Sandwich composites and core materials
How they work and why you should use them

Design stronger, lighter and more competitive products
Gain core knowledge for more competitive products

How can you answer the seemingly exponential growth in demand for better products, leading to fiercer competition and regulations in your industry? Most likely you need to make significant improvements across multiple areas at once.

Sandwich composites and core materials are vital elements in pushing your products to a higher level of competitiveness. They are the answer for making products stronger, faster, lighter, more durable, and a whole host of other benefits. We have developed this guide to highlight the benefits of sandwich composites and explain the basic mechanical theory behind them, as well as introduce the various core materials DIAB offers. For deeper explanations, we recommend viewing the complete DIAB Sandwich Composite and Core Manual at www.diabgroup.com. Of course, we are here to help you every step of the way. Use these guides as springboards for discussions with our experts to determine your optimal solution.

Why use sandwich composites?

Sandwich composites are becoming more and more popular in structural design, mainly for their ability to substantially decrease weight while maintaining mechanical performance. This weight reduction results in a number of benefits, including increased range, higher payloads and decreased fuel consumption. All have a positive impact on cost as well as a decreased impact on the environment.

These benefits are possible because, as has long been known, separating two materials with a lightweight material in between increases the structure’s stiffness and strength. This distinction, along with many other material characteristics available through strategic choice of core material – such as thermal insulation, low water absorption, sound and dielectric properties, among others – benefit a wide range of industries and applications, including wind, marine, aerospace, transportation and industry.

Typical sandwich composite:
The skins are thin, strong and stiff, and the core is light and structurally strong enough to keep the skins in their relative positions under loading.
Decrease weight

One of the most driving reasons to use sandwich composites is that they provide mechanical properties to much lower weight than traditional monolithic materials (for example, steel). It is not only the sandwich principle itself that makes this possible. Sandwich composite materials also enable designers to engineer with extreme precision to their loading requirements. Core is one of the variables in a sandwich composite that enables this due to the wide range of mechanical properties it provides. In other words, a sandwich solution will prevent over engineering, save weight and increase performance compared to many designs that use conventional materials such as wood and steel.

The combination of sandwich principle and core material saves energy and enables faster and more effective solutions in many areas. For example, sandwich composite design is an absolute necessity to reach competitive cost per megawatt from wind energy. In transportation, lower weight in container or vessel construction enables higher payloads resulting in reduced emissions.

Sandwich composites provide vital strength and speed for the sports equipment segment. In industry, a lightweight solution can result in faster and smaller robots. In construction, a bridge or façade designed with sandwich composites facilitates fast, effective installation. Clearly, the benefits of lightweight solutions go on and on.

Obviously, anything that moves consumes energy. The heavier it is, the more energy consumed. Since using sandwich composites makes structural designs lighter, sandwich solutions are extremely environmentally friendly. With a sandwich solution, less material is consumed in the construction. This saves resources as well as weight in the final construction, making the construction less energy-consuming over its lifetime.

To illustrate the impact weight has on the environment, follow any kind of vessel – whether airplane, bus, train or car – through its lifetime (25 years). Every kilo saved in its construction results in less energy needed to move people or materials around the world. Less energy expended every day for 25 years saves the environment from enormous amounts of pollutants.

Due to increasing fuel costs, many industries are also realizing it is not only good for the environment, but it also costs less to design with lightweight solutions. The environmental impact of material choice in the beginning (energy) and in the end (recycling) of a vessel’s life cycle is minor (as long as the material choice saves weight) in comparison with the vessel’s fuel savings over its lifetime.

Reduce the impact on the environment

Obviously, anything that moves consumes energy. The heavier it is, the more energy consumed. Since using sandwich composites makes structural designs lighter, sandwich solutions are extremely environmentally friendly. With a sandwich solution, less material is consumed in the construction. This saves resources as well as weight in the final construction, making the construction less energy-consuming over its lifetime.

To illustrate the impact weight has on the environment, follow any kind of vessel – whether airplane, bus, train or car – through its lifetime (25 years). Every kilo saved in its construction results in less energy needed to move people or materials around the world. Less energy expended every day for 25 years saves the environment from enormous amounts of pollutants.

Due to increasing fuel costs, many industries are also realizing it is not only good for the environment, but it also costs less to design with lightweight solutions. The environmental impact of material choice in the beginning (energy) and in the end (recycling) of a vessel’s life cycle is minor (as long as the material choice saves weight) in comparison with the vessel’s fuel savings over its lifetime.
Designers appreciate sandwich composites for allowing freedom in their designs, as opposed to conventional construction materials such as metal and wood, which are usually limited in their shape from the beginning or result in heavy solutions. When building sandwich composite structures, the materials are shapeable in almost any kind of form until the last stage of production in which they get their final shape. This allows for non-linear and smooth designs, which can be done not only for esthetic reasons but also for aerodynamic reasons.

Additional benefits with sandwich composites

Those described above are the main benefits and reasons many industries use sandwich composites. However, with diverse structural core materials to choose from – each with its own set of material characteristics – you can obtain additional benefits. (By structural core material we mean a core material that has a specification and tolerances, as well as significant mechanical performance.) Here we mention a few of the most important benefits.

Fire, Smoke & Toxicity (FST)
FST regulations are tough in applications involving public transportation like buses, trains and aircraft. In order to “harvest” the benefits of sandwich composites, some structural core materials have specific raw materials making them self-extinguishable as well as nontoxic when burning, qualifying them for use in public transportation.

Thermal insulation
Polymer core materials are built up by a cell structure. These cells are filled with air. Due to this, some core materials do not transfer heat or cold well. This could be of great benefit in, for instance, the building industry, subsea applications or applications where insulation is important.

Sound insulation
Based on the same principle of cell structure, some core materials (particularly those with closed cell structures) have a good ability to insulate/absorb sound. This is useful in many applications, such as speakers, but first and foremost in aircraft interiors, where good sound insulation improves the interior environment in commercial airliners and private aircraft.

Corrosion resistance
Removing the risk for corrosion has a significant impact on ensuring long operational lifetime for an application. With their non-corrosive properties, using polymer core materials and polymer skins eliminates the risk for corrosion damages on a structure. This makes sandwich composites ideal for marine applications as well as subsea structures.

Very low water absorption
For applications used in marine environments or in places with moisture or condensation, polymer core materials are excellent. The reason for this is, once again, the closed cell structure. This prevents water or moisture from entering the core and increasing weight or ruining mechanical performance. This is also important for aircraft interiors, where traditional materials like honeycombs trap water in the cell structure, adding weight during its lifetime. In comparison, most closed cell polymer materials have extremely low water vapor permeability or water absorption over their lifetime.

Ease of repair
Sandwich composites are easy to repair. Cracks and slamming damage can be repaired relatively easily without reducing the structure’s mechanical performance. Compared to steel, for which a large part of the structure must be cut out and replaced, professionals can repair a sandwich composite locally without reducing the performance or the design.

Dielectric properties
Some core materials have excellent dielectric properties. This means they do not interfere with radio waves – useful when designing and building radomes, spherical housing for radar equipment or x-ray equipment.
Basics of sandwich composite

The intention here is not to provide complete guidance to engineers in how to design sandwich panels, but to give a basic introduction to how sandwich composites work using illustrations and simplifications for those who are new to the concept.

The sandwich principle

Sandwich-structured composites are a special class of composite materials with the typical features of low weight, high stiffness and high strength. Sandwich is fabricated by attaching two thin, strong, and stiff skins to a lightweight and relatively thick core.

The sandwich is analogous to an endless I-beam in the sense that when subjected to bending, the flanges carry in-plane compression and tension loads (as do the sandwich skins or laminates) and the web carries shear loads (as does the structural sandwich core). As with a traditional I-beam, when the flanges (skins) are further apart, the structure gains more proportional stiffness. A thicker core achieves the same, but it also provides an overall low density, resulting in a high stiffness-to-weight ratio.
The comparison between a steel panel and a composite sandwich panel illustrated below indicates the potential of weight savings from using sandwich.

<table>
<thead>
<tr>
<th>Example sandwich</th>
<th>Example steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q = 1000 N/m²</td>
<td>Q = 1000 N/m²</td>
</tr>
<tr>
<td>17 mm sandwich</td>
<td>5 mm steel</td>
</tr>
<tr>
<td>L = 1.5 m</td>
<td>L = 1.5 m</td>
</tr>
</tbody>
</table>

- **Example sandwich**
  - Weight: 4.3 kg/m²
  - Deflection: 30 mm
  - Safety factor: 5.7

- **Example steel**
  - Weight: 39 kg/m²
  - Deflection: 30 mm
  - Safety factor: 3

With the same criteria for deflection, the weight savings with sandwich design is almost 90%. (This example compares standard materials.) Additional benefits with sandwich panels are thermal insulation, acoustic damping, buoyancy and corrosion resistance.

**This graph illustrates the exponential effect of how increased core thickness yields increased stiffness to a relatively low weight penalty.**
Description of a typical sandwich composite

A typical sandwich consists of skins or laminates with a much thicker (in relation to the skins) structural core in between. Each part in a sandwich has its particular function as described below.

Faces (outer and inner skins)
The faces carry the tensile and compressive stresses in the sandwich. The local flexural rigidity is often so small it can be ignored. Conventional materials such as steel, stainless steel and aluminum are often used as face material. It is also suitable and common to choose fiber or glass-reinforced plastics as face materials. These materials are easy to apply. Reinforced plastics can be tailored to fulfill a range of demands like anisotropic mechanical properties, freedom of design, excellent surface finish, etc.

Faces also carry local pressure. When the local pressure is high, the faces should be dimensioned for the shear forces connected to it.

Core
The core’s function is to support the thin skins so they do not buckle (deform) inwardly or outwardly, and to keep them in relative position to each other.

To accomplish this, the core must have several important characteristics. It has to be stiff enough to keep the distance between the faces constant. It must also be so rigid in shear that the faces do not slide over each other. The shear rigidity forces the faces to cooperate with each other. If the core is weak in shear, the faces do not cooperate and the sandwich will lose its stiffness.

It is the sandwich structure as a whole that gives the positive effects. However, the core has to fulfill the most complex demands. Strength in different directions and low density are not the only properties the core must have. Often there are special demands for buckling, insulation, absorption of moisture, aging resistance, etc. The core can be made of a variety of materials, such as wood, aluminum, and a variety of foams.

Adhesive (Bonding layer)
To keep the faces and the core cooperating with each other, the adhesive between the faces and the core must be able to transfer the shear forces between them. The adhesive must be able to carry shear and tensile stresses. It is hard to specify the demands on the joints. A simple rule is that the adhesive should be able to take up the same shear stress as the core.

It is of utmost importance that the skins properly adhere to the core to give the expected structural behavior. The skin can be made of numerous materials, such as aluminum, steel, carbon, or glass fibers, which has a big impact on the sandwich composite’s final performance.
Manufacturing a sandwich composite part can involve various types of processes. However, as mentioned earlier, it usually consists of an outer skin, core and inner skin – all of which follow the geometry neatly to facilitate an effective lay up.

To make manufacturing as efficient as possible, you can receive the core in pre-cut sheets (so-called kits) that fit well together and in the mold.

Manufacturing the final application

One of the main benefits of sandwich composites is freedom of design. In order to achieve different geometries, such as flat, single curves and double curves, we apply cut patterns to the core material. These cuts enable the core to form in different shapes, such as a wind blade or boat hull. Depending on the type of geometry, we apply different types of cuts in order to optimize weight and resin consumption.

For more information, download the DIAB Finishing Guide at www.diabgroup.com or contact us for a printed copy.

For more information, download the DIAB Kits Guide at www.diabgroup.com or contact us for a printed copy.
Choose the right material for your needs

As explained earlier, sandwich composites enable light and strong designs as well as a number of additional benefits. DIAB provides a wide range of core materials for use in sandwich composites. Each material provides specific characteristics suitable in various conditions. Below, you have a summary of our full material offering. In addition, DIAB provides a wide range of finishing, kits and engineering services to assist you in application development with sandwich composites.

For more in-depth information about the fundamentals of core materials as well as which materials are most suitable for your applications, you can view our complete DIAB Sandwich Composite and Core Manual online at www.diabgroup.com

**Divinycell Matrix**
Superior strength to weight; used in multiple industries, including wind and marine.

The Matrix Series is the latest addition to the Divinycell family and is our most iterated product. Following our concept of Focused Performance, Divinycell Matrix is a structural, all-purpose grade delivering relevant mechanical properties at the lowest possible weight. Matrix complements Divinycell H perfectly and provides a complete range of high-performing, all-purpose core materials.

**Divinycell H and HP**
Excellent strength to weight; used in multiple industries, including wind and marine.

Divinycell H and HP are structural, all-purpose grades with excellent strength-to-weight performance and a wide range of mechanical properties. They are also good environmental selections with high performance over time. Divinycell H is compatible with most wet resin systems. Divinycell HP is high-temperature resistant and suitable for most pre-pregs.

Further, with its low thermal conductivity, Divinycell H is especially suitable as insulation for low and cryogenic temperatures. Resistance to hydrocarbons makes it the perfect material for LNG storage insulation. A special grade, Divinycell CY, is approved as rigid insulation for the GTT (Gaztransport & Technigaz) NO96 design, both as an insulating and supporting type.

**Divinycell P**
PET core; used in transportation, construction and wind industries.

Divinycell P is a recyclable, structural PET core material well-suited for land, transportation and construction applications. Divinycell P also has excellent fire, smoke and toxicity performance and is apt for high-temperature processes.

**Divinycell F**
FST core specifically developed for use in aircraft interiors and non-structural parts in commercial aircraft.

Divinycell F is a recyclable/reprocessable PES (Polyether-sulfone) core specifically developed for aircraft interiors. F is an excellent substitute for honeycombs, and decreases the weight and cost of aircraft interiors.

**Divinycell HT**
High-temperature resistant core suitable for pre-preg; commonly used in private aircraft.

Divinycell HT is good environmental selection due to its excellent strength-to-weight ratio and high performance over time. It is suitable for structural designs in aircraft applications and is available with full production traceability. Divinycell HT is suitable for pre-pregs processing as well as wet resin systems and infusion.

**Divinycell HCP**
From sea level to 700 meters depth.

Divinycell HCP is developed for various types of subsea applications and has very low buoyancy loss and water absorption under long-term loading conditions. HCP provides excellent buoyancy, insulation and impact protection.

**Syntactic foams**
From 700 to 10,000 meters depth.

Syntactic foams provide unique mechanical properties – including high compressive strength, high buoyancy per kilogram and low water absorption – making them ideal for a wide range of subsea applications requiring high performance and long lifetime.

**ProBalsa**
Used in marine and wind applications in combination with foam.

ProBalsa is an organic core material with exceptional compressive strength. It is used in a wide range of applications and can also be combined with polymer core materials in, for instance, wind blades.
Making you more competitive

DIAB is a world-leading supplier of sandwich composite solutions that make our customers’ products stronger, lighter and more competitive. Our extensive experience in providing sandwich composite solutions to customers has made DIAB a leading partner in the sandwich composite industry. DIAB’s solutions combine high-performance core materials, value-added kits, engineering and process services.

Core materials | Knowledge | Kits | Processing | Engineering | Training |
Global presence – local service

DIAB Group
Box 201
SE-312 22 Laholm, Sweden
Phone: +46 (0)430 163 00
Fax: +46 (0)430 163 96
E-mail: info@se.diabgroup.com

DIAB, Divinycell, Matrix and ProBalsa are registered trademarks in countries all over the world.

www.diabgroup.com