National 12 Amateur Foil & Boom Building Guide

1st revision	1978	Andrew Turner
2nd revision	2004	Graham & Geoff Camm

1. Choosing the shape and construction method

1.1 Shape

Making your own foil is not difficult so don't be put off by expert talk of NACA sections, gybing foils, buoyant rudders, laminar flow sections, aspect ratios and the need for great expertise with tools in order to produce a fair section. . . It's really not that tricky. The shape options to consider for both rudders and centreboards are covered in the tuning guide; the notes here cover the basic manufacturing method.

The key decisions are:

1. Length: for a rudder ~740mm below the waterline will provide good control in strong, gusty winds. Centreboards should generally be the maximum length allowed in the class rules.

2. Profile shape: spoon rudders were fashionable in the 50s and are good for pushing a boat around a corner but are generally a bit slow. Generally a straightish leading edge and an elliptical trailing edge are good.

3. Section profile: Naca sections are best for rudders and there are some good software packages which will plot aerofoil sections and allow you to print templates available. Have a look for "profili" on the internet. Section thicknesses vary between 20mm for very low drag sections (which can easily stall) to 50mm for buoyant rudders. 25 to 32mm is a pretty standard section width. Laminar flow sections can also be used for centerboards (Bim Daser has produced plans).

1.2 Choice of material

Solid mahogany type timber can be used for rudders, alternatively a cedar core wrapped in glass or carbon makes a stiff blade that will have good longevity. A carbon foam sandwich construction will be the lightest and can be very strong but delicate sections are harder to make with foam and there is a tendency for the sections to warp or bow during manufacturing. Either method can be used for a centreboard. If using wood it is advisable to laminate it from strips of wood (rather than a single piece) which when glued together will prevent the finished board from warping.

2. Making a rudder / centre-board in wood

A symmetrical cross section is the most important and difficult to achieve using templates. The following method is recommended. Manufacture the aerofoil as a series of tangents to the already plotted cross section by suitable marking out on the blade and use of a plane and straight edge. The sharp transitions between the individual tangents are then blended into each other by eye using a power sander working in a rocking movement from front to back edge. The final blending operation removes very little material. It is easy to maintain a symmetrical cross section about the centre-line.

The procedure is as follows:

1. Plane the piece of timber flat and to thickness, then cut out the desired side profile.
2. Mark the centre-line and two lines 1 mm either side of this line around the edge of the profile.
3. Mark lines with pencil 30 per cent and 45 per cent of the width back from the leading edge.
4. Draw three tangents to the previously plotted leading edge profile. Transfer the positions of the interceptions of the tangents with the front edge profile as illustrated. Transfer the positions of the interceptions of the tangents with the front edge on the front edge of the rudder blank with a marking gauge.
5. Shape the trailing edge on both sides forming a flat surface until a straight edge just touches the 45 percent line and the line 1 mm from the centre line.
6. Mark the interception of tangent 1 with the broad surface of the blade on the wood and plane off the excess material to form tangent.
7. Mark the interception of tangent 1 and tangent 2 on the newly formed surface and form tangent 2. Similarly for tangent 3 and its interception with tangent 2.
8. Finally, blend in all sharp transitions with a spokeshave, sand, then varnish or paint.

For stripped cedar construction. The edges of the strips used will need careful preparation being both square and flat along their length, for the gluing operation use either sash cramps or make up temporary clamps similar to those used for plank scarfing which will hold the separate pieces flat. The pressure to squeeze the glue joints together comes from wooden wedges, Figure 37. Use polythene between the clamps and the work piece to prevent sticking. Having created the basic profile shape the profile as described above vacuum bag a glass laminate layer all over.

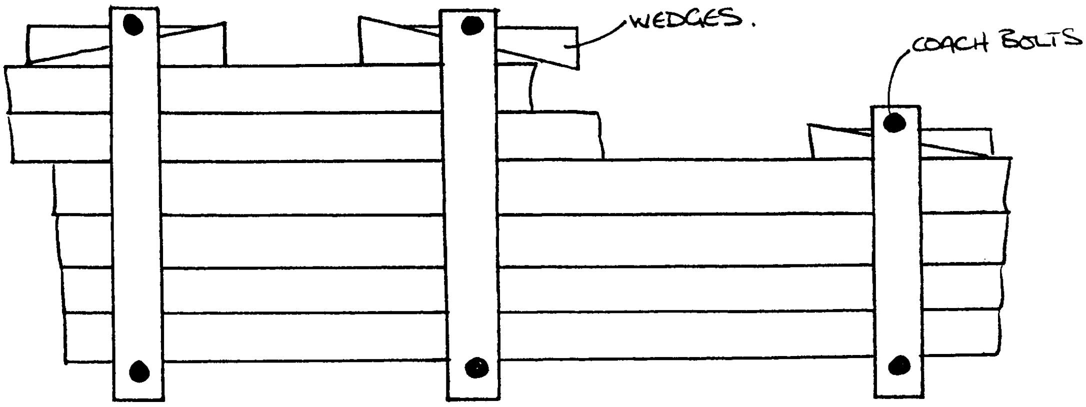


FIG 37 CLAMPS FOR LAMINATING C/BOARD.

3. Making a rudder or centre-board in foam

There are many ways of making a blade and a stock in foam. The following section describes two possible methods that are easy for amateurs and don't require a mould to be made to get a good finish. It should be possible to make a centreboard between 2.5 and 3.5 kg and rudder blade around 1.5 kg using this method.

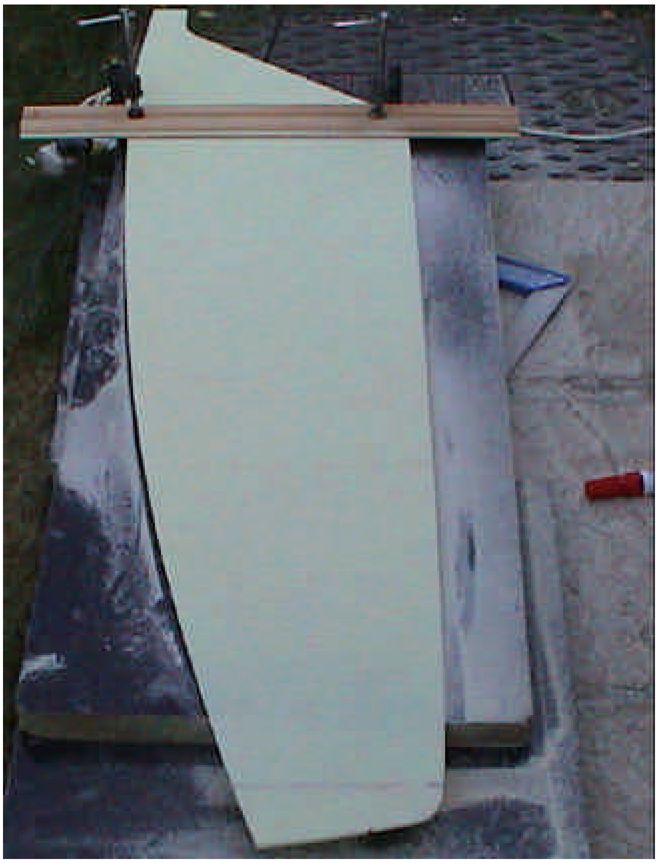
1. Plot the section and cut out templates.

Don't forget to allow for the thickness of the lamination (typically 1 to 1.5mm) before plotting your section.

Then mark the side profile onto the foam and cut out using a jigsaw. It is best to use a pretty dense foam for this to prevent it denting ~100g/m3.

2. Make the section in two halves and mark contour lines of constant depth on each half. Then rout to depth along these contours.

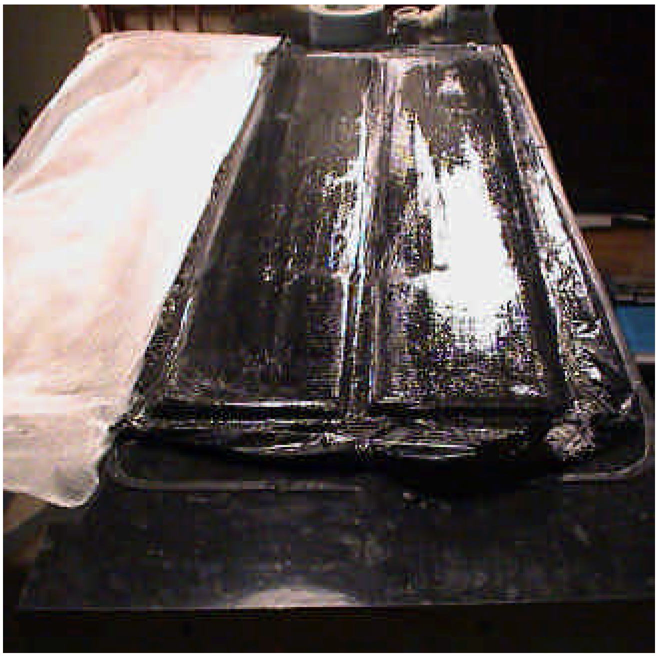
3. Mark the bottom of the slots with a permanent marker and sand the remainder of the profile to the marks using coarse sandpaper and a block of wood.



Finally smooth over the profile and round corners as required

Check the profile using templates for the section. Make a template for every 15cm or so down the blade.

4. Laminate the foil in halves. Apply three layers of 200g/m2 uni-directional carbon, one run from head to tip, the second run from head to 2/3rds length and the third from head to 1/3rd length (note the stresses increase towards the water line hence more carbon there)



5. Bond the two halves together, Use two lengths of straight wood and pack out the blade either side. It is vital to get the blade straight and avoid twist during this operating

6 .Trim around the profile

7. Check profile to templates – look for bending or warping in the blade.

8. Fill any dents or ridges, for example a line and small ridge will be visible at the end of the UD tape. Filling at this stage (prior to the final wrap) means you will have a smooth profile at the end.

9. Wrap and vacuum bag a 200g/m2 carbon weave. Use a continuous piece of cloth around the whole blade.

10. Trim around the profile

11. Coat the whole blade with a layer of epoxy without filler

12. Sand to a smooth profile. There is a neat technique to see the low spots and avoid sanding the fibres. Spray paint the whole blade white, then sand it off. The spray paint acts as a indicator of any hollows, if the dust goes black then stop immediately

13. Fine sand

14. Varnish / paint

15. Polish

4. Making a rudder stock

There are three main types of rudder; fixed, daggerboard and lifting. Both the lifting and daggerboard types require a stock. The manufacturing process is similar for both, but before we dive into the manufacturing process, let's just think about the forces at work on the rudder.

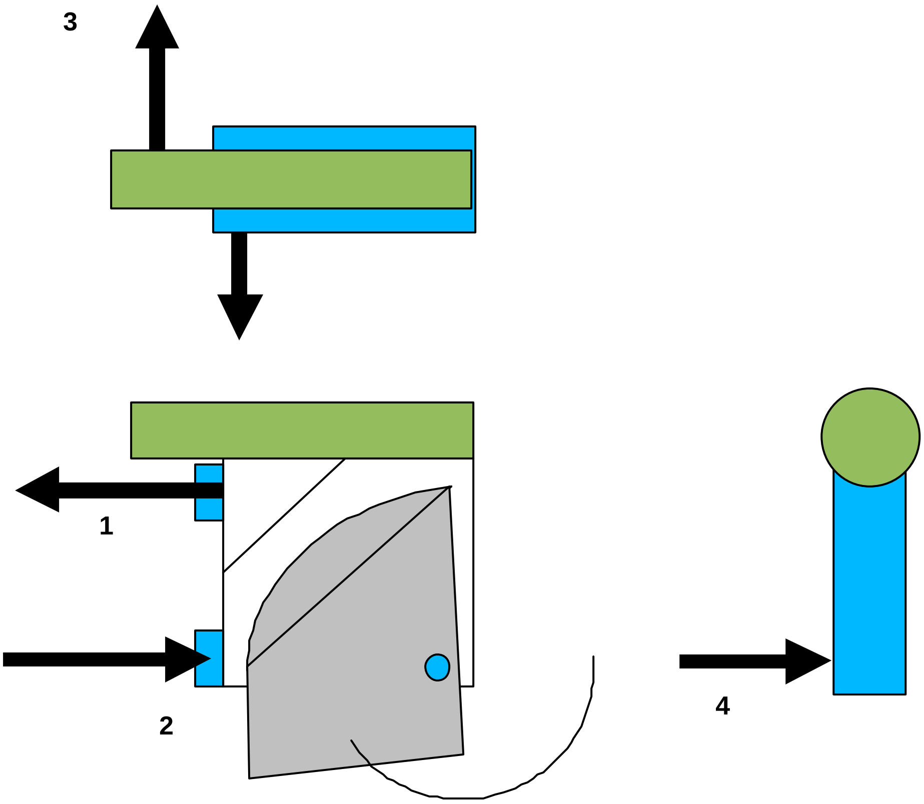
Forces

The objective of making a rudder stock is to make it stiff, strong and light. The rudder stock is probably the most highly loaded component of a boat, hence strength is required. Think of the forces when you are pushing hard on the tiller to avoid a broach!

Stiffness is required because any wobble in the blade results in the rudder going through the water sideways and the boat slowing down, and in loss of control.

Keeping it light is important to reduce the weight in the ends of the boat, and you can't get much further back than the rudder (although the helm's buttocks may try every now and again).

The diagrams show the forces on the stock.



1. Compression on top pintle
2. Tension on bottom pintle
3. Torsion on tiller
4. Torsion on stock

4.1 Type 1 – Lifting rudder stock

1. Laminate a flat sheet of high density 5mm foam (100g/m2) with 200g carbon weave on both sides. The panels for the stock can then be cut out of this using a normal hand saw or jig saw. Use a fine hack saw with a metal blade for fine cuts.

2. Make a tiller

Take a piece of PVC pipe of diameter between 32 and 50 mm, put on some mould release agent and then wrap with carbon Three or four wraps of 200g/m2 weave should do the trick.

When wrapping be sure to pull the cloth tight as you work it round the tube. Any slack will bunch up and make a ridge when vacuum bagged.

Vacuum bag in the normal way and add heat.

When bagging a tube make sure you either put a stopper in the end of the tube or push plenty of the bag inside the tube as when the vacuum is applied the bag will be sucked into the tube. If you have a good vacuum pump the suction may cause the bag to break.

3. Shape the top of your rudder blade

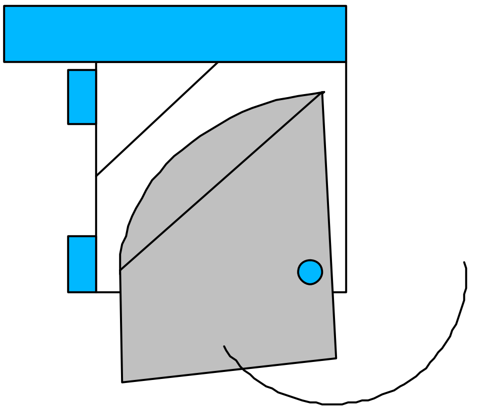
Assuming the pivot point goes at the back of the blade (approx 20-25mm from the trailing edge) then your blade should look something this. Cut a radius from the front edge to the head using the pivot as the centre.

4. Make the basic box

Lay the head of the blade on some cardboard and trace around it. Then add on some clearance at the front, back and top edges for the thickness of your foam panel. Cut two side panels and two spacer pieces to sandwich between them for the front edge and the top. Also cut a piece to make an internal chamfer.

Sand the spare pieces to the same thickness as the board. Clamp together and test that the blade fits in nice and snugly. Sand the spacers until the blade makes that snug fit.

Make a bonding epoxy mix, apply to all surfaces then clamp together. (see picture)



5. Apply flanges

To stiffen the back and bottom of the stock cut flanges out of the pre-laminated foam sheet. Bond these on with the rudder blade inserted in the stock to make sure the slot is the correct size.

The top picture shows the bottom flange, extending approx 20mm from the side panel. Note: the bottom flange is cut as a slot leaving joining material on the back of the flange, this is to help the slot in the stock retain its dimensions during manufacturing.

The second picture below shows the rear flange with a radius on the top. The radius on the top is cut to extend over the top of the stock and meet up with the tiller.

Once the parts are bonding fillet all the joints.

Note: the top spacer should be recessed slightly so that when the tiller is bonded on it sits on both the spacer and also the top of the side panels

The picture (right) shows the three components, highlighting a key way cut into the rear of the stock body

6. Bond the tiller

Apply plenty of epoxy under the tiller and fillet around the joint at the rear of the flange.

Use parcel tape to apply pressure and hold it in position.

Ensure the tiller is parallel with the body of the stock at this point.

7. Bend up the bottom pintle

It is common for the bottom flange of the stock to rise up towards the back in order to avoid interfering with the stern wave. If this is the case then the flange at the bottom pintle needs to be bent to be square to the front of the stock.

This can be done using a hot air gun (see picture)

8. Apply reinforcement for the pintles and pivot

These are the areas that really take the hammering so we recommend bonding on some wood or Tufnell. It doesn't weigh much and really spreads the stresses well.

The pintles should be mounted so the centre is around 16mm from the front face of the stock. A neat way to make pintles is to use some stainless, aluminum or carbon tube with an internal diameter which matches your fittings, then space it off using wood (see picture)

A circular disk around 40mm diameter cut out of 12mm marine ply makes a good pivot reinforcement.

Bond these on and fillet.

Use parcel tape and clamps to hold them in position.

Note: Getting good alignment on the pintles is vital at this point. Any mis-alignment will lead to a stiff rudder and increased wear. The best way to align is to run a continuous tube from the bottom pintle to the top and then cut them to size later.

9. More reinforcement

It adds very little weight but when it is blowing old boots and you're surfing at blistering speed down a 10' wave at Pevensey or Tynemouth you'll be thankful for this extra carbon.

Apply uni-direction carbon tape around the front pintles and over the tiller. Three wraps over the top pintle should do but I would recommend 6 – 8 over the bottom pintle as this takes more load in tension.

A couple of single wraps over the tiller should suffice

10. Time for bagging

A final wrap of 200g/m2 carbon weave should tidy the job up nicely and keep all the pieces together

Note: When bagging make sure there is plenty of bag stuffed into the slot in the stock and also up the tube to avoid the vacuum distorting the components. It would be a good idea to insert something the correct width in the slot to prevent the stock being distorted during this bagging operation.

In the picture the stock is bagged up and Geoff is listening for air leaks.

Picture: To get a really good lamination you need a high temperature ~30 – 40 degrees. A makeshift polystyrene tent and fan heater can help

11. And now to bag the outer

But before you do it would be wise to scoop out the foam at the bottom of the stock either side of the slot and fill with a hard epoxy mix. This is because there is a lot of sideways force which might crush the foam.

Turn the stock upside down and apply a couple of layers of 200g/m2 weave to the base and rear to hold together these pieces. Whilst you are at it add a couple of extra small strips just in the vicinity of the front pintle

12. Finishing

To protect the epoxy resin from UV degradation give it a light sand down and a coat with a polyurethane varnish. This also brings out the nice contours of the weave and looks really sexy.

13. Weighing in

You should be able to make a stock between 500 and 600 grams and save yourself a few quid in the process.

4.2 Type 2 – Dagger board

The manufacturing process for the dagger-board stock is similar to the lifting stock, but a little easier as no parts need to rotate, the blade is just going to slide vertically. The main difference is the starting point, Instead of making a box using pre-laminated sheets you start by wrapping carbon around the blade (wrap some polyethylene sheet around it first), this creates the body of the stock and all flanges are bonded on to this in a similar method to above.

5. Making a boom

The main properties for a boom are for it to be light, strong and stiff. Using carbon it should be possible to make a fully fitted out boom around 2kg.

1. Coat some drain pipe (~75mm diameter) with mould release agent. Or use a length of thick plastic sheet.

2. Wrap uni-directional carbon 200g/m2 around the pipe and wet out with a laminating epoxy. Apply two layers from gooseneck to the mid point of the boom, followed by another two along the whole length. Finish off with a couple of wraps of carbon weave along the full length. Pull tight as you go because any slack will result in a ridge forming during the bagging process.

This bit is really best done with some helpers as handling a 2.5m sticky length of cloth is really tricky on your own.

3. Vacuum bag. Be careful with the bag going into the drain pipe, allow plenty of slack and stuff the bag into the pipe otherwise the vacuum will cause it to burst.
Reinforce the ends with a couple of extra layers of 200g/m2 weave

4. Bond in a gooseneck. Wood or some aluminium / carbon tube reinforced with plenty of carbon should do the trick. Don't underestimate just how much compression force is on this small joint.

5. Bend test – how much weight for how much deflection? If you can bounce up and down on the middle whilst the ends are supported on books then it should be ok.

6. Varnish

7. Fit out and go sailing