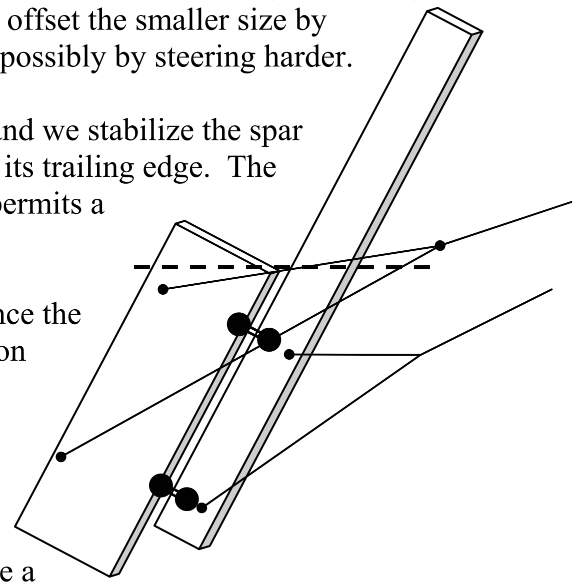
A Simple Backup Rudder for Ocean Voyagers

Michael Moradzadeh (Michael@yachtPC.com)
Cayenne, Passport 40, WMPC 2000 & 2002

In the 2002 WMPC, five boats had serious rudder problems, and one boat was abandoned. Here is a simple design for a backup rudder that is light, small, and cheap.

Rudder Design

A common rule of thumb is that the backup rudder should be at least half as big as the original rudder. This should be big enough to steer the boat. You offset the smaller size by deploying the backup rudder abaft the normal rudder and possibly by steering harder.



Our design is set out here. The rudder attaches to a spar, and we stabilize the spar with guys. We limit stress on the rudder by steering it by its trailing edge. The rudder is therefore supported around its perimeter. This permits a lighter, slimmer, and less expensive design overall.

The major role of the spar is to hold the rudder down. Since the guys take up the side-to-side stress, the only critical load on the spar is upward compression. A 2x4 or spinnaker pole will easily handle the job.

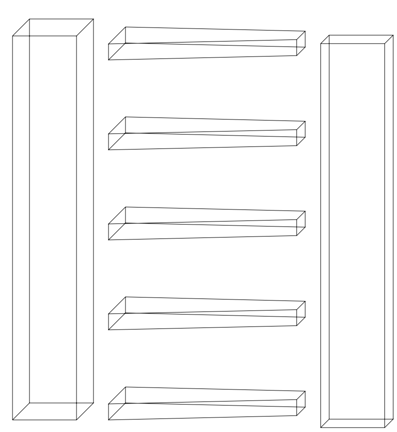
Specifics

Cayenne is a Passport 40, a "performance cruiser" displacing 12 tons. Looking at the existing rudder, I chose a rudder area of four square feet. This is a bit more than half the existing rudder. I also know this to be adequately sized having tried out a prior model.

Smaller boats can scale the rudder down, preferably by shortening it, keeping the same width. Larger boats could scale up in either direction. If you are over 50 feet, you'll probably want to scale everything up!

Construction

The leading edge is a 2x4. The trailing edge is a 1x4. The sides are made from ¼ inch plywood. The top, bottom, and 3 internal ribs are wedges cut from either ¾ inch ply or a hardwood. The whole thing may be sheathed in a layer of light fiberglass to improve strength.



All lumber should be kiln-dried. The plywood should either be marine ply or certified sanded ABX exterior plywood. The "certified" ply at Home Depot is remarkable! No voids.

1. Cut the plywood, the 2x4 and the 1x4 to length (4 feet). The plywood should be 16" wide, though wider would work also.

2. Cut out the wedges for the ends and ribs. These will be as wide as the 2x4 at one end and as wide as the 1x4 at the other. The easiest way to cut these, I found, is to cut a 9" plank out of your heavy wood. Then set your table saw's sliding miter gauge at about 2° and cut in alternating directions using your rip fence as a stop. Cut several extras.

3. Once the wedges are cut, lay them out with the long pieces on one of the plywood sheets. Unless you are Norm Abrams, your wedges will be uneven. Sort them from widest to narrowest, clamp them together, place between the 2x4 and the 1x4, and belt sand with fervor. Your goal is to make the whole arrangement fair, so that the wedges mate nicely with the stringers, and each is fairly similar to its neighbor.

4. Build the internal frame of the rudder. Test-fit first. Lay the 2x4 down with its narrow edge facing up. Position the wedges one at each end and the other three evenly between them. Use masking tape on one side to "hinge" them in place. Goop some epoxy thickened with colloidal silica to the "mayonnaise" stage into each joint. Stand the ribs up and tape the other sides down. Now goop some more thickened epoxy onto the tips of the ribs and stand the 1x4 on them, taping in place.

5. Once the epoxy has set, get out the old belt sander and fair the stringers and the wedges so that the whole frame will accept the plywood skins without significant gaps. If you want to be fancy, you can work in a bit of a curve, which will make the whole thing stronger and a bit more aerodynamic. Be sure to wear a face mask. The epoxy dust is bad for you.

6. Use tack-and-glue technique to attach the first skin to the frame: Lay the frame over the skin and mark the positions of the ribs. Do the same with the other skin. The prudent worker will mark each skin as left or right, and its top and forward directions. Now put the skin on the frame and drill pilot holes every 8 inches or so for the screws that will hold your assembly together while the epoxy sets. Mix a batch of epoxy, thickened to the syrup or mayonnaise consistency. You'll need about 10 squirts per side. Apply the epoxy to the frame, lay the proper skin over it, and screw it down. I like to use stainless deck screws for this. Stainless is good in case you want to (or need to) leave some screws in the assembly.

7. Flip the thing over. Now you have some options. You may epoxy the inner surface of the skin so as to exclude water, and/or you may fill the spaces between the ribs with foam to reduce the risk of waterlogging. For foam, I used "Great Stuff" triple-expanding foam. The 20 oz can was enough to do two rudders, and this material is compatible with WEST epoxy. If you overfill, the stuff will overflow the frame à la Lucy and Ethel, and you'll have to wait till it hardens to trim it down. Attach the other skin.

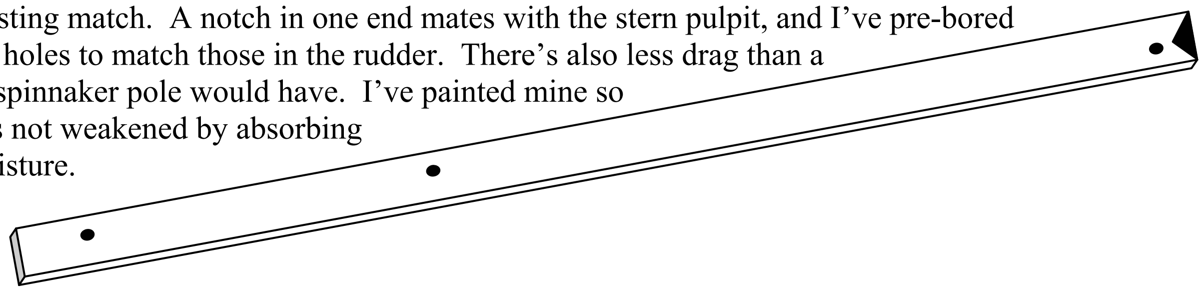
8. Once the epoxy sets, remove the screws. Make the rudder more aerodynamic: at the trailing edge, set your table saw to 45° and chamfer the edge. At the leading edge, first make a 15° cut on each side and then a 45° cut, to give a rounded profile. Try this on some scrap first. Run the ends through the saw as needed to even the plywood with the wedges, and then chamfer them at 30°, or just round over using a router. Get out the belt sander and smooth everything out.

9. Glass the rudder. Cut your glass to size. Then fill any gaps or holes with thickened epoxy. Immediately lay the glass in place and start wetting it out and smoothing. You can do this one side at a time (wish I had) or you can hang the rudder from a couple of screws and do both sides at once (sloppy work). When the epoxy has set, trim the edges and glass some tape around the edges. Admire your work.

10. Bore four holes. Two half or 5/8 inch holes spaced in one rib from each end and centered in the 1x4 and 2x4. Use a router or a file to smooth the edges of the holes. You can add a fifth hole for a retaining lanyard if you want.

The rudder is complete. You only need to pre-fit it to your boat. This involves making or identifying the spar you will use, pre-setting the lines, and **testing it.**

I prefer to carry an 8-foot 2x4 with one edge shaped like the rudder as the spar. It's fairly light and may come in handy for other emergency tasks such as splicing a boom or an impromptu jousting match. A notch in one end mates with the stern pulpit, and I've pre-bored the holes to match those in the rudder. There's also less drag than a 4" spinnaker pole would have. I've painted mine so it is not weakened by absorbing moisture.



Reeve lines through the upper and lower leading edge of the rudder, center them, and tie square knots tight against the edge. This is the pivot point for the rudder. Attach these lines to the spar so that the rudder can pivot freely. Remember to attach things so the rudder does not ride up!

Now attach four lines: two from the quarters of the boat through the holes in the trailing edge of the rudder, and two to the spar. See the diagram in figure 1. Don't tie the lines off as bridles till you have the geometry right. You'll want the rudder control lines to be as far outboard as possible and the spar guys to be both outboard and more forward.

Haul in the spar guys so that the spar comes down to at least 45° or deeper. Cleat them off. Get underway. The steering lines should be led to spare winches, though you can usually steer by pulling on the centers of the lines. Try to steer the boat, both with the rudder fixed amidships and swinging freely. If it is all working right, tie the steering lines into a bridle; this will be easier to manage. Whether to tie the spar guys into a bridle is a matter of choice.

Congratulations! You have a backup rudder. That's one task down and several dozen to go!

Appendix: Math

How much force will be applied to the rudder? This question is key, as a too-light rudder will break. However, a set of overly conservative assumptions will leave you carrying a blade that could steer the *Queen Mary!*

On ours, I calculated a load of about 700 pounds tops. This assumes all values are maxed out (sharp turn at extreme speed). We would still add some backup strength beyond this.

Our rudder, being supported at its edges will need to support around 700 pounds over a portion of its 4 foot length. Since we support the rudder at four points at its edges, we generate a maximum of only a few hundred pounds of force over any portion of the rudder.

Weighing a couple hundred pounds myself, I was in a great position to bench test the rudder by standing on it. It suffered no appreciable deflection when my entire stocky bulk was applied to its entire span.

How Much Force?

The basic formula is

$F = A * C * \frac{1}{2} * \rho * V^2$

Where

F = Force in pounds

A = wet area in the direction of water flow

C = coefficient of lift or drag

ρ = water density (slugs per cubic foot ≈ 2)

V = velocity of water flow

Application of formula

A = 2.8: although the side area is 4 square feet, the rudder presents its narrow edge to the water except when turning. Even with an extreme rudder angle of 45º, the area "seen" by the water is only 2.8 square feet.

C = 1.2: The coefficient of drag for a nicely faired ellipse is about .3; for a rectangle it's 2. We'll fair it and call it a very conservative 1.2.

V = 14: how fast will water flow past your rudder? This value is squared, so it's important. Our top speed (going down a wave in a 40 knot squall) is 13.9 knots. Hint: sail more slowly!

So, if $F = A * C * \frac{1}{2} * \rho * V^2$ then

$F = 2.8 * 1.2 * \frac{1}{2} * 2 * 14^2 =$ **688 lbs.**