Test to compare the camber shape (vertical cross section) of junk sail panels.

To examine the distribution of camber across the height of an angle shelf foot panel, and to compare 30 degree shelf with 45 degree shelf in that regard, I made four different panels (1000mm x 400mm) from a fairly stiff, 75gsm nylon cloth. Two at 30 degree shelf (designed camber 8% and 10%), two at 45 degree shelf (designed camber 8% and 10%). In addition, two panels were made with the seamless "barrel round" (or "round only") method, as documented by Arne, as I was expecting to see some contrast.

When the panels were inflated, the result was: there was little difference between the shapes of any of them, apart from the actual amounts of camber. To use flat-bottom dinghy terminology: the shapes across the height of the panel are all somewhat flat on the "sides" and "bottom", with a "soft chine" transition in roughly the same place - even with the barrel round panels.

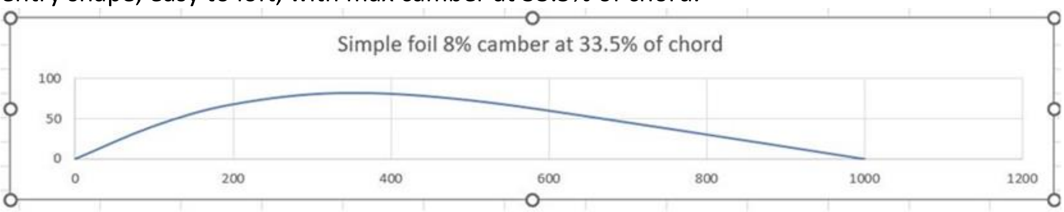


I was afraid that the type of cloth might have been a problem, perhaps not representing the real-life situation, due to problems scaling down in size.

Second set of tests
I did the complete experiment all over again, this time making panels from 30 gsm PelTec, an extremely light and soft but strong, Tyvec-like material, almost transparent, a bit fiddly to use but hopefully better representing at scale, the typical cloth used in making full size junk sails. The seams were made with basting tape only; stitching this light material did not seem necessary. There are a few creases and wrinkles – but generally it was easy enough to get the gist of each of the panel shapes.

These panels (1000mm "along the batten" by 400mm "between battens") are wider than normal narrow junk sail panel. Their p/B ratio of 1000/400 more resembles the proportions of the Amiina lower mains panels. It may be that the p/B ratio has some effect on the shape of the resulting panel when inflated.

Three panels (30 degree shelf foot, 45 degree shelf foot and barrel-round) were made, with a "designed camber" of 8%. The foil shapes were all mapped from the same identical foil, a simple, relatively sharp entry shape, easy to loft, with max camber at 33.5% of chord.

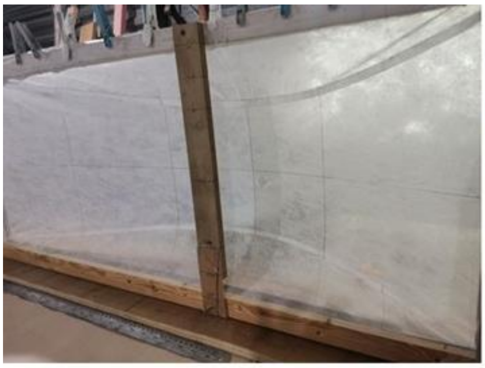


(The angle shelf foot panels were designed with a "tin plate" camber of 8%, and for the barrel round panel I just used the same foil above, scaled it to a get a maximum camber of 45mm, and used the resulting shape for the "rounding", hoping this would give a camber of about 8%.)

Three more panels were made, identical to above, except the designed camber was this time 10%, and I gave the barrel-rounded panel an extra 10 mm of round.

These six panels were framed, and inflated with a leaf blower. The resulting cambers, as measured, were:

30 degree shelf: 9% and 10.5%
45 degree shelf: 8.6% and 10.5%
barrel-round the cambers measured out as: 8.5% and 10%.
(It seems to be normal for shelf foot panels to get a measured camber which is greater than the designed, or “tin plate” camber). So, we have two sets of three, with comparable cambers, to compare.



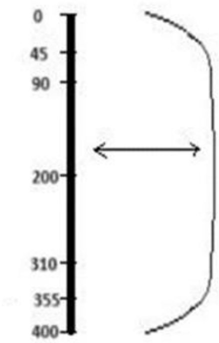
45 degree shelf 8% camber

The first surprising thing to notice is that the “soft chine” or transition between the middle, or “belly” of the panel, and the top and bottom “sides” of the panel, does **not** coincide with the position of the shelf seam. (In most photographs of shelf foot sails, the shelf seam creates that optical illusion, as in the left-hand photograph above. However, the photograph on the above right shows that the soft chine transition does not occur at the shelf seam). Indeed, the barrel round panel, which has no seam at all, exhibits an almost identical cross sectional shape.

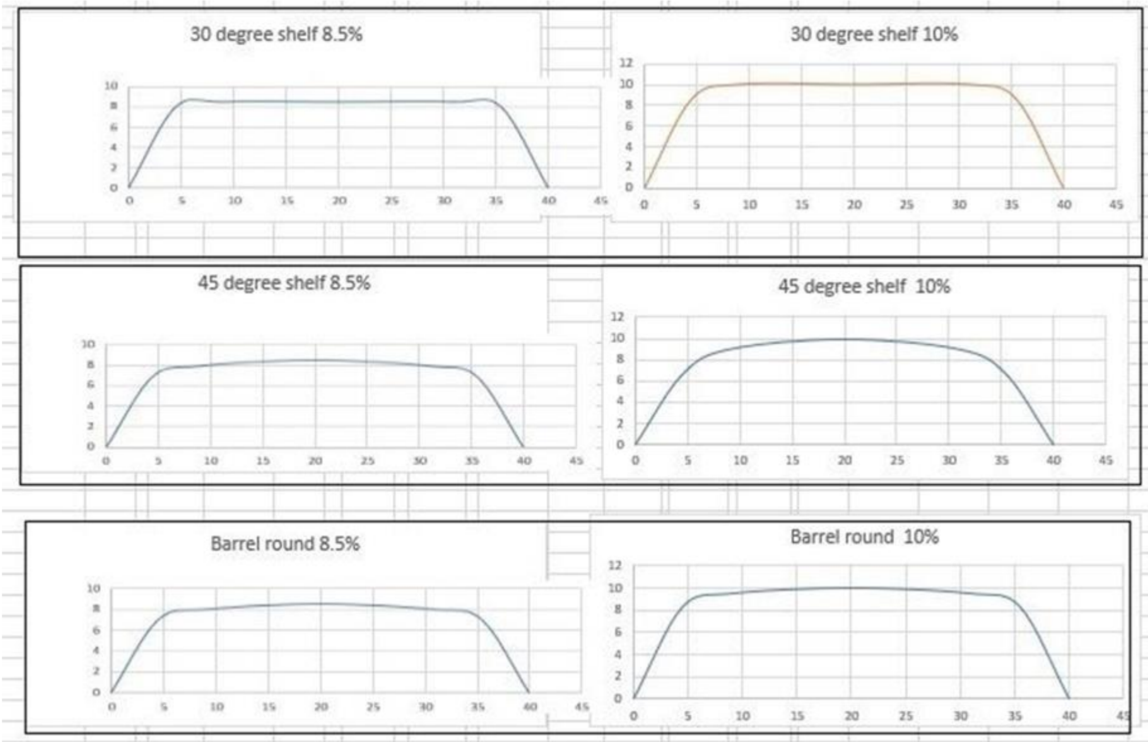
Barrel round 10% camber

30 degree shelf
10% camber

An attempt was made to measure the camber at various points along the height of the panel, from "lower batten" to "upper batten" along a line through the point of maximum camber.
Across the 400mm height, the measurement points (which became X-coordinates" were at: 45mm, 90mm, 200mm, 310mm and 355mm. The measurements of camber at the various points up the height of the panel became the Y- coordinates, and the Y-value at the point "200mm" is in fact the measured maximum camber, mentioned in a previous paragraph.

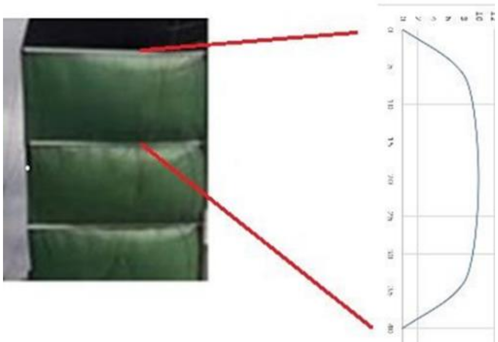


In order to compare the distribution of camber (as opposed to the amount of camber) the Y values of all of the data sets were scaled so that the maximum camber was 8.5% (for the first data set of three) and 10% (for the second data set).
The results were put back into the excel spreadsheet, which produced the following graphs:



The extreme edges of the panels were too difficult to measure, and the resulting automated "smoothing" of the data is a little odd, so the graphed shapes are slightly different from what the eye could see. The sides of the panels tended to be a little more curved than the flat sides represented here, and where the middle section of a panel rolls into the "soft chine", those little bumps on some of them are a quirk of the data smoothing algorithm, and may be ignored.

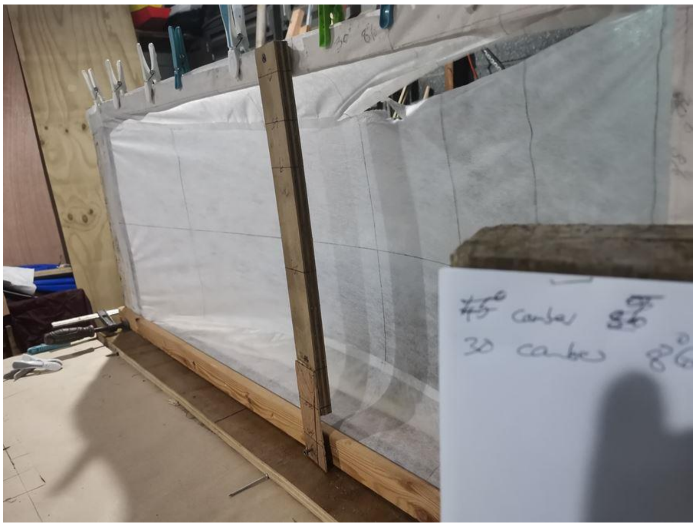
If these graphs look like round plastic wash basins (inverted) then the 30 degree basins will hold a little more water than the 45 degree basins, because the “bottom” is flatter and the “sides” are very slightly closer to vertical, especially at the very outer edges. This amounts to a slightly better distribution of camber across the height of the panel.



(The basin shape in the 45 degree10% (the 4th diagram) looks rather like a vertical cross section of the panels on my *Serendipity* (which were made from a very, very soft nylon approx. 70 gsm – cloth taken from an old well-used spinnaker)).

At the extreme outer 3 or 4 cm at the edges, there was no measured data and this distorts the graph a little. In reality the panels all tend to be a bit more “horizontal shelf-ish” at the edges than the graphs indicate – as already mentioned. This was more noticeable in the 30 degree shelf and the barrel round panels, and less in the 45 degree panels. The differences were not great, and the middle 80% - 90% of the graphs is a pretty fair representation.
The second thing which surprised me most was how closely the cross section of a barrel-round panel resembles the cross section of a 30 degree shelf angle panel. The outlier here is the 45 degree panel, which does seem to distribute camber in a more shapely but perhaps slightly less efficient manner than the other two, though it seemed to me to be slightly easier to inflate.
I did observe, while using this very light and flimsy material, that the panels all seemed to be distributing the forces within the cloth in a rather similar and (to me, unexpected) way. The middle cloth of the shelf foot panels seems to be fully tensioned, leaving the shelf cloths to act more as “gap fillers”. Not entirely – but the shelfs seemed a bit less tensioned than the middle.

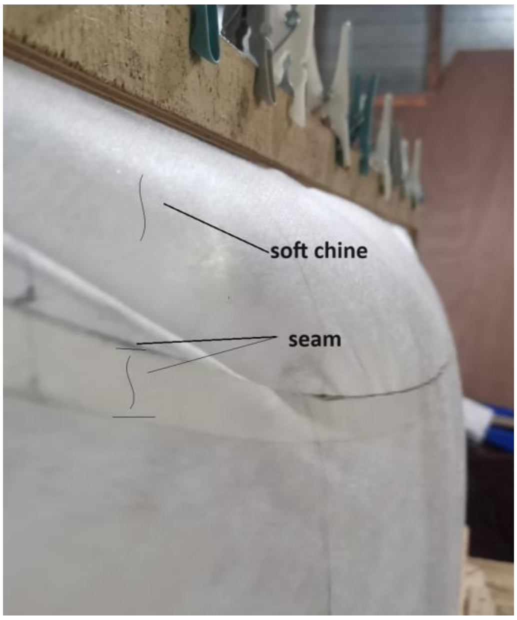
Indeed, one of the shelf foot panels split along a seam from the gale force of the leaf blower (no stitching was used here, only basting tape) - the middle cloth continued to do the job on its own and the panel did not really change shape.



Above: panel split but shape more or less unchanged.

So, I think the middle cloth is doing a bit more than its share of the work.

Arne refers to the way a barrel-round panel seems to “rob cloth” from elsewhere in the panel in order to take up a smooth shape – this barrel-round method which “should not work but does work”, seems to do the job in a similar way to the angle shelf foot panels - the middle part of the barrel-round panel does seem to load up and become quite flat, rather like the angle shelf panels, leaving the “rounded” outer edges free to turn in that characteristic “soft chine” shape that all of the panels seem to have.
The “soft chine” or transition between the “sides” of the panels and the slightly curved “bottom” does not coincide with the shelf seam, as already noted. The cloth decides where that soft chine occurs – and indeed puts the soft chine pretty much in the same place regardless of where the seam is, and the same soft chine appears there even in a seamless barrel-round panel.



It seems as though maybe the panels all "rob cloth" from the middle in order to take up a fairly universal panel shape, regardless of construction method.

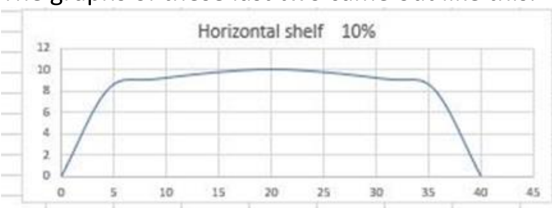
At the end, there was a bit of PelTec left over so I made a horizontal shelf (zero degree shelf angle) panel and to reduce “bagginess” went for a designed camber of 6%. The panel still bulged out a fair bit and the resulting measured camber was 11%, which I scaled back to 10% for a comparison with the shape of the other "10%" panels.

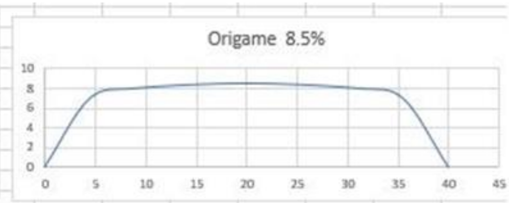
Horizontal shelf 6% (11%)

I thought I should also try an origami panel (see Paul McKay's article in JRA Magazine Feb 2021, #85.) Very simple to make – it's just a trapezium. Amazing how well it took shape. (The cleverness of some of these people who think up these ideas, never fails to amaze me). I made it from a bit of Tyvec and gave extensions of 53 mm to the luff, to shoot for 10% camber. The resulting actual camber was a distinctly "shelf-ish" 8.5%, similar to the others, so we can compare it with the other 8.5% panels.

Origame 10% (8.5%)

The graphs of these last two came out like this:





Basically the same shape as the others, not much difference.

I should point out that the measurement points (45mm, 90mm, 200mm, 310mm and 355mm) across the height of the panel were too coarse to accurately represent the first and last few cm of any of the panels, and this (together with the way the data-smoothing algorithm works) is part of the reason for the "sameness" of all of the graphed shapes.

The low angle shelfs (0 degrees and 30 degrees) - together with the barrel round and the origami panels did all have a bit more of a "horizontal shelf" at the outer edges of the panel, than the 45 degree shelf panels which were indeed a little bit more flared and a bit more curved – distributing a little less camber to the outer edges. The photographs show this, better than the graphs.

Never-the-less, the graphs do represent the middle 80-90% of all the panels well enough that we can say there is not a lot of difference between any of them in the over-all way in which camber is distributed across the height of the panel.

Visually, all of the panels were remarkably similar in vertical cross section shape, and it is very difficult to believe that there would be any measurable difference in their performance as junk sail panels.

(1) Choice of cloth, and aspect ratio of panels, may have as much if not more) effect on the distribution of camber over the height of a panel, as shelf angle.

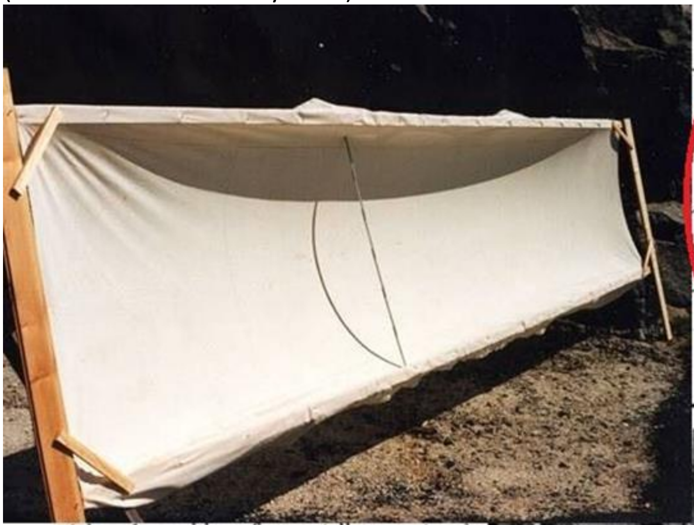
(2) No attempt was made to measure cambers along the chord (the longitudinal axis of the panels), but it was clear to the eye (and the photographs show it) that this curve too has little to do with the construction method of the panel, or the shelf angles etc. They were all built from the same basic foil shape – and they all turned out very similar in longitudinal shape in the resulting panels. (This might not necessarily be the case if the foil were a "blunt entry" shape, or heavily cambered in the first 10%-20% of the chord, as in the jib panels of a SJR - a matter which is probably not so important, maybe not even relevant to sails which are contiguous, or to the mains panels of a SJR, due to the proximity of the mast).

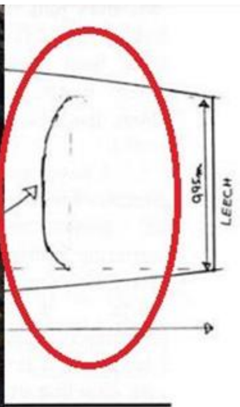
(3) These trials examined just one very small aspect of a parallel shaped, "closed ends", junk sail panel. There is no attempt made to draw any inferences about what might be the best way to make a sail (horizontal shelf, angle shelf, round and broad seam, barrel round, origami etc). That old question can be debated elsewhere.

(4) The SJR jib is an "open end" panel, with leech flying free and restrained only by the sheeting angle cloth. It should therefore be regarded as a different case and none of the above applies to it. (My personal opinion is that the parameters of the Amiina MkII sail may be close to optimum and I think angle shelf foot is the preferred method for the jibs in that special case, for reasons given by Slieve in his Notes).

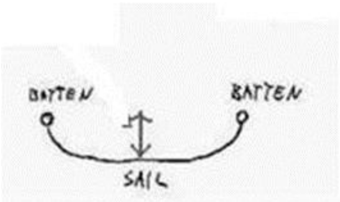
(5) There is nothing new or remarkable about these results. Here is a test panel made by Arne in 1993, and some early sketches made by Arne and Slieve during that period of pioneering the modern cambered panel.

(JRA Newsletter #30 July 1995)

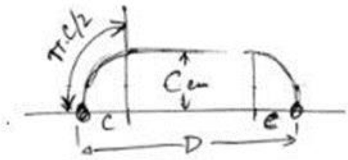




(plus 1, waiting for a taller mast ...), identical horizontal panels, plus 2 top-panels. Basic dimensions are boom/battens/yard = 4.6m, yard-angle = 68° and boom-rise = 10°. Each of the horizontal panels has 20cm rounding along the battens on upper and lower sides, which gives about 40cm max camber. The 2 top-panels were both made with 10cm rounding. This was later reduced along the yard, as the camber in the top-panel initially turned out to be too deep. The photos *(See over) were* taken in evening sun, and the shadow patterns should give you an idea of the camber.



Arne



Slieve