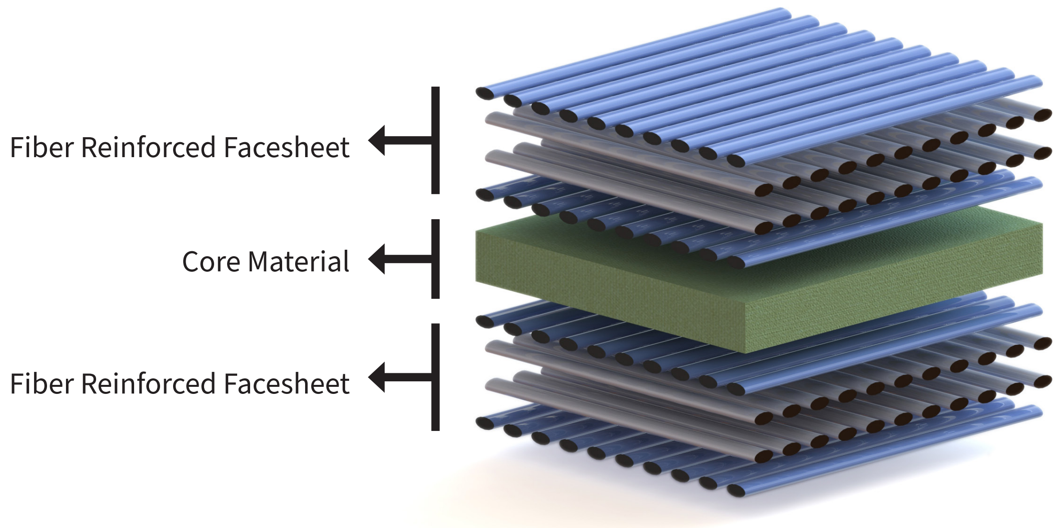
DESIGN GUIDE

COMPOSITE SANDWICH PANELS

AVIENT

Introduction to Composite Sandwich Panels

A composite sandwich panel combines reinforced polymer facesheets (or "skins") with an internal core. The core may be made from various substrates such as balsa, foam, or honeycomb structures. A sandwich panel acts as an I-beam under load. The facesheets are subjected to bending stresses—tension and compression—while the core resists shear stresses. This construction provides superior strength-to-weight ratios compared to other materials such as wood and metal.



WHY COMPOSITE SANDWICH PANELS?

Unlike wood, sheetrock, or sheet metal, composite sandwich panel construction can be designed to maximize performance and minimize weight. They are custom engineered to meet specific performance requirements: varying core thickness to affect stiffness, core materials to affect weight, fiber content to modify stiffness-to-weight ratio, and resin material to affect strength. This versatility enables customized performance for a variety of end-use applications

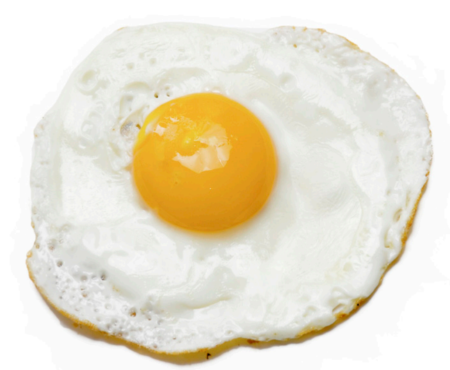
This guide provides a deep dive into composite sandwich panel materials, performance, and design; performance data for various panel constructions and comparisons to traditional materials such as plywood. and end-use application examples.

Material Selection

Avient offers a wide variety of fiberglass reinforced facesheets using both **thermoplastic** and **thermoset** resin systems. The facesheets utilize continuous glass fiber in a high fiber volume content (50–70%). The panels are formed by consolidating the facesheets and the core in one process.

THERMOSET RESIN SYSTEMS

Thermoset resin systems require a curing process to chemically cross-link the polymer. The resin starts as a liquid and becomes solid after curing, making the structure permanently rigid. Because the polymer is cross-linked, thermoset resins have high temperature stability, are resistant to creep, and have good mechanical performance. Thermoset resins require additional chemicals for processing, such as curing agents, hardeners, and inhibitors. Additives can also be added to the system to improve toughness, UV resistance, or flame retardancy.



Like an egg that begins in liquid form cannot be "uncooked" after heat is applied, thermoset resins are permanently set when cured.

COMMON THERMOSET RESIN OPTIONS				
Properties	**Polyester**	**Vinyl Ester**	**Polyurethane**	**Epoxy**
Mechanical	Good	Better	Best	Best
Chemical	Good	Better	Good	Best
Electrical	Good	Better	Good	Best
Bonding	Good	Better	Best	Best
Cost	$	$$	$$$	$$$
Characteristics	Good cost/ performance	Resists water, organic solvents, & alkalis	Rugged & flexible	Excellent insulating properties, chemical & heat resistance

THERMOPLASTIC RESIN SYSTEMS

In contrast to thermosets, thermoplastic resins are not molecularly cross-linked, and can be melted and reshaped multiple times after initial forming. Thermoplastic resins are recyclable, and offer excellent impact resistance, toughness, and noise and vibration damping. Additives can be incorporated into thermoplastic resins to improve toughness, UV resistance, or flame retardancy.

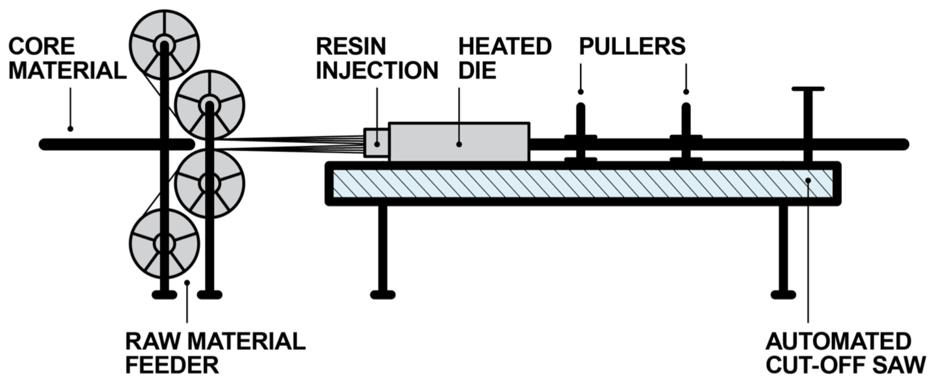
Similar to ice that is solid when frozen and melts to become liquid, thermoplastic resins can be melted and re-formed through the application of heat.

COMMON THERMOPLASTIC RESIN OPTIONS				
Properties	**Polypropylene**	**PET**	**Nylon**	**PEI, PEEK, PSU, PPS**
Mechanical	Good	Better	Better	Best
Chemical	Best	Better	Better	Best
Electrical	Best	Better	Better	Varies
Bonding	Poor	Best	Better	Varies
Thermal Insulation	Good	Better	Better	Best
Cost	$	$$	$$	$$$
Characteristics	Hard to bond, good insulator	Easy to bond, good surface finish	Excellent chemical and heat resistance	Highest heat capability

LAMINATE FACESHEET MATERIALS

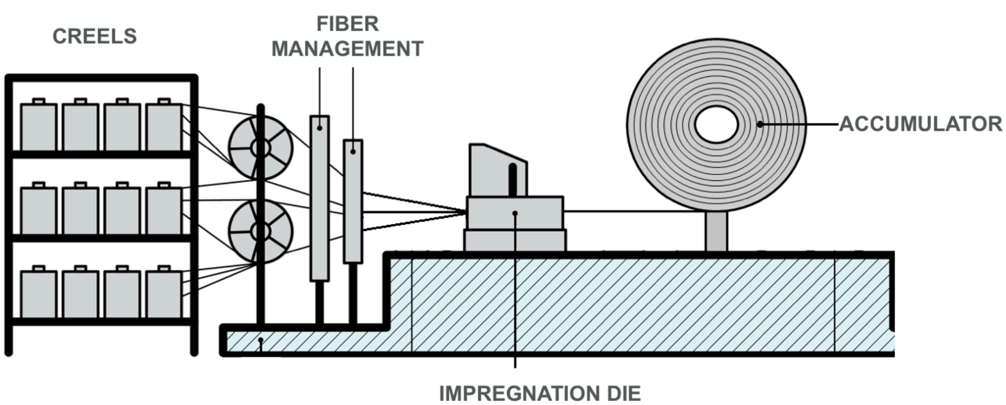
To make Glasforms™ CRTM™ **thermoset** panels, Avient uses a continuous resin transfer molding process in which resin is injected to saturate continuous glass fibers as they are pulled through a die and bonded to the core material. The facesheets are customized to specific fiber volumes and orientations to meet target performance requirements.

Continuous Resin Transfer Molding (CRTM™) Process

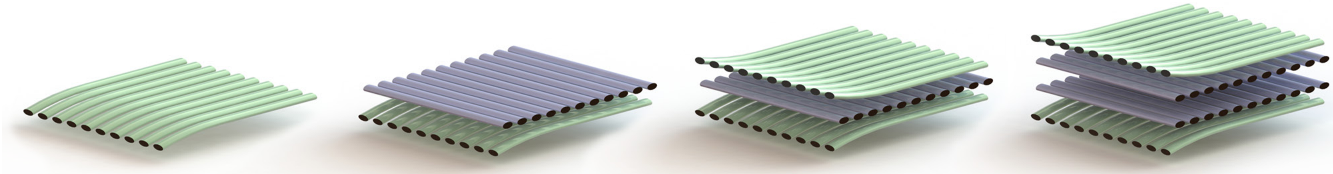


Avient's Polystrand™ **thermoplastic** tapes are made in a continuous process that pulls fibers through a die to saturate with resin and form into single-ply, continuous sheets. Laminate facesheets for panels are created by stacking various layers of unidirectional composite tape in off-axis, 0- and 90-degree orientations based on the property requirements of the panel. These composite laminates provide mechanical performance where structure is needed in the panel construction.

Polystrand™ CFRTP Tape Forming Process



Typical Polystrand™ Thermoplastic Laminate Configurations



Unidirectional composite tape

2-layer composite laminate 0°/90°

3-layer composite laminate 0°/90°/0°

4-layer composite laminate 0°/90°/90°/0°

CORE MATERIALS

The core material provides shear resistance for the sandwich panel construction. Panels can be constructed with a variety of core materials such as foam, honeycomb, and wood; selection is based on end-use application and requirements. The table below provides a property comparison for a variety of common core materials used in panel construction.

COMMON CORE OPTIONS					
Properties	**End-Grain Balsa**	**PET Foam**	**PP Honeycomb**	**PVC Foam**	**SAN Foam**
Compression Strength	Best	Better	Good	Better	Better
Tensile Strength	Better	Better	Good	Best	Better
Shear Strength	Better	Better	Good	Best	Best
Moisture Absorption	Poor	Best	Best	Best	Best
Heat Resistance	Good	Poor	Poor	Better	Best
Ease of Processing	Best	Best	Better	Better	Best
Formability	Poor	Best	Poor	Best	Best
Cost	$$	$$	$	$$$	$$$

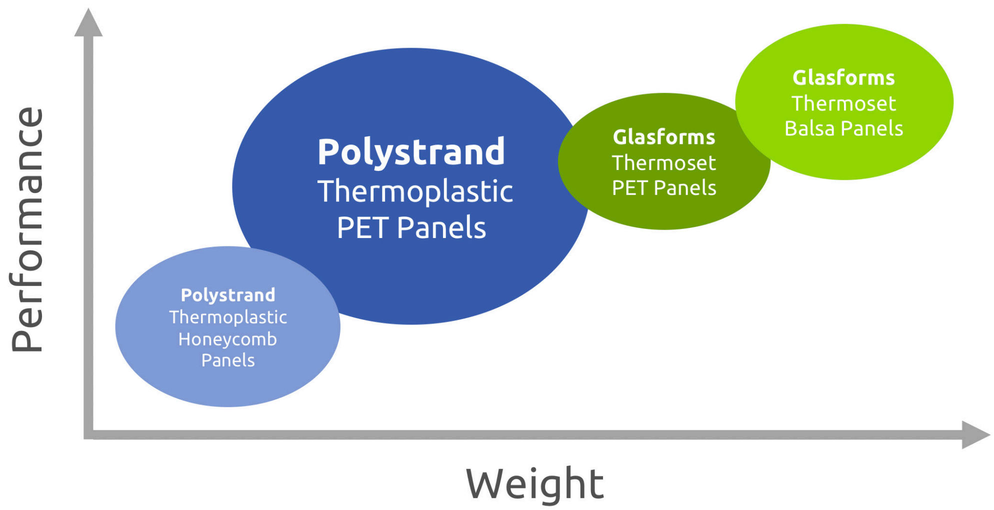
AVIENT COMPOSITE PANELS

Avient consolidates thermoset and thermoplastic facesheets with various core materials to create a variety of sandwich panels. The table below provides an overview of typical panel material combinations and characteristics.

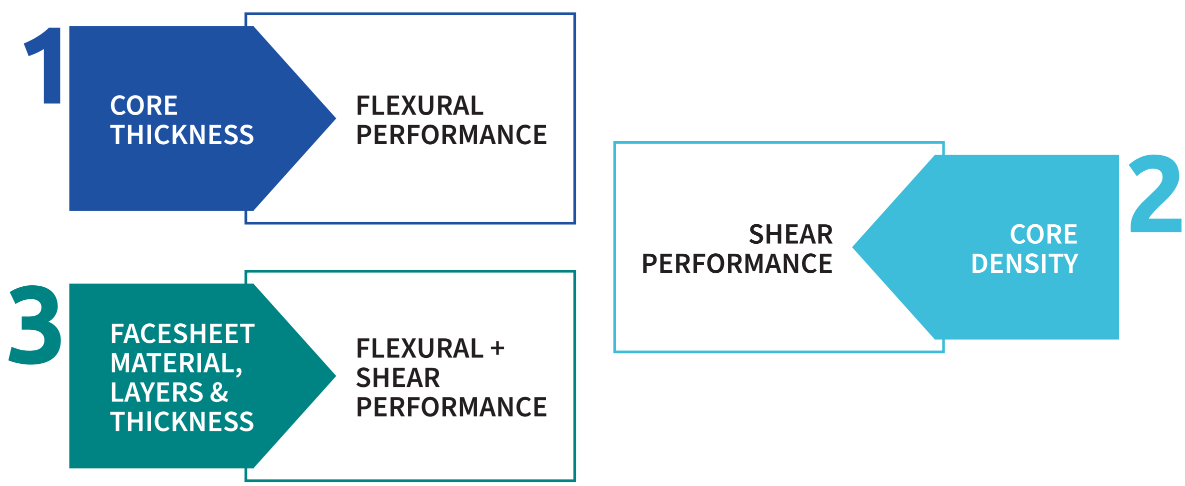
AVIENT PANEL COMPARISON: MATERIALS AND CHARACTERISTICS		
	Glasforms™ CRTM™ Thermoset Panels	**Polystrand™ Thermoplastic Panels**
Facesheet Resins	Unsaturated Polyester (PE) Vinyl Ester	Polypropylene (PP) PET
Facesheet Reinforcement	Glass Fiber	Glass Fiber
Core Materials	End-Grain Balsa PET Foam	PET Foam PP Honeycomb
Characteristics	Structural Panels Superior Mechanical Performance Higher Density Thicker Facesheet Capability Machinable	Light Weight Excellent Impact Resistance Formable Value Engineered Facesheets Recyclable

Sandwich Panel Performance and Design

The graph below illustrates the performance vs. the weight correlation for Avient's typical composite panel solutions. Performance generally correlates directly to weight of the panel. Improvement in performance can typically be achieved with thicker facesheets, thicker cores, or higher density cores. Polystrand thermoplastic panels allow for lighter weight and a wider range of performance levels due to the versatility and customization achievable with thermoplastics compared to thermosets.



Three key factors affect the performance of a sandwich panel: core thickness, core density, and facesheet material and thickness. The charts and graphs that follow will illustrate these performance considerations across various panel constructions and configurations.



FLEXURAL PERFORMANCE

Like an I-beam, a sandwich panel is stiffer than a sheet because of the moment of inertia of the cross-section, as illustrated by the formula to determine the bending stress of a simple beam.

Based on this formula, a larger moment of inertia, or “I” value, would reduce the effective bending stress. And because the thickness of the beam is used to determine the moment of inertia, there is a direct correlation between the two. This increase in the moment of inertia reduces the amount of bending stress, which equates to increased stiffness in the beam.

Similarly, the thickness of the core is directly proportional to the stiffness of a panel. Thicker panels are stiffer than thinner panels. As the thickness of the panel increases, the bending stress lessens. A thicker panel is less likely to break than a thinner panel under the same amount of bending stress.

Unique to sandwich panel construction is that while the stiffness of the panel increases exponentially as the thickness increases, the panel weight does not, as illustrated in the table below.

BENDING STRESS CALCULATION

$$\sigma_b = \frac{My}{I}$$

σ_b - Bending stress

M - Calculated bending moment

y - Vertical distance away from the neutral axis

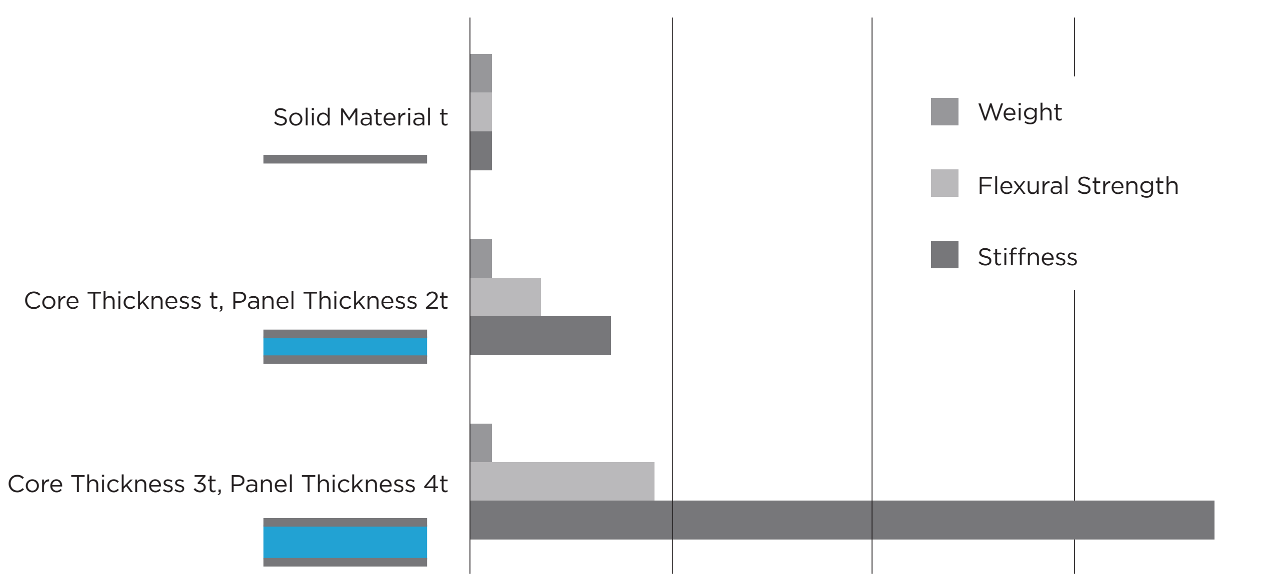
I - Moment of inertia around the neutral axis

Where $I = \frac{1}{12} bh^3$

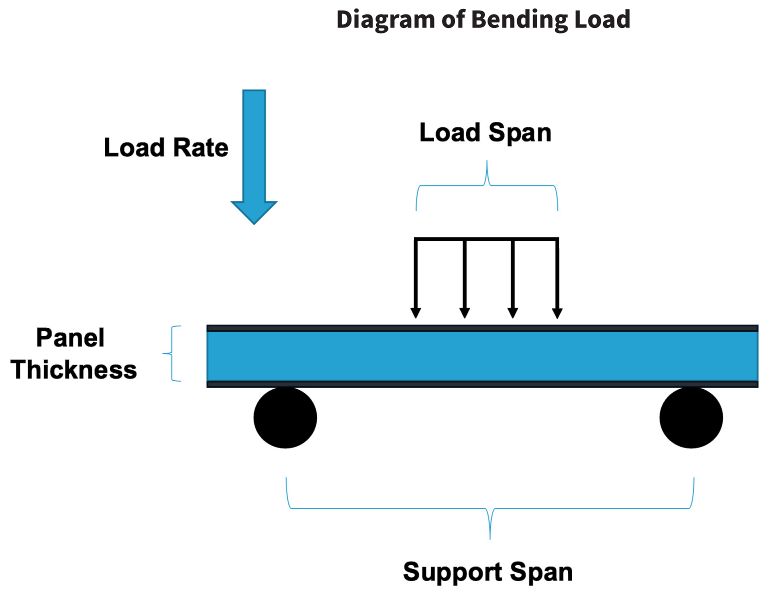
b - Width

h - Height

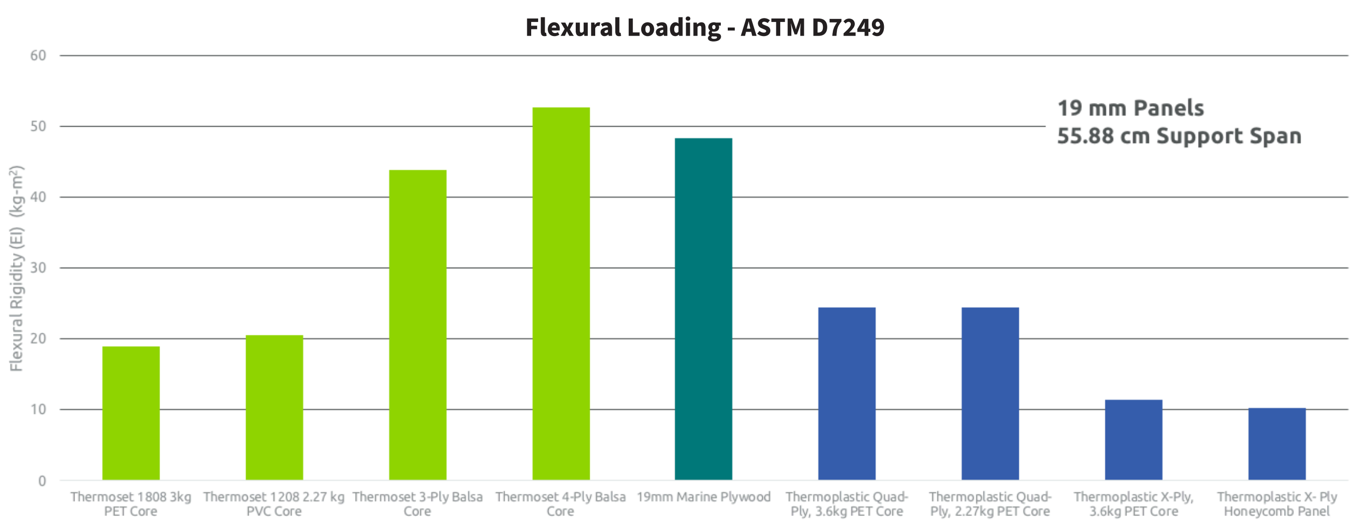
Comparison of Panel Weight and Thickness to Flexural Performance



Flexural rigidity is a measure of the resistance of a panel under bending loads. It is calculated by multplying the flexural modulus of a panel by the moment of interia (EI). This is commonly used in beam bending equations and can be used to evaluate panels based on the load rate, load span, support span, and boundary conditions of the end-use application.

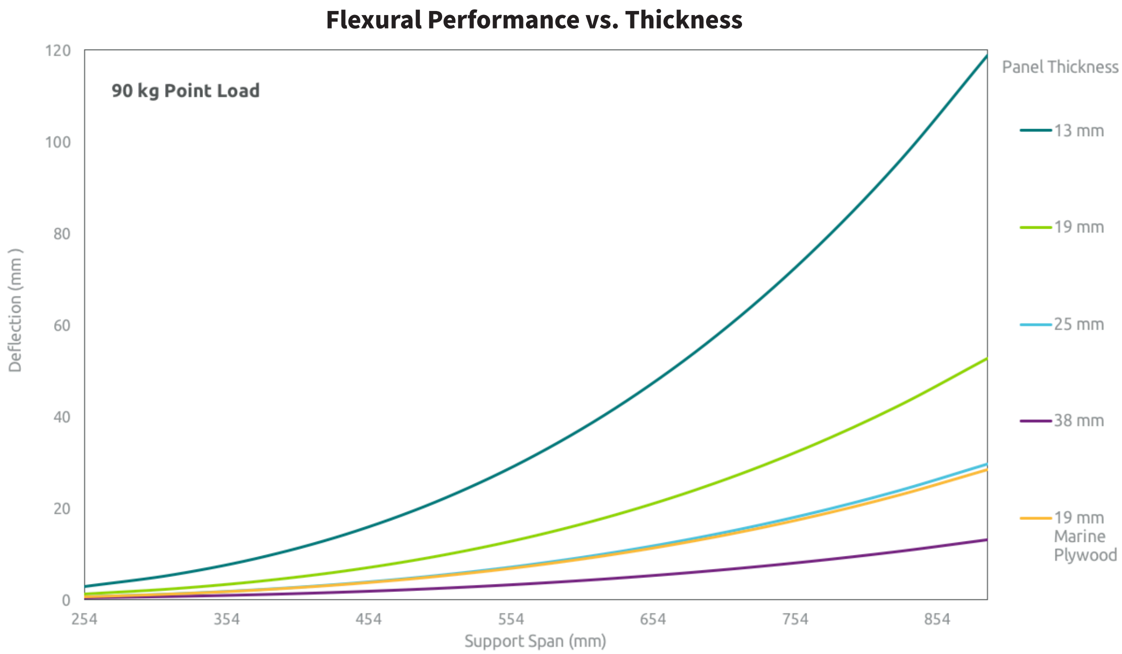


The graph below compares the flexural rigidity of various sandwich panel constructions and marine grade plywood, and illustrates how varying the facesheet layers and core material—while maintaining the same overall panel thickness—can affect flexural performance.



ASTM D7249 is the standard for testing composite sandwich panels for flexural properties. The test is conducted at a support span of 55.88 cm.

The graph below illustrates the predictive correlation between panel thickness and flexural performance at various support span distances. Panels are constructed of quad-ply PET facesheets with 3.6 kg PET foam core, loaded with a center 90kg point load and ends were simply supported. The graph demonstrates the deflection of each panel thickness at increasing support span distances.

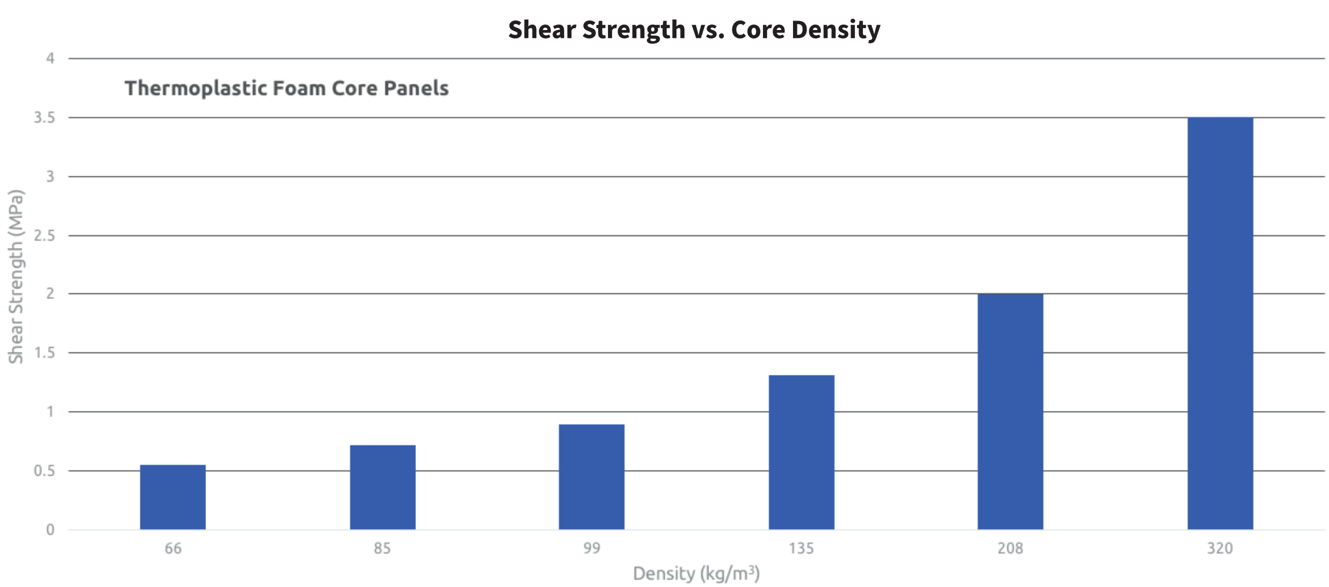


The results of this testing indicate that increasing the core thickness of a panel exponentially increases the flexural performance. Thicker panels deflect significantly less, even at longer support spans.

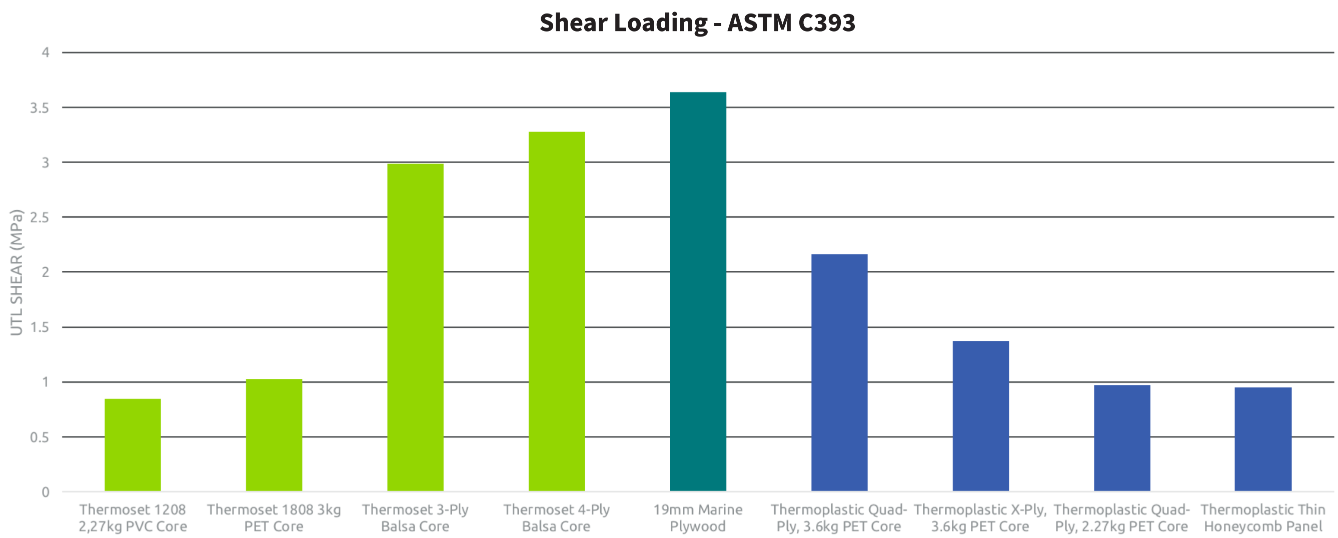
It is crucial to consider the loading the panel will be subjected to, the distance between supports, and an acceptable deflection when selecting a panel for a specific application.

SHEAR PERFORMANCE

Increasing the density of the core directly improves a panel's shear strength, as illustrated in the graph below. However, increased core density also equates to increased overall panel weight.



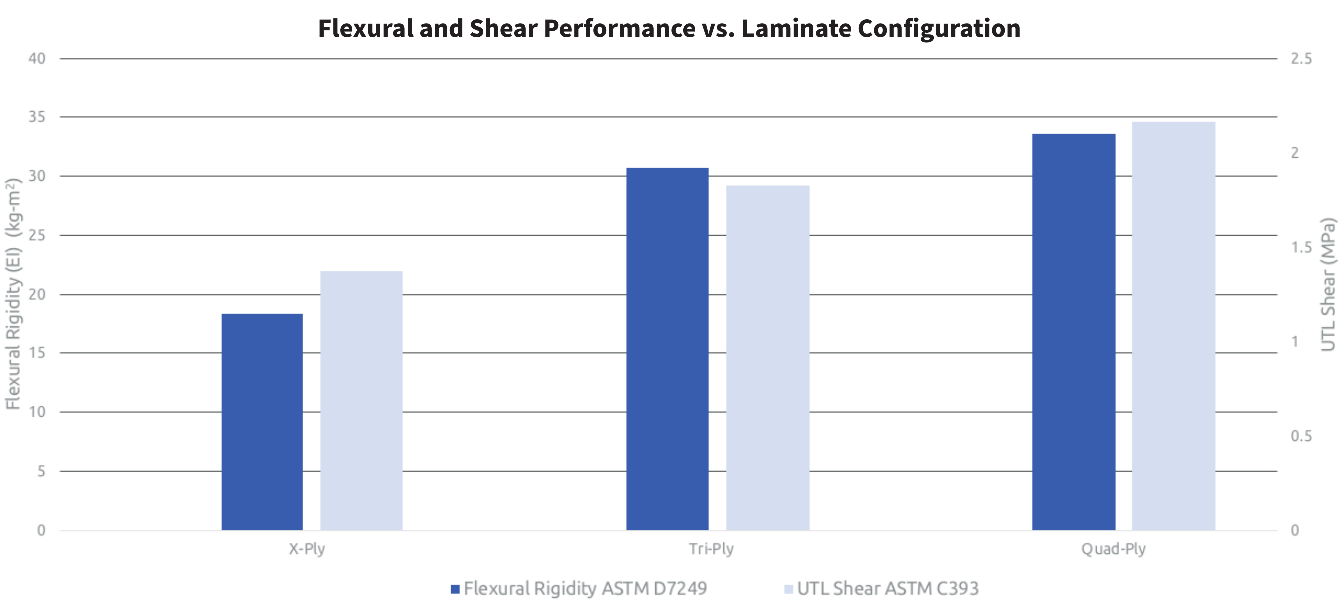
The graph below illustrates how increasing core density and the number of layers in the facesheets both improve shear performance. Thickness is not included in this graph because it is insignificant to shear performance.



ASTM C393 is the standard for testing composite sandwich panels for shear properties. The test is conducted at a support span of 15 cm

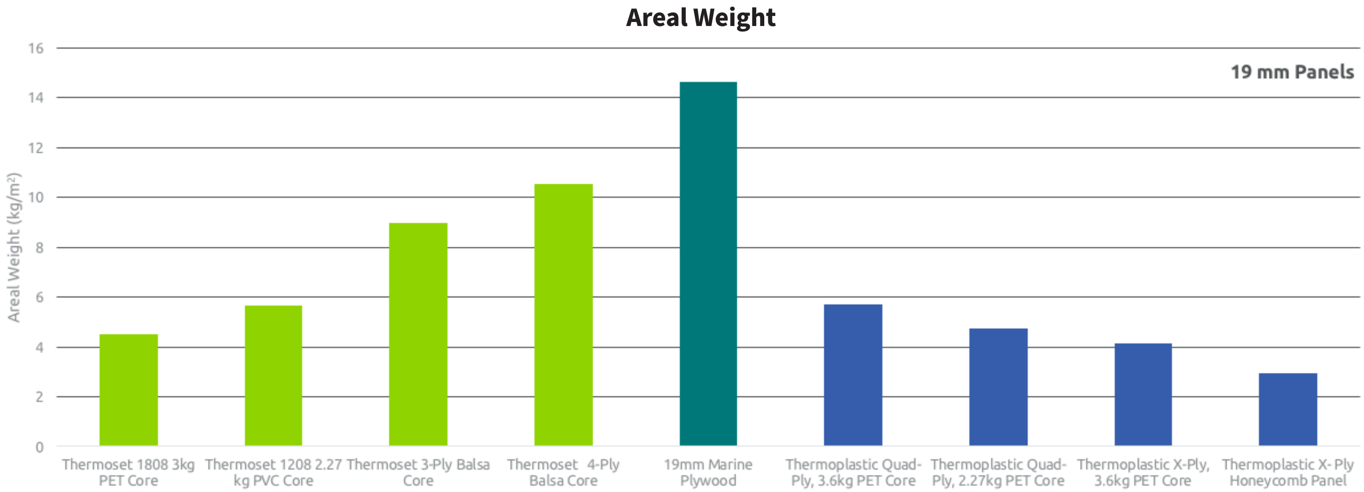
FLEXURAL AND SHEAR PERFORMANCE

Increasing the number layers within the facesheets of a panel improves both the flexural and shear performance. The flexural and shear properties increase because the thicker laminate can resist a higher load. This reduces the deflection of the sandwich panel and less force is applied to the core. The thicker facesheets are stiffer—the panel will deflect less at higher loads. Core thickness and core density remain constant.



AREAL WEIGHT

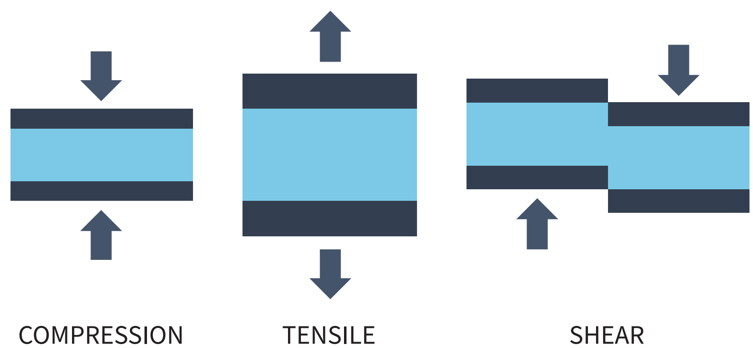
The graph below provides a comparison of the areal weight of various panel configurations at the same thickness. The thermoplastic panels are lighter than thermosets, but all are lighter than plywood.



PANEL LOADING CONSIDERATIONS

When designing a panel, it is important to consider the forces that will be applied to the panel when in use in order to optimize performance.

Three primary loads that typically affect panel applications are compression, tensile, and shear force.



Compression

Compression loads are inward forces on the panel surfaces. Applications where panels would experience compression load include trailer or truck beds, flooring, and marine decking.

To optimize for compression, panels must be designed to minimize deformation or crushing under compressive loads while maintaining minimal panel weight.

Tensile

Tensile loads are outward pulling forces which strain the adhesion between the core and facesheets of a panel. When panels undergo bending loads, one facesheet is in compession while the opposing facesheet is in tension. Designing a panel to prevent delamination of the skins is necessary when optimizing for tensile load.

Shear

Displaced bending forces on a panel are called shear load. Panels experience shear loading when installed across short loading spans or on uneven surfaces such as a ramp for vehicles.

Considerations such as how the panel is supported in use must be accounted for when designing for shear loads. The facesheets must be configured to deflect enough to prevent shearing of the core.

PANEL FAILURE MODES

When designing and testing panels for specific application requirements, understanding when and how a panel fails is critical to optimizing panel performance (and minimizing failures) in end-use applications.

The illustrations and photos below depict three common panel failure modes: compression, delamination, and core shear.

Facesheet compression failures present as a fracture in the facesheet material on the compression side of the panel. This may occur when the load is concentrated vs. distributed over the panel.

Delamination occurs when, under bending loads, the facesheet material peels or pops away from the core substrate. This can indicate that either the panel is too stiff or thick to appropriately yield to the bending load and support span, or the panel has an insufficient bond strength between the facesheet and core material.

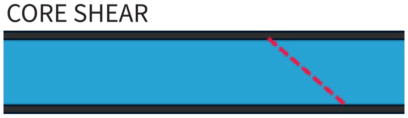
Core shear typically happens when the panel deforms and flexes until the core material ultimately breaks or shears. Panels experience increased shear loading during impact events and when support spans are close together.

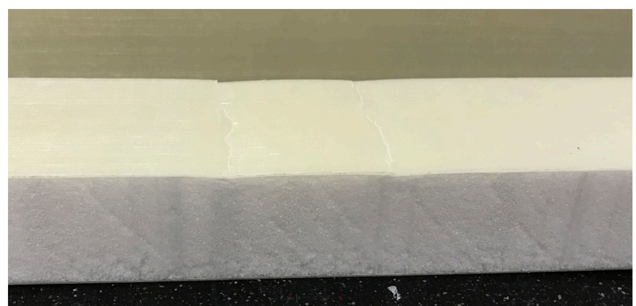
These failures can occur in isolation, however, more often panels exhibit compound failures indicating a combination of factors that contribute to performance deficiency.

COMPRESSION

DELAMINATION

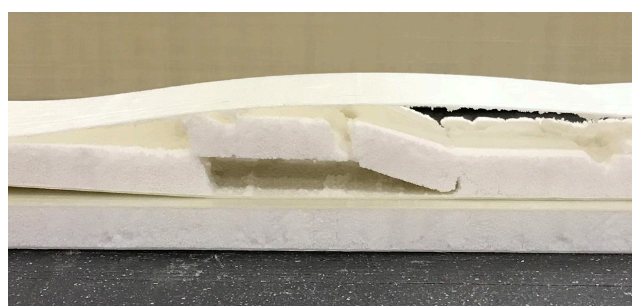
CORE SHEAR





SKIN COMPRESSION

SKIN DELAMINATION



SKIN DELAMINATION + CORE SHEAR

Sandwich Panel Applications

MARINE

- Stringers
- Bulkheads
- Decking
- Ceilings
- Hatches
- Covers
- Cabinetry
- Fittings

TRUCK & RV

- Ceilings
- Cabinetry
- Load floors
- Sidewalls
- Aerodynamic components

BUILDING & CONSTRUCTION

- Modular panels for temporary structures
- Garage and industrial doors
- Walls and flooring

RAIL

- Doors
- Flooring
- Interior panels

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