The Aeroic Sine Wave Spar

Let's get a wiggle on.

James Hammond

Aeroic Sine Wave Spar installed on a Corsa 118″. (image: James Hammond)

This time I'm going to let you know a little about the Aeroic Sine Wave Spar *— what it is, how it happened, what it does, and how it's made. I'm not going to bore you with loads of math because I have never used any for this application. Once the idea came, like the wheel almost, it seemed so damn logical. I still don't know how effective it is in the numerical domain. The proof, I hoped, would be in the testing and so it proved to be. — JH*

Is This a New Idea? Emphatically: No.

The *Aeroic Sine Wave Spar* (ASWS) is far from a new idea and has been used in several military and commercial aircraft by Boeing and Grumman among others — but I actually didn't find this out until I began to cook up my own idea. After I actually tried it, it seemed to be such a good solution to many problems that I was sure it must have been used before on full sized aircraft. So I went looking for it on Google and sure enough I found it. That said, now, if you look on Google, half the references are to my own work and the excellent explanations of good buddy and co-conspirator Konrad Dudek.

Photo 2: A sine wave aircraft spar section. (image: James Hammond)

How Did the ASWS Happen?

Going back a bit I have to admit that the ASWS was born from laziness, or maybe boredom or a bit of both. In my time, actually from the mid-1970s when I first began in radio, I have made a great many model sailplane spars of different kinds, but I had never been totally happy with what I'd done for quite a few reasons — in order of my dislike:

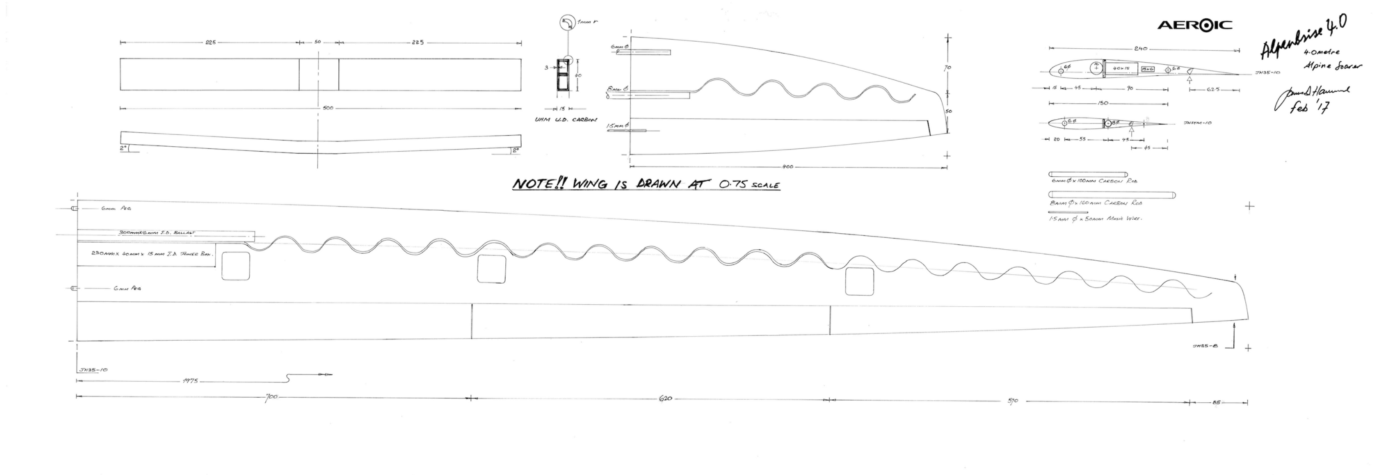
- Heavy
- Bulky
- Expensive
- Difficult to make
- Time consuming to manufacture
- Poor in torsion unless wildly reinforced with larger than life spar caps
- Dubiously effective

The situation was that I was always wracking my poor brains for some way to make lighter, slimmer, less costly, easier and faster-to-make spars with good torsion resistance, and overall more effective than the alternatives. Seems like a tall order, and for many years it was just a dream. Until one day I had an epiphany.

Bingo

I discovered the humble carboard box, but this was not just any cardboard box, it was a super strong thick-walled version used to pack heavier marine engine parts, and maybe it was that feature that attracted my attention. I guess I may have been studying the box somewhat wistfully, remembering that my old friend Roland Sommer — another Taiwan 'refugee' and now sadly passed away — had in his younger days used corrugated cardboard as a core material for F3B model wings. A true modeller, and owner of *Wowings*, Roland was always a dab hand at repurposing everyday materials.

My eyes fell on the centre section of the box material — made of heavy folds of corrugated paper. Then suddenly it occurred to me, in fact like a flashbulb going off; I could see a potential new way to use those wave-like folds, this time by situating them vertically instead of horizontally, and that's how it all started. I hate to say it, but this was a real case of 'thinking outside the box' (pun entirely intended).



Drawing 3: ASWS in the Alpenbrise alpine soarer flying surfaces. Note that the spar is curved to follow the maximum thicknesses of the flying surfaces and has a straight portion near the root to mate with the wing joiner box. (drawing: James Hammond)

Got to Try It…I Was Fired Up

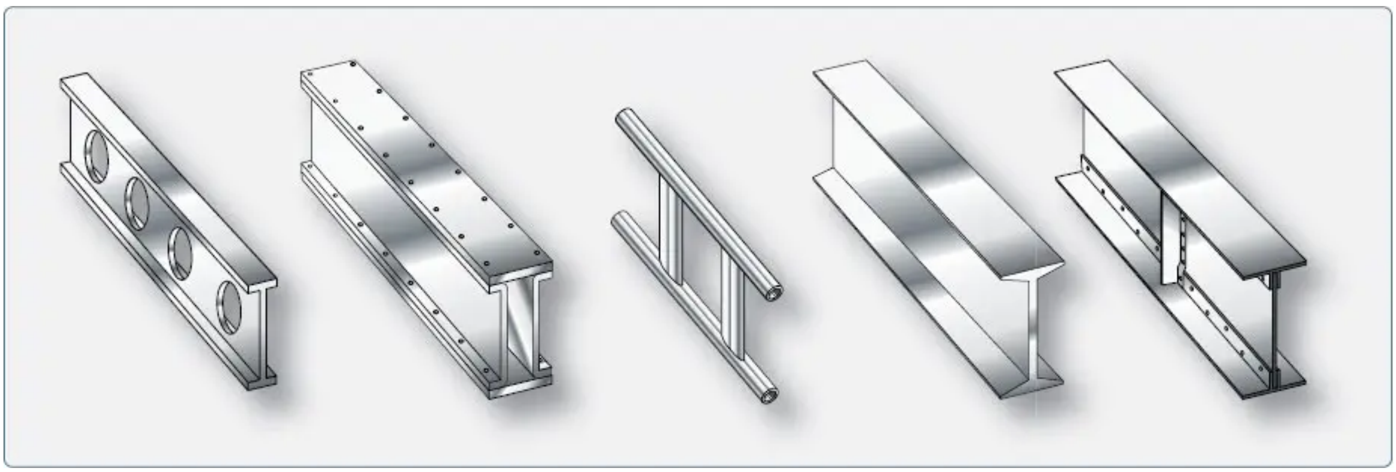
That was one of those occasions where I was almost falling over myself to get something made up that could prove the theory that was developing like an erupting volcano in my brain. The mould was easy — I just drove to the local DIY shop down and came away with a 6 x 3 sheet of plastic roofing material, with about 50mm peak-to-peak frequency. By that time, I was already calling it a 'sine wave spar' though I have to say I'm not actually sure that roofing material is a true sinusoidal profile, but it was going to do what I wanted which was to prove or disprove the idea. Perfect.

Photo 4: A whole sheet of early spars. Later the carbon was reduced and carefully oriented for optimum strength. (image: James Hammond)

I soon had the plastic sheet mounted and turned into a serviceable tool to lay up my first effort. Not wanting to go too crazy I just did a simple six ply lamination of carbon with the plies all in the same 180-degree orientation — in other words the worst case. After curing I cut the sheet and mounted the resulting "spar" into an old (damaged) Redshift model wing mould with a normal glass/balsa/glass layup and a pair of double carbon spar caps. I hardly slept during the 48 hours it took to get it out of the mould and honestly it wasn't the best job with imperfect bonding at the top — but it was enough. By this time, I was completely convinced that it was going to work — logically it just had to; but he big question was — how well?

Now, with my thanks, here's a slightly edited explanation from Konrad Dudek which was originally posted on the Aloft Hobbies Slope Forum:

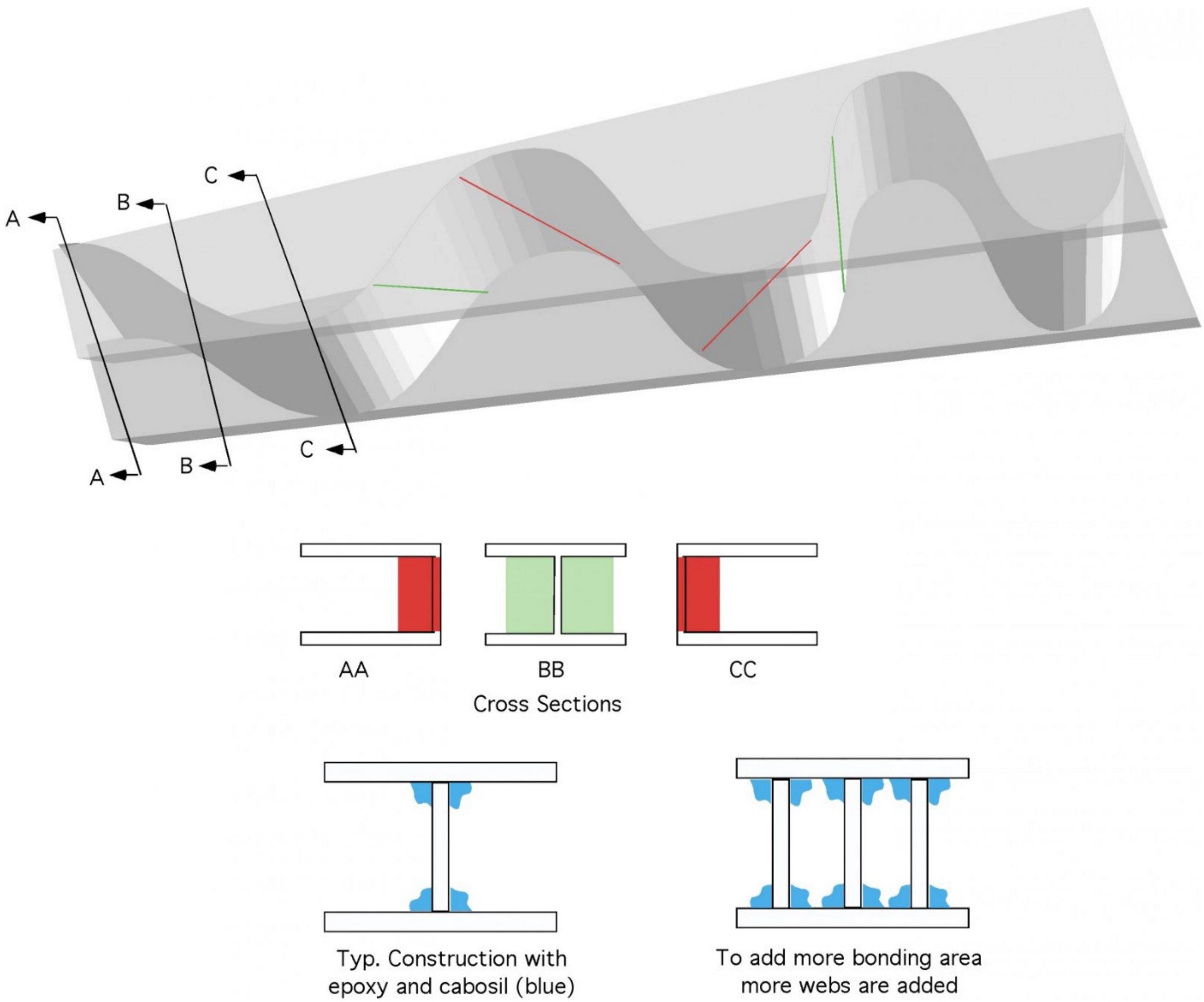
> *Let's set a base line using the I-beam and box beam models.*



Drawing 5: Various spar configurations.

> ***I-Beam***
>
> *It offers a lot of strength for any given amount of material (cross section) against bending. The further apart one can place the spar caps the stiffer the beam is against bending, as I recall this goes up by the square root of the distance. But the I-beam performs badly against any torsional loads it is very easy to twist.*
>
> ***Box Spar***
>
> *It performs much better against torsional loads. But if keeping to the*

> *cross section (mass) the same size spar caps would need to be brought closer together to allow for the material of the box webs. This is a huge cost in bending moment if one recalls the advantage of keeping the spar caps apart. Therefore, most box spars will need to suffer a weight penalty in added material to keep the spar caps as far apart as possible.*



Drawing 6: Cause and effect. (drawing: Konrad Dudek)

> ***Sine Wave Beam***
>
> *The serpentine web offers the best of both the I beam and box beam. With the vertical web going from one side of the spar caps to the other*

> *side of the caps the sine wave beam is much stronger against torsional loads than the box spar. The resulting sine wave beam is almost as light as the classic I beam but there can be slight weight gain compared to the I beam as the effective length of the vertical web is longer; but this can be adjusted in practice by judicious use of the carbon fibre during manufacture. Alternating the UD carbon layer numbers and layer directions between 180 and 45 degrees provides optimum strength.*
>
> *The advantages over ‘conventional’ spars are easy to see and measure by load and torsion testing of a sacrificial sample wing, as Doc H did in the beginning.*

Other Advantages of the ASWS

Flexibility

Although its technically monolithic after manufacture; until the ASWS is bonded into the wing, it is relatively flexible laterally, and that means it is really easy to train it onto the thickest part of the wing throughout its length — thus making it the most effective that it can be. This ideal positioning is hard or impossible for straight spars to emulate without cranking.

Strength Distribution

The strength and weight distribution are very easily controlled and easy to vary by layering the UD carbon plies according to the position of the spar in the wing. i.e. More fabric at the roots and less at the tips.

Bracing Directions

By changing the angles of the UD fabric plies to give directional bracing between 45 and 180 degrees, the strength distribution and resistance to bending and torsion can be infinitely varied and applied exactly as needed for the position.

Testing

When tested ‘against’ or maybe it’s better put as compared to a well-made conventional box spar, the ASWS showed up as about 30% of the total weight and gave a 15 to 20% increase in tension/compression stiffness while improving the torsional stiffness by about 75%. Quite impressive.

How It Turned Out

Running through my list, I was startled at how well it had come out:

Photo 7: An early experimental ASWS on some G10 glass plate. This method was abandoned in favour of direct bonding to the spar caps. (image: James Hammond)

Weight

About half the weight of a “conventional box spar assembly that I had been using.

Bulk

The ASWS is really skinny and although it takes up more space laterally, it's also somewhat flexible and will conform easily to the maximum thickness point of an elliptical planform wing — which I always use.

Cost

Possibly slightly more expensive that a box spar in the beginning (It turned out that I had used a lot more carbon than was actually needed.

Difficulty in Manufacture

No, it's the simplest spar even and can be made in large sheets that are later cut to suit.

Manufacturing Time

There isn't a lot — it's fast to produce.

Torsion

Compared to what I had before — ***wow***.

Overall Effectiveness

Massively improved.

Amazingly, it wasn't just a bit better than a box spar but for strength to weight ratio, the ASWS — yes, by that time I have to admit that I had claimed it — was in a whole new league of its own. Hence, the *Aeroic Sine Wave Spar* has been a feature in all of the Aeroic Composite Aviation Products model sailplanes since 2014.

I invite you to give it a try and see if you don’t agree!

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