A lesson from Mr Spruce H Mast

Who said that a spruce tree cannot speak - they shout at me!
Here is what one of them told me:

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Hi Arne,
my name is Spruce H Mast (..H for Hollow...). I am a round, hollow tube of spruce with a diameter of 20cm and with the wall thickness being 20% of that diameter.
My breaking moment at this D = 20cm is 3100 kilopond meter (kpm), at least. When deciding on which diameter of me you should use as a junkrig mast for your boat, you need to know or guess...

- .. the righting moment of the boat.
- .. the intended kind of sailing. If ocean voyaging is on your mind, make me 3 times stronger than the boats righting moment (JR sloop). If the sailing is less ambitious, reduce that strength factor to 2.5 times or even 2.

The righting moment of any boat is
Mr = Displacement x max righting lever.
If the max righting lever is not given, you have to guess it:

- A boat with narrow beam and high ballast ratio has a righting lever, Lr, of about ¼ of the beam, that is Lr = 0.25B.
- A very wide boat with little ballast has a righting lever, Lr, of only 1/5.5 beam, that is LR = 0,18B.

You have to guess where your boat is on this scale. In most cases you are on the safe side if you guess that Lr=0.20B

Example: Let's say your boat has a displacement, Disp. = 2500kg with a beam, B = 2.40m and 40% outside ballast.

- If you guess that the Lr = 0.20B, the righting moment of the boat is
  Mr=2500kg x 2.40m x 0.20 = 1200kpm
- However, if you guess that the Lr = 0.25B (1/4 of 2.40m), then the righting moment comes out at
  Mr = 2500kg x 2.40m x 0.25 = 1500kpm

If you play safe and opt for the highest righting moment of 1500kpm and with a 3 times strength factor for offshore use, the mast needs to have a

breaking moment of Mb = 3 x Mr = 4500kpm.

All you need then, Mister, is to beef me up from my initial Mb of 3100kpm at 20cm diameter, to something that gives 4500kpm. Here is the procedure:

- Find the beef-up factor ..
  Kb = wanted strength/strength at 20cm = 4500kpm/3100kpm = 1.45.
- BUT! The strength of me, the mast, varies with the *cube* of my diameter. In other words, my diameter varies with the *cube root* of my breaking moment. In cold numbers this means that the diameter factor = the cube root of Kb, that is

Kd = Cube root of 1.45 = 1.13

- Finally find the needed diameter D = 20cm x Kd = 20 x 1.13 = 22.6cm.

Now that is the worst-case diameter. If you estimate the boat righting lever, Lr to be only 0.20D and only want to sail in sheltered waters, you will find that I'll do fine with a D=18,4cm. Check it yourself!

A final word before you leave - don't make me too tall! If my length above partners, LAP, exceeds 40 times my diameter, then I may start complaining when pitching in a bad head sea!

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Sooo, as you see from the above, the big, foggy, variable factors lie not in the calculation of the strength of the mast, but rather in deciding the loads that it will have to take. That is the same problem as with all sorts of masts

Stavanger 20141103
Cheers,
Arne

PS 20141104: This is actually a shortened and slightly altered version of *"Arne on Mast scantlings...",* **found under** *Other technical Articles* **on my page**: http://www.junkrigassociation.org/arne