Corecell™ in Marine Structures

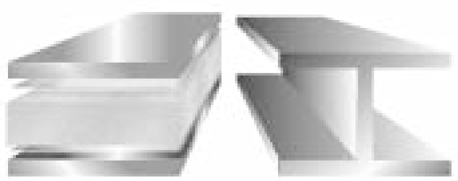
Contents

Why Sandwich Construction

Single skin laminates, made from glass, carbon, aramid, or other fibres may be strong, but they can lack stiffness due to their relatively low thickness. Traditionally the stiffness of these panels has been increased by the addition of multiple frames and stiffeners to reduce the panel size, adding weight and construction complexity.

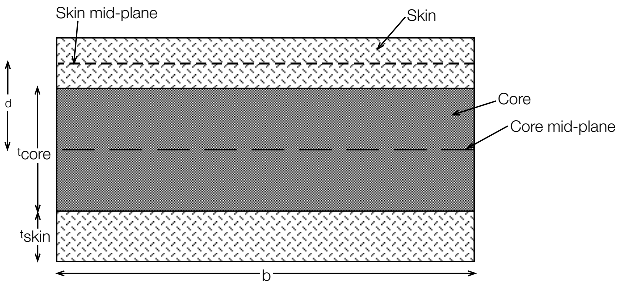
A sandwich structure consists of two high strength skins separated by a core material. Inserting a core into the laminate is a way of increasing its thickness without incurring the weight penalty that comes from adding extra laminate layers or extra framing. In effect the core acts like the web in an I-beam, where the web provides the lightweight 'separator' between the load-bearing flanges. In an I-beam the flanges carry the main tensile and compressive loads and so the web can be relatively lightweight carrying the shear loads. Core materials in a sandwich structure act as a continuous web and are similarly low in weight compared to the materials in the skin laminates.

Sandwich construction works in the same way as an I beam



A composite sandwich consists of a strong skin and a light-weight, stiff, core material

Sandwich construction dramatically increases stiffness whilst reducing weight.



A sandwich's stiffness is proportional to the cube of the increased core and skin thickness

Core Materials in Marine Applications

Together with the resins and reinforcements used in the laminate, the core is a vital part of the overall structure and needs to be designed to satisfy the demands placed on it. These demands can be severe, and are usually different in different parts of the structure.

For example, a hull bottom is subjected to wave slamming and occasional point impacts from floating object, but it generally remains at a modest temperature since it is continually immersed in water. A topside or deck structure forward can also see slamming loads, but aft usually do not see the same high impacts but may well experience very high surface temperatures, particularly if painted a dark colour. These very different conditions give rise to the need for different laminate and core materials if the structure is to be optimised.

Corecell - Optimised for the Marine Industry

Corecell's Styrene Acrylo-Nitrile (SAN) chemistry is unique and is optimised for marine applications. By using SAN as the base polymer, the different grades of **Core**cell have distinctive properties that are specifically suited to marine structures.

The Benefits Inherent in all **Core**cell

- **Stable in a marine environment**
- **Built-in toughness**
- **Fine cell-size**
- **Superior uniformity**
- **Eliminates outgassing problems**

Stable in a Marine Environment - All **Core**cell foams are closed-cell in structure. This means that they cannot act as a 'sponge' and absorb water in the way that honeycombs and balsa can. Even if cores are never intended to be exposed to water, damage can occur and water can creep in through cracks and around fittings. **Core**cell will not change its properties in this situation, whereas balsa can rot and honeycomb cells can fill up with water. The SAN polymer is also known for its chemical resistance and is thus highly resistant to the chemicals seen in a marine environment such as fuel oil and hydraulic fluid.

Built-in Toughness – SAN is an inherently tough polymer. In the case of **Core**cell A-Foam, this creates ultra-tough and damage resistant foam. Other **Core**cell grades also benefit from this SAN characteristic, demonstrating robustness in handling and final service that exceeds other more rigid polymer foams. Whereas **Core**cell's toughness is inherent in its polymer backbone, more rigid foams can only be slightly toughened through the addition of plasticisers, which can leach out with time. The toughness of **Core**cell also manifests itself in the wide variety of **Core**cell product forms that are simply not practical from more brittle foams. This includes contoured formats in **Core**cell that are produced by cutting with a knife-blade at depths and densities where other foams have to resort to using wider saw cuts, something that dramatically increases resin uptake. The SAN toughness can also be used to create fine taper edges such as those used on fillet strips or 'bead and cove' planks, and it also generates high handling strengths, even in thin sheets. Easy machining, with a wide variety of equipment, is also common to all **Core**cell products.

Fine Cell-Size – Inherent to all **Core**cell foams is a fine cell size, which derives from both the chemistry used and the manufacturing process. This cell size has a dramatic influence on the amount of resin that is absorbed into the surface of the foam, an effect that becomes even more pronounced in flexible product forms such as contour-scrim (CS) or double-cut (DC) where the exposed surface area is much increased. Modern resin infusion processes also increase resin uptake in a core, as they ensure that all surface pores and the gaps between contour blocks are thoroughly filled with resin. Experiments have shown that a 1" (25mm) contour-scrim panel of 60kg cross-linked PVC (X-PVC) when fully infused with resin will weigh approximately 50% more than the equivalent panel made of **Core**cell T400, through the combined effect of the higher surface resin absorption and the wider, saw-cut gaps of the X-PVC This has a dramatic effect on the final weight of the structure and totally changes the 'real' density of the core material.

Superior Uniformity – **Core**cell is manufactured in blocks of foam that are later sliced to the required thickness for use. The manufacturing process used for **Core**cell produces foam that is extremely consistent from one block to another, as evidenced by the density tolerance within which **Core**cell is supplied. Since mechanical properties are proportional to density, this tight and consistent density range translates to tight and consistent mechanical properties as well as weight from one block to another. For example, the stated density range of X-PVC from block to block is -10 to +15%. For balsa it is typically ±18-20%. For **Core**cell it is ±5-7%. This same consistency block to block can also be seen in **Core**cell through the thickness and across the surface of any individual sheet. With **Core**cell, you know precisely what properties you are getting in your foam.

Eliminates Outgassing Problems – **Core**cell is produced in a different way than cross-linked PVC's, with cells containing nitrogen rather than carbon dioxide. The **Core**cell expansion process is also carried out 'dry' as opposed to in water or steam as is used for X-PVC. Not only does this result in a much shorter production cycle for **Core**cell, but also the resultant foam has less tendency to 'outgas'. This phenomenon can cause all sorts of problems during construction, especially at elevated temperature. Even in service, exposure of the finished structure to the high surface temperatures that can arise when a dark-painted structure is exposed to the sun can cause ugly outer-skin blisters if excessive outgassing occurs. Even more insidious, though, is the chemical make-up of the gases that come out of X-PVC foam. Even if using 'de-gassed or high-temperature' X-PVC foam, minute quantities of chemicals emanating from the foam can interfere with the cure of epoxy prepregs and adhesive films adjacent to the core. This 'inhibition' manifests itself as an under-cure of the material. This may not always show as a low bond-strength, but it can be detected by the low 'glass transition temperature' (Tg) of the prepreg or adhesive film. Even if the bond appears fine, a laminate or adhesive film with a reduced Tg is structurally impaired and will not have the long-term structural properties that would be expected of a fully cured material. **Core**cell does not contain the chemicals that cause this inhibition and so it can be safely and reliably used with prepregs and catalytically cured, long open-time epoxies.

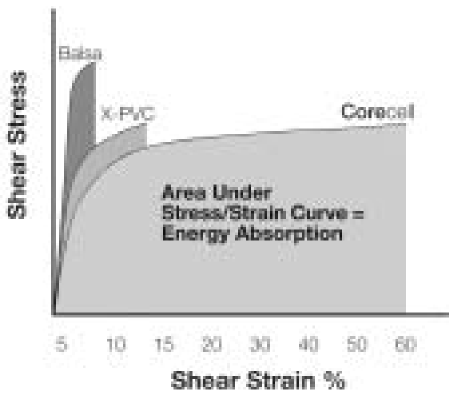
Corecell A-Foam and P-Foam - Ultra Tough Foams

- **Ultra-high resistance to shear cracking and fatigue**
- **Withstands very high impacts and slamming loads**
- **Superior styrene and temperature resistance to linear PVC foam**
- **Easily thermoformable**
- **Ideal for hulls and other dynamically-loaded structures**

Corecell A-Foam and P-Foam are related products, sharing the same ultra-tough characteristics. They are intended for the same applications, the primary difference between them being the recommended processing temperature. **Core**cell A-Foam is intended for use in low-temperature manufacturing processes (<65°C) such as hand lay-up and liquid resin infusion. **Core**cell P-Foam is heat-stabilised so that it can be used with marine prepreg systems in cure processes up to 85°C, and as with all **Core**cell, it shows none of the chemical inhibition effects that are common with X-PVC Foams.

Ultra-High Resistance to Shear Cracking and Fatigue – **Core**cell A-Foam and P-Foam are the original **Core**cell, well known for their incredibly high toughness and resistance to shear cracking. When loaded in shear (the primary loading mode for any core material), **Core**cell A-Foam and P-Foam exhibit far higher shear elongation before failure than balsa or X-PVC. For example, **Core**cell A-Foam and P-Foam will typically deform 50-65%, X-PVC 15-35% and Balsa <2%.

A typical stress/strain curve is shown below. The total area under the stress/strain curve is an indication of the total energy that the core can absorb before failure, and so in an overload situation these **Core**cell products will stretch and deform without cracking, whereas balsa and X-PVC quickly reach a deformation where cracking and failure occurs. This shear cracking quickly spreads into the core: skin interface causing delaminating and potentially catastrophic skin rupture. The more 'ductile' behaviour of **Core**cell is widely used to produce highly robust hull structures that if overloaded will simply 'stretch' without any catastrophic failure. This same ductile characteristic also gives **Core**cell A-Foam and P-Foam an extremely high resistance to fatigue failure from the repeated loadings that high performance hull structures experience in service.



Withstands Very High Impacts and Slamming Loads – The ductile, energy-absorbing nature of **Core**cell A-Foam and P-Foam means that when loads are applied at high speeds, the foam demonstrates a remarkable increase in strength over X-PVC. This 'strain rate effect' has been well documented by researchers working for the Swedish Navy and in recent work by the University of Auckland. These high strain rates can occur in incidents such as impact with a floating object or dockside, as well as in high-speed wave slams. In these situations, **Core**cell demonstrates a resistance to failure that is far superior to the more brittle foams, as illustrated in the pictures below. Here a high-speed shear loading has been induced in the test pieces, simulating an impact on the outside of a boat hull, close to the location of an internal frame or stiffener.

Single Skin Fibreglass
7 x Biax 1808, 1 x mat, polyester resin
Panel weight 15.6 kg/m^2; 3.1 lb./ft^2

- Heavy
- Punctured
- Serious structural damage
- No longer watertight

Cross-Linked PVC Foam
80 kg/m^3 (5 lb/ft^3)
Panel weight 14.4 kg/m^2; 2.8 lb./ft^2

- Serious structural damage
- Core shear failure
- Skin delamination

Balsa
Panel weight 16 kg/m^2; 3.2 lb./ft^2

- Total structural failure
- Core shear failure
- Damage not visible on surface
- Heavy

Corecell
A500 80 kg/m^3 (5 lb/ft^2)
Panel weight 14.4 kg/m^2; 2.8 lb./ft^2

- No structural damage
- No core shear failure
- Isolated damage only
- No crack propogation
- No leaking
- Easily repaired
- Lightweight

Superior Styrene and Temperature Resistance to Linear PVC Foam – Linear PVC foams, such as Airex R63, share the same highly ductile and tough characteristics of **Core**cell A-Foam and P-Foam. However, this ductility comes at the price of a low resistance to styrene and a very low service and process temperature. The low service temperature can even show itself in hulls being deformed and dented by the pressure of a boat support in a sunny environment. **Core**cell overcomes these problems with a styrene and heat resistance that is far better suited to modern boat structures and manufacturing processes, particularly resin infusion.

Easily Thermoformable – The highly tough characteristics of **Core**cell A-Foam and P-Foam are maintained at their best by minimising the cuts and joints in the core. By using heat to curve the core, rather than cuts, highly curved parts can be made from plain sheets of foam. Corecell A-Foam and P-Foam are easy to form in this way by using simple heating systems.

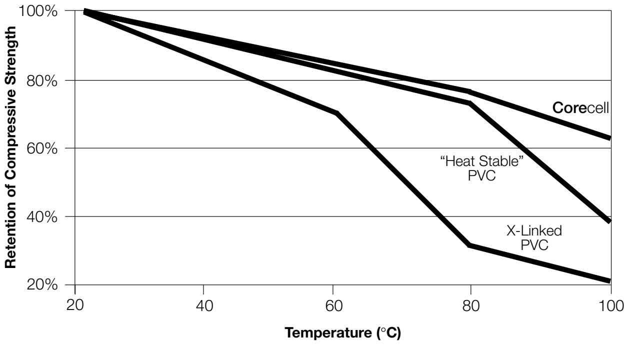
Corecell **T-Foam - The Stable Foam**

- **Increased rigidity over Core**cell **A-Foam and P-Foam**
- **Stable to over 100°C**
- **All the** Corecell **benefits at a competitive cost**
- **Ideal for decks, superstructures and interiors**

Increased Rigidity over Corecell **A-Foam and P-Foam –** **Core**cell T-Foam is the newest member of the **Core**cell family and is formulated to have slightly higher stiffness properties, and even greater styrene resistance than the more ductile **Core**cell A-Foam. Although **Core**cell T-Foam benefits from the inherent toughness of SAN, the higher rigidity makes it more suitable for those parts of structures where stiffness is an important criterion and loads are less dynamic in nature. Decks, superstructures and interiors of boats are optimal marine applications for **Core**cell T-Foam as a natural replacement for cross-linked PVC or balsa.

Stable to over 100°C – The formulation of **Core**cell T-Foam generates a remarkable thermal stability for polymer foam. At 100°C conventional cross-linked PVC foams retain less than 20% of their room temperature compressive properties, whereas **Core**cell T-Foam retains nearly 60%, surpassing even that of 'high temperature (HT)' X-PVC's. This stability means that boat structures such as topsides and decks exposed to direct sunlight, or other sources of heat, will not lose their properties and the effects of core print-through will be minimised.

The high temperature stability of **Core**cell T-Foam also means that it can be used in manufacturing processes to at least 120°C with short durations during a cure cycle to over 150°C. This makes it ideal for use with conventional prepregs and in some liquid infusion processes where high resin exotherms can often be seen.



All the Corecell **benefits at a competitive cost – Core**cell T-Foam brings you all the inherent benefits of SAN foam chemistry described earlier: stability, toughness, fine cell size, uniformity and outgassing resistance. However it does so at a lower cost where it can be a highly competitive alternative to replace X-PVC. Furthermore, with its very fine cell size and its ability to be knife cut, **Core**cell T-Foam can dramatically save on the amount of resin absorbed in infusion processes, saving weight and resin cost.

Corecell S-Foam - For High Pressure Buoyancy

- **High hydrostatic crush strength and water resistance**
- **Ultra-fine cell size**
- **Lower density than a syntactic**
- **Ideal for deep-sea buoyancy applications**

High Hydrostatic Crush Strength and Water Resistance – Corecell S-Foam has been designed specifically for use in sub-sea buoyancy applications. Its resistance to crushing means that it can withstand depths of over 1300m, and its closed-cell structure gives it a high water resistance that ensures buoyancy is maintained over time. With its very high compressive strength, **Core**cell S-Foam can also replace other materials, such as plywood, when creating high strength inserts for through bolting in composite laminates.

Ultra-Fine Cell Size – Corecell S-Foam has the smallest cell size of all the Corecell products and in lamination processes it absorbs very little resin, thus minimising weight gain. The small cell size and the product's inherent toughness also contribute to the excellent machining qualities of **Core**cell S-Foam. Here, complex shapes can be created using a variety of milling, routing, sawing and drilling techniques.

Lower Densities than Syntactic Resin Film - **Core**cell S-Foam is available at lower densities that can be achieved with a syntactic, with standard products ranging from 150 to just over 300kg/m^3. As with all **Core**cell products, this density is very uniform throughout the sheet and between batches, something that can be hard to achieve with a liquid syntactic casting.

The Corecell Advantage

In summary, the **Core**cell family of structural core materials includes an optimised material for every part of an industrial sandwich structure. The **Core**cell product range is backed by SP's full technical support package, from design right through to finished laminte testing. **Core**cell structures are in service the world over and lead the way in cost-effective sandwich technology.

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