KELSALL CATAMARANS

The Core of the Sandwich

By Derek Kelsall, 2009

On the topic of cores in the structure of boats of all kinds, no one has more direct experience and involvement than I. Involvement which covers foam in designs, in the boat shop and on the water, over more than forty years. If I have not seen or know of any factor introduced into any debate on this topic, it is irrelevant.

In any comparison of suitability for a purpose, the only valid factors are those which affect the production of the vessel and the operation of the vessel over time. All other factors are irrelevant. For example, it is irrelevant if the compression strength of balsa is higher than that of foam where the foam has never been known to fail in compression in normal use.

Today no one will argue against the use of sandwich composite structure for boats. The sandwich for panel stiffness is the equivalent of the I beam for beam stiffness. Stiffness is the critical factor for most parts of the shell structure of boat. The stiffness is proportional to more than the square of the thickness. This means, double the thickness and 8 times the stiffness. If the thickness is in the core, the weight penalty is minor.

One of the most important advantages of PVC foam core is that the stiffness can be achieved in the sandwich, removing or reducing the need for internal stiffeners. This means a cleaner interior and less work is involved in both construction and fit out.

PVC foam still standing proud of concrete since 1969

The industry standard core for catamarans and almost all production boats of any size, is cross linked PVC foam (or the similar SAN foam) with fiberglass skins, as I pioneered in 1965. This is an ideal combination, providing strength, least weight, built in insulation, durability etc., for boats of all kinds and it is economical.

PVC foam is available in different densities, thicknesses and as either cross linked or linear. We have used PVC foam in every conceivable way, on hundreds of boats. This is 43 years of designing, which includes 20 years when custom boat building and daily involvement with storing and moving boats, was my second business. All types of boats were designed and built, including at least 5 which were largest of type at the time and all were foam sandwich. Foam has proven to be entirely reliable for all of our work. I have seen many alternatives come and go. Some promised cost savings but did not pass the simplest of tests. If attracted by the offer of an alternative core, do what I do. Get a sample. Put it into boiling water for a few minutes and then transfer to cold water. If this shows no ill effects, just let it soak for a few days or weeks. Structural strength is obviously essential. Durability and compatibility with the skins is next. Insulation, weight, impact resistance, versatility in use etc., are some of the other factors to consider.

PVC has the reputation in some sectors of the industry for being expensive. The cost of foam is often compared to plywood, made on cost per area. That comparison fails to consider the huge wastage (which can be 40%), when working with 8x4 sheets and the area needed for joining. Foam has very little wastage in the way we use it and in every true comparison I have made over the years the total foam sandwich cost has always been very competitive and usually the least overall cost. When including the value of insulation, essential to live-aboard comfort, it has always been the least cost. We start with the basic materials, at the least cost. We do not use the strip materials or pre-made panels, which cost more, of any kind.

The Foam boats to which the Kelsall name was associated in the early days began with a designed, built and raced Toria, to win the 1966, 2000 mile Round Britain Race. (I had previously completed the Solo Atlantic race on the first true multihull to do so). This was followed by building 58 ft. Sir Thomas Lipton to win the 1968 Solo Atlantic race. Many others followed with one, two and three hulls. The next big race was the first Whitbread Around the World. 78 ft., GB 11 was built for Chay Blyth, wth his crew of Marines, to be the first to finish. Five more Whitbread races and at last count 50 Atlantic crossing to her name, this remarkable and probably the most traveled yacht ever, is still going strong.

Airex were one of the first if not the first producers. They offer both the Cross Linked PVC and a Linear PVC. The later is particularly flexible and tough, but expensive. It is ideal for forming and for high impact applications. Cross linked has been used for all of our designs, with a few designs using some parts of linear. Today, our usual specifications are for all cross linked PVC.

In 1969, in the small town of Sandwich, in Kent, UK., I constructed a concrete slipway using PVC Foam off-cuts as the spacer between the concrete sections. The picture was taken on a visit two years ago. After twice daily washing with the tide, the foam still stands proud of the concrete and shows no signs of deterioration. Ie. forty years of full exposure.

Contour Cut Foam

Contour core in the wrong hands has caused problems. It only applies when used in moulds. All voids must be filled for it to be satisfactory. The foam will not rot, but if water does get in, it will tend to travel along the channels in the contour foam if they are not filled. Once the water is in, it is difficult to see a good way to remove it. Ideally, resin infusion would be used, which would fill all voids. All of our work is done with plain sheets.

Below Water Line

There is a belief in some quarters that foam should not be used below the water line. We have always used everywhere and can see no reason not to use below the waterline. I could argue that there is more pressure inducing water to pass into a core above the WL due to the changing temperature and conditions. The records for problem free, durability of PVC foam can not be challenged.

Styrene Attack on PVC Foam

If the foam is exposed to Styrene for sufficient time, there will be some softening of the foam. Over time, the softening will dissipate. In practice, we ignore the problem and always have. The main point here is that if there is going to be any softening it will be evident immediately. If it is minor it will disappear. We have tested regularly over the years, and although there was a time when hot coating and the like were recommended by manufacturers, we no longer read this message.

Outgassing of PVC Foam

This is a topic to be aware of but of no real concern unless planning to use a dark color for the boat. It is due to the PVC being slightly undercured and releasing gasses at higher temperatures. A few of our boats have had the foam given extra cure in an oven before use. I have seen out-gassing on two boats only. Both were palm size bubbles visible in the outer skin, both on one side of the bow and both on dark colors. Repair was to cut out, patch, refinish and forget.

PU Foam

Polyurethane foam is readily available and has some similar characteristics to PVC foam. The main difference is the brittle nature of PU. This makes it unsuitable for any structure which is likely to be subject to even minor impact. An impact tends to break the foam cells immediately under the impact area, damaging the all important bond between skin and core. PU is commonly used for insulation in lightweight density. To achieve the structural strengths needed for boat parts, the density must be increased, at which point much of the price advantage is lost.

Honeycomb

Honey comb can be the least weight, which may be appropriate for an extreme racing machine. There are plastic, paper and aluminium honeycomb cores available. Plastic is the most widely promoted.

The honey comb has large cells the full thickness of the core, which need to remain void, limiting its use for such as Resin Infusion. In contrast, the surface of the PVC foam has small cut cells. In practice these fill with resin, to provide both full adhesion between skin and core and backing for the thin skins which are essential to light weight. The bond area to the skins to honeycomb is much less than foam and is likely to be the weak link in the structure. I do not claim to have done exhaustive tests. The foam does the job. It has been proven a thousand times over and it is economical. The honeycomb alternatives offer no advantage for exterior structure. I take the view that if nothing is broken, lets not try to fix it. PVC has been 100% reliable, but also more versatile (than any other) in use for forty plus years.

The Promotion of Alternatives to Foam Core

Recent months have for one reason or another involved me in debates on cores for composite structures. The most recent comes from the promotion of Polycore and of Nidacore. Both are plastic honeycomb, to which the above apply. Both are claimed as having superior properties to PVC foam, for instance, and to be suitable for all purposes. The later claims, with the questionable supporting data, I find concerning.

My first test of plastic honeycomb demonstrated that the thin skins that we use, are under considerable pressure due to changes in temperature and that the smallest fissure will allow water through. Of course, the same fissure may happen to the skin on the foam, but there is no where for any quantity of water to go, no rotting and of course no evidence on the boats.

Visiting the Nidacore website, we find a comparison table, consumer magazine style, with various factors given a score and a total score. The surprise is not that Nida comes first but that balsa comes second and totally unbelievably, the message is that PVC foam is the least suitable core for boat building. This is flying in the face of 40+ years of indisputable evidence to the contrary.

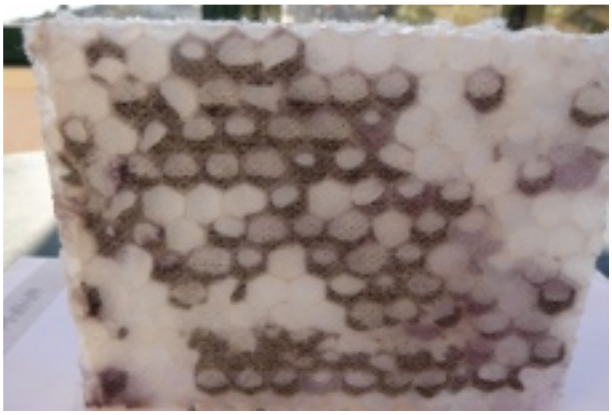
A nice boost for balsa perhaps. Skeptical perhaps, but I see Nida aiming at the market where PVC foam dominates in the boat core industry. Look at the list of factors. No mention of the difference in bond area to the skins. No mention of the fact that light rays will diffuse through honeycomb, the glass skins and the typical white paint finish. No mention of resin infusion. We then note that Nidacore honeycomb scores higher than PVC foam for versatility. No one who has ever spent one day working with foam could look at plastic honeycomb and give it a score above foam on this count. Looks to me like a pre-planned result and the scores adjusted to suit. That balsa, placed as the second most appropriate core, was given a low score for water resistance should have excluded it from any serious comparison anyway. Nida used to sell pvc foam sections to create bevels!! Nida is now introducing a foam core itself!!

Nida core plastic honeycomb, in the comparison table, has a score of 3 out of ten for sheer strength. A 3 score would be taken as being less than satisfactory. This shows just how ridiculous the comparison is. This is to say, go ahead and use this material, do not be surprised if it breaks, but it is the best because it has all kinds of other desirable properties.

Another part of the Nida brochure has a heading “Rot Proof”. The first words under the heading are PVC and SAN foams. Rot has never, ever been associated with these foams in any way. Another blatant attempt to undermine foam core. Styrene can soften PVC. In practice, it simply does not affect the typical project. I have done many tests on typical laminates and conditions. The only effect I have seen was on test panels I made before using the foam on any boat. The resin was high styrene type, the foam was thin and the cure conditions were not good. Initially the parts were not very stiff. Two weeks later they were stiff. We have ignored the problem ever since. If there is a problem it will be evident immediately. Ie it is not something which happens over time, such as rot in timber.

I received a sample of the plastic honeycomb suitable for infusing, which has a 50 micron film under the polyester scrim. After putting the sample into hand warm water for a few minutes and then transferring to cool tap water, half the cells have water in them. Some appears to pass through the film and some travelling under the film from the open edges.

I have samples from another plastic honeycomb producer who also claim it is good for all boat structures. One sample comes with a 1mm skin. The hot/cold water treatment fills the cells. We use 1mm skins in many places. Any wet deck or hull on a sun and showers day has this high pressure system sucking moisture in through the smallest fissure. Once in, who knows. It is not coming out and frost must add to the hazard to the structure.



Nidacore Plastic Honeycomb with 50 micron film each side after emersion
in hand warm water and transfering to cool coloured water

The comparison table, to those in the know, must discredit Nida's own products. There is nothing wrong with Nidacore for the right purposes; interiors in particular, but on the evidence I have seen so far, not for outside main structures.

Balsa

Balsa is an alternative core, which is promoted by suppliers and which is endorsed by many designers and hence by boat builders. I have no hesitation in condemning all use of balsa in boats. If you are a boat buyer, never buy a boat with balsa in the structure. No designer with any REAL boat experience could specify balsa. By real, I mean spending time on the water where you encounter other boats, sailing all boat types, particularly the older ones and in boatyards where these balsa boats end up needing extensive repairs or get scrapped. That all round experience tells you that water will get into everything on a boat, unless extraordinary care is taken. Real boat experience is not found in the design office or around new boats and never on any design course. The real world of boats is not the typical designers scene anyway. I recommend a quick Google of ''wet balsa'' for an introduction to the potential for problems.

My first encounter with balsa was about 1968 when I saw the effects of leaving off-cuts of balsa sandwich exposed to the elements. Within days, the fiberglass skins peeled off. For a short period of time, we used balsa in decks of a 25ft. speed boat we moulded for another company – not my spec. We took great care to not expose to moisture in the air except for the minimum working time to get it covered with fiberglass. I do not see the same warnings today. Another encounter shortly after was in the decks of a popular catamaran of the time. Within months, some were showing signs of water getting into the balsa decks. I had already made myself a rule coming from observing the difference between foam and plywood after exposure to sea conditions and finding the plywood was wet and the foam sandwich bone dry. I decided that the foam sandwich materials would be entirely suitable and more convenient for all parts of the boat. That rule – never put anything into the structure which can take up moisture and rot. I have followed that rule in all specs that I have written. I can guarantee that those boats are sound today. I regularly encounter balsa in boats or via contacts. Invariably it is for it's problems after water has entered the balsa. Major surgery, or scrapping is involved.

How can balsa be endorsed by the industry after the above experience over such a long period of time? I see it as some belief that epoxy resin has some magic properties which exclude moisture for ever. The very idea is crazy. Live on the typical boat for any period of time and you will be amazed at how the water gets into everything. Put balsa into the structure and that balsa will rot. The biggest problem for the owner is that there is no way to know till the problem is serious. It may happen this year or next or in twenty years. The main point of my argument is that there is absolutely no gain anywhere. There is the argument that balsa is better in shear and compression than foam but that ignores the fact that better is only better if it solves a problem. The problem is not there when foam is correctly specified and used. Foam has never, ever let us down.

If a boat built 40 years ago, which is passing survey today with flying colors and is as light weight as to-days best, there is no way that anyone could argue that my spec in 1965 was not entirely appropriate for the purpose. I can take you to the boats. They will be good for another forty years. These old boats, of which I admit we never considered their future in such terms of how many decades, keep coming back and always with the same story of basic sound structures. I find it very satisfying. I would certainly find it very unsatisfactory if I had to tell a current owner or potential buyer that these boats have gone past their use by date, which would be the case if there was balsa in the structure.

The whole industry should grasp this nettle. Do all boat owners a favour. Get rid of the balsa time bomb.

Not convinced. Try this. The skins we use are often 1mm thick or less. Imagine a water tank made of 1mm of fiberglass. Would you expect it to keep water in. I wouldn't. The skin of a boat to protect the core is measured in hundreds of square meters, all of which are subject to impact of some kind from time to time.

Then talk to a chemist. He will tell you that no material is a total barrier to water. Ie. if all the appropriate measures have been taken (a considerable expense and never, ever guaranteed) the water will still get through in time. No one is ever going to give a full guarantee against rot. Neither is it easy to find in its initial stages. Then, what about the guy who goes aboard with a drill further down the line. He may have no idea what the structure is or of the potential damage he could do.

The following is a quote I picked up from the web, which encapsulates the situation rather well. ''Oh well...as long as designers keep designing for balsa core and builders keep skimping on their boat building I reckon down the road owners like myself will keep whinin'. I guess if I'da been more successful I'd be buying new boats and letting the next guy suffer''.

A debate on a number of forums recently left no doubts of the wisdom of banning balsa. The only rational argument in favor was a long list of designers and builders endorsing it. Sounds improbable that all these experienced boat people could have the wrong notion of balsa. One has to understand this industry to understand this situation. Fashion has a huge influence. One does it, others follow. Could it be that admitting a poor materials recommendation could open the door to claims. On the other hand as long as everyone else is endorsing the material it might be difficult to make a case. That balsa problems are being hidden is fact. I hear them but the designers continue their promotion. I know at least one situation in which the buyers pay a premium for the ''wonderful balsa core'' to put in their boats.

The stories I have heard and seen would fill a book – from soft around all windows after five years, to an all balsa, nice looking 55 foot cat with no chance of repairing due to the extent of the rot, to owners talking about the 'compost' in their boats.

Comment on the Nida Comparison

I give my view on Nida above based on a recent visit to their website, following a discussion with a client. I make no particular apology for picking out Nida as it is obviously applicable to this article but also blatant sales talk. I now have more samples and the Nida booklet on cores. My views are reinforced. Every argument I read is flawed and irrelevant. I will point out however, that Nida are not alone in such sales oriented arguments. The same kind of misinformation can be found selling many other materials. Designers are just as guilty of misinformation or is it over enthusiasm. I find it only steers me away from those products.

Nida have a new foam based core, which costs less than PVC. No, I am not excited. It raises more questions – but do not look to Nida for the answers. I do not get an answer when raising these points with the company.

The boat builders do the hard work and the owners pay. It is my contention that these people, on whom the whole industry relies, deserve better than to be faced with sifting through this rubbish to find the truth.

The Skins

We began using unidirectional glass and polyester resin on 80 kg/cu.m. crosslinked PVC foam. I have never seen any reason to change that basic specification. Today we do use vinylester resin for some projects. It has a higher water resistance and a higher elongation to break. We usually let our clients make the choice. We do not recommend epoxy resin, unless for an extreme boat in some way, where the ultimate in light weight is the objective. Epoxy will work fine for KSS, but is more cost and more importantly, more toxic.

Any of the fiber options of glass, carbon, kevlar etc., can apply with PVC Foam sandwich core.

Summary

The core of the sandwich, is the ‘core’ of the structure and a LOT MORE.
I would be the first to welcome a material which could offer cost or handling advantages over the PVC foam as a core. Reading the promotional material, balsa and plastic honeycomb sound like great materials. To get the truth however, you need to dig deeper. Too many designers and boat builders have not done their homework on this one and do not have the relevant experience to make an informed judgement.

To those with the relevant experience, in this context, PVC Foam and San foam are remarkable materials which no other material has challenged to date.

Toria. First foam sandwich yacht built in 1965

Great Britain II. First to win first Whitbread Round the World Race. Probably *the most travelled yacht*