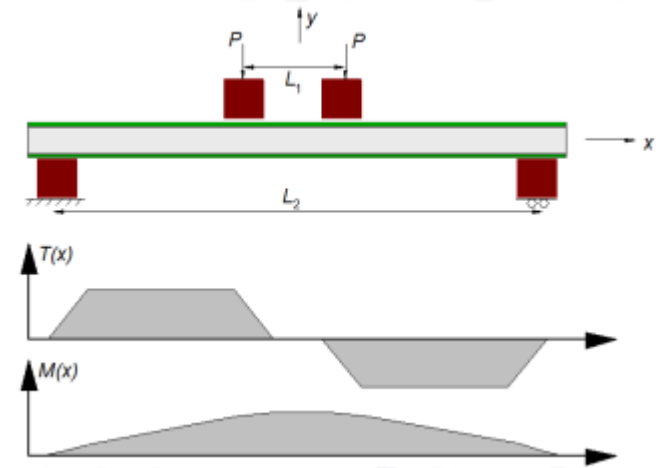
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// HIGH DENSITY PET

- Balsa has fantastic properties on paper but testing in 4-Point Bending show something else. ArmaPET Struct GR250 has clearly higher shear strength when tested in 4-Point Bending than balsa beams (50 mm thickness).



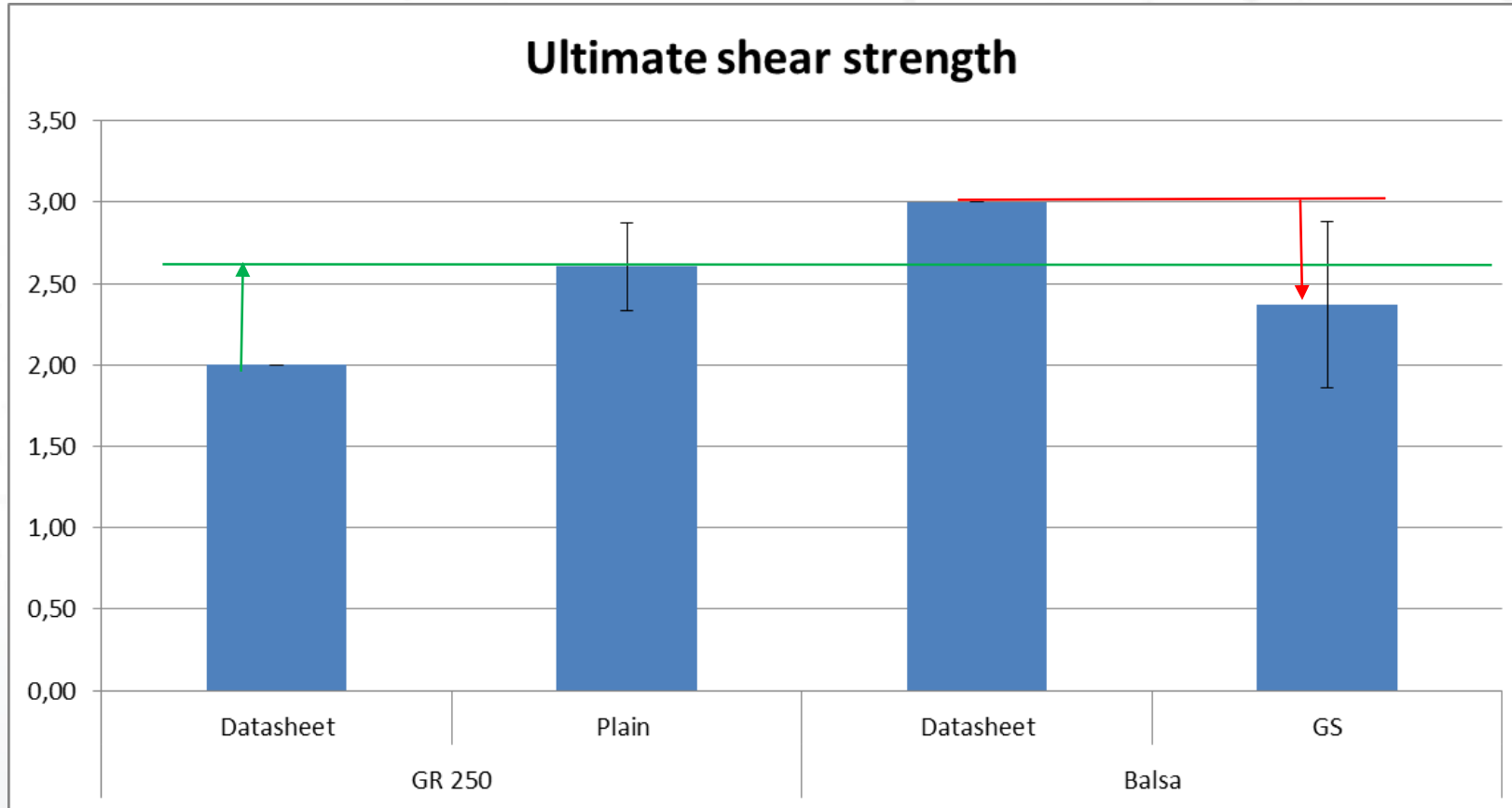
- Note: The ds properties for ArmaPET Struct GR250 are still conservative and the shear strength can be expected to increase from 2.0 MPa to around 2.5 MPa.



- Four-point bending test rig

// HIGH DENSITY PET

- ArmaPET Struct GR250 has clearly higher shear strength when tested in 4-Point Bending than Balsa beams.



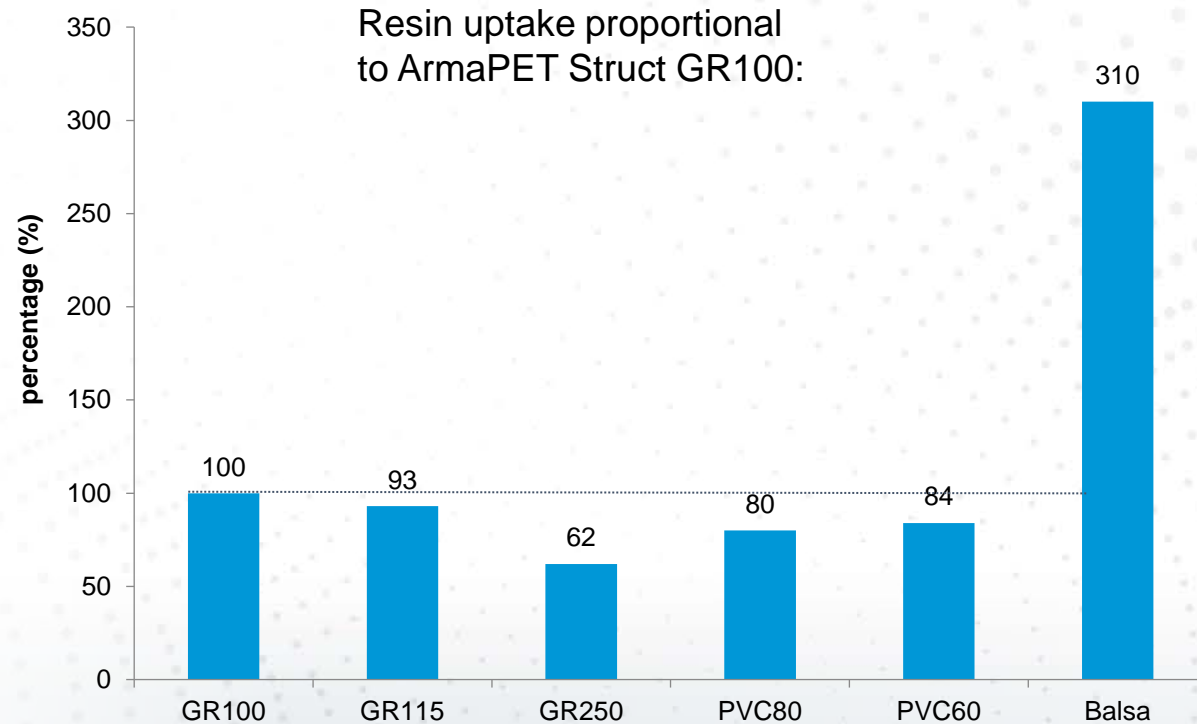
Core thickness, (mm):	Multiply specified core shear strength by the following factor:
12.7	1.0
25.4	0.83
38.1	0.74
50.8	0.69

Core thickness [mm]	Multiply specified core shear strength by the following factor:
12.7	1.11
19.0	1.00
25.4	0.92
38.1	0.83
50.8	0.77

But we still have the higher density/weight of the PET Core??

Results comparing listed datasheet and 4-point bending shear strength for ArmaPET Struct GR250 and EGB 155 respectively

// HIGH DENSITY PET RESIN UPTAKE



Resin uptake is density dependent.



Especially compared with end-grain balsa, the difference in uptake will make significant savings in weight and cost.

ArmaForm vs. end-grain Balsa:

ArmaPET Struct GR250

$$5 \text{ kg/m}^2 + 0,6 \text{ kg/m}^2 \text{ resin} = 5,6 \text{ kg/m}^2 \quad 21 \text{ €/m}^2$$

Balsa155

$$3 \text{ kg/m}^2 + 3,8 \text{ kg/m}^2 \text{ resin} = 6,8 \text{ kg/m}^2 \quad 15 \text{ €/m}^2$$

ArmaPET Struct GR250:

saving in WEIGHT of 1,2 kg/m²

savings in COST of 5,2 €/m²

Note: Cost of resin

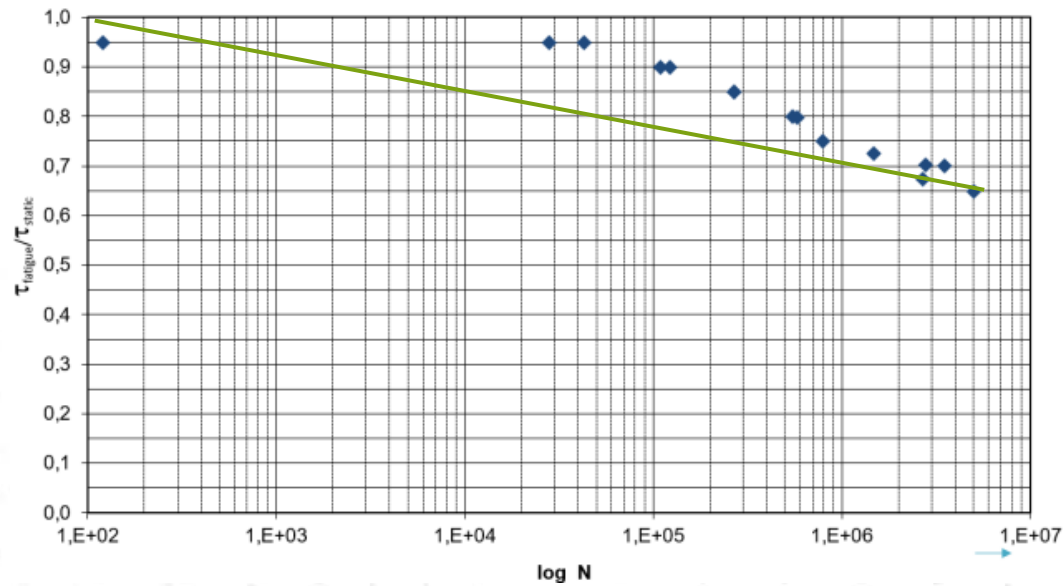
3,5 €/kg

// HIGH DENSITY PET



Fatigue testing on ArmaPET Struct GR200 at KTH

ArmaPET Struct GR200:



ArmaPET Struct GR115:

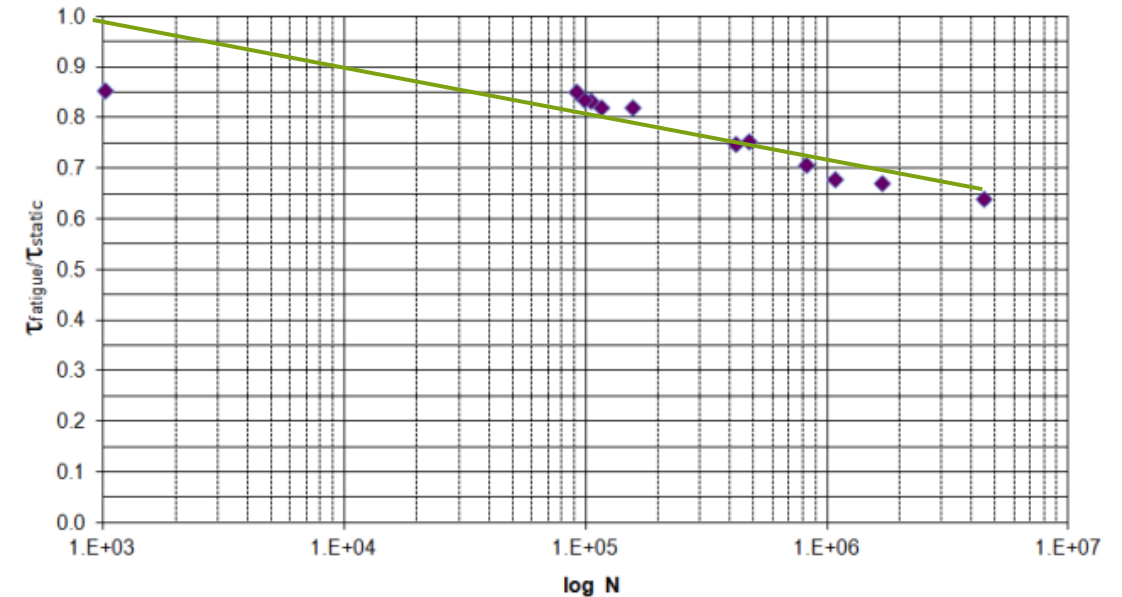
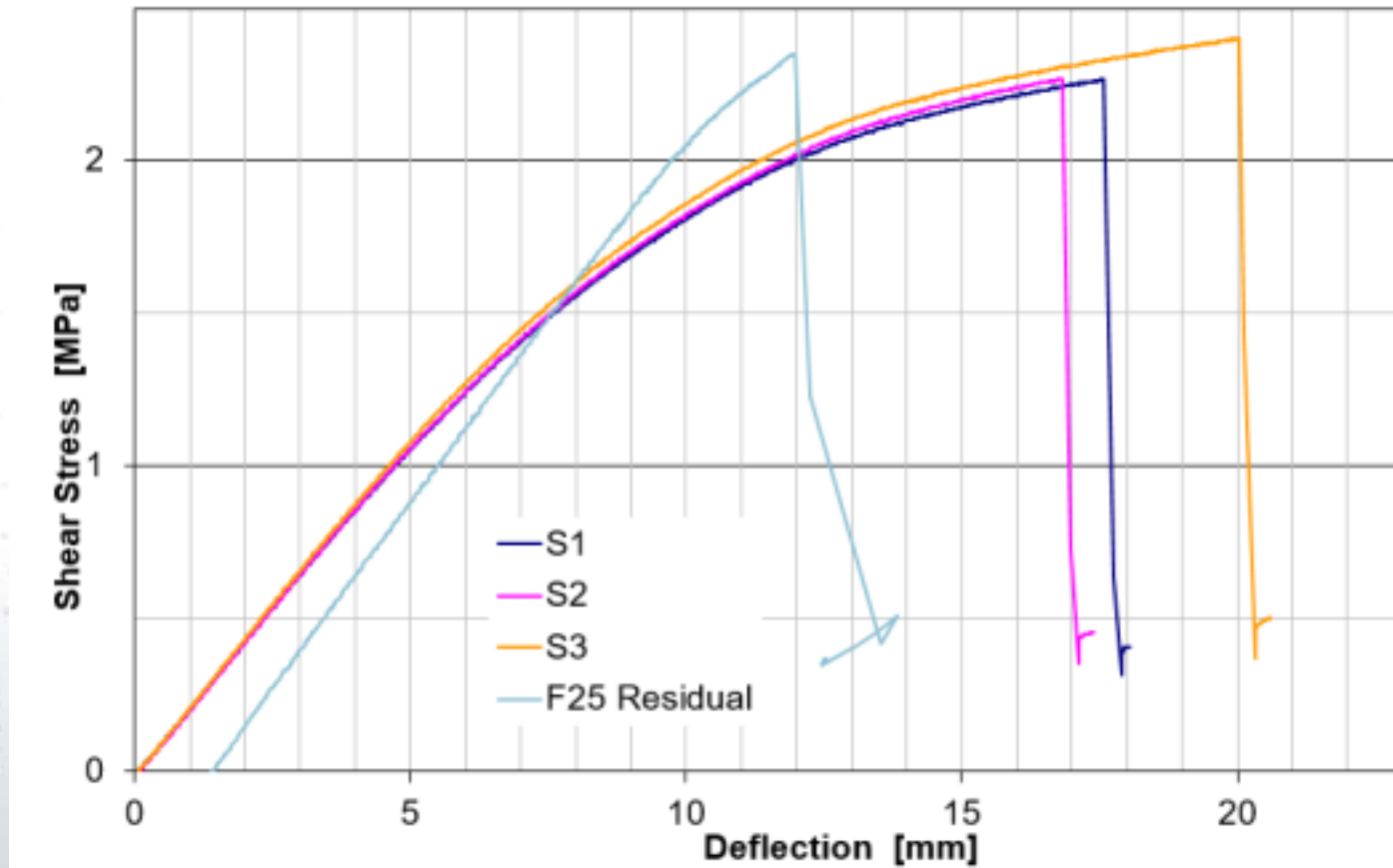


Figure 9. Normalized S/N diagram ArmaFORM GR 115

Correlation between ArmaPET Struct GR200 and previous testing on ArmaPET Struct GR115 and other grades are extremely close and again confirm that **results are density independant if normalised.**

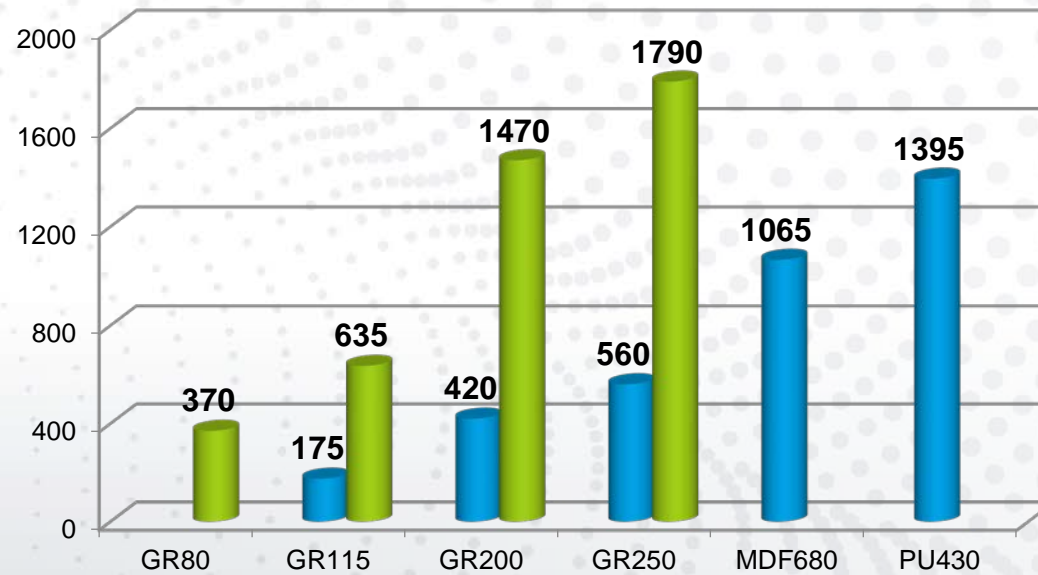
The fatigue threshold level is >60% and GR grade easily exceed the DNV GL requirement on $m > 10$, for ArmaPET Struct GR115 $m = 16,9$ and testing on ArmaPET Struct GR200 indicate at least this number.

Static testing show after 5 million cycles at 65% loading
no degradation of strength or stiffness for ArmaPET Struct GR200.



// Refrigeration truck

- Refrigeration truck manufacturer in China
- Floor: GR250 + FRP skins
- GR250 replaces plywood
 - Weight reduction: 4kg/m²
 - Lower water absorption
 - Higher screw retention



Note: Green is for screw anchor and blue for screw only

// SUMMARY

Advantages for r-PET Structural cores vs. Conventional solutions.

- No moisture sensitivity
- Excellent fatigue properties
- Low density variation and flat sheets
- Excellent processing stability
- Possibility to recycle the core, scrap from kitting today and the rest after the end of the product life cycle
- A core solely based on recycled PET material, improves LCA

Compared to wood based (EGB/plywood) solutions

- Lower weight after infusion
- Lower produced cost
- And better shear strength and ductility



Q & A

THANK YOU
