Non-Certified Wood Testing and Selection

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Fly Baby CF-UFL

Preface

This is how I select non-certified wood for my airframe. This doesn't mean that this is a recommendation for any else! I have included various references and links so you may make your go/no go decision for your wood selection and testing. If you are unsure ask an experienced person for help. My experience with wood is limited to only one wooden airframe restoration project. I learned my test method from a very experienced homebuilder/designer. I also learned a bunch from lots of reading and from picking the brains of fellow homebuilders. Depending where you live you may be required to involve your wood testing and inspection procedure with your designated inspection authority.

Inspection

First, I inspect for visual defects. EAA Sport Aviation and Experimenter articles and CAM18 (AC43-13) give excellent guidance for culling unacceptable wood. Next, I ensure that grain orientation and slope are within the required limits: 15 to 1 slope, edge grain etc. I assign a serial number to each board that is tested and transfer this number to each piece cut from it.

Testing my wood: Determining DENSITY

First, I determine density, as the listed wood strength is related to density: I have been told that density is a better judge of wood strength for wood rather than just "rings per inch", and rings per inch aren't necessarily a good judge of the wood's strength on its own, either.

If your wood's density is on the light side, then the strength should be proportionally lighter as well. With higher density, it should break at a proportionally higher PSI than the ideal published strength of the same wood species. Look very closely at the sample... if it doesn't conform to this rule of thumb, if in doubt, discard it!

If the wood is outside of the required strength to weight for aircraft wood but is otherwise free of defects, I may relegate it to non-critical secondary structure. I would not use this wood for primary structure such as wing spars or longerons. If in doubt discard it. The published required *minimum* rings per inch are:

SPECIES	Density	Min rings/inch	Strength in bending
Sitka Spruce	28 lbs/cubic foot	6 rings minimum	9,400 psi
Red pine	33 lbs/cubic foot	6 rings minimum	10,800 psi
Douglas Fir	33 lbs/cubic foot	8 rings minimum	10,900 psi
Western Hemlock	30 lbs/cubic foot	8 rings minimum	11,000 psi
Port Orford Cedar	29 lbs/cubic foot	8 rings minimum	10,200 psi
Western Larch	37 lbs/cubic foot	8 rings minimum	11,000 psi
California Red Fir	28 lbs/cubic foot	8 rings minimum	9,400 psi

(Ref "EAA building the CUSTOM AIRCRAFT with WOOD Volume 1"; other references, such as "the Machinery's Handbook" and older engineering manuals also give wood properties and strength of materials. "Evans Light Plane/Designer's Handbook" is also a great reference)

I record the mass and density of the board (see formula below) and I save all the test samples taken from the board. I also like to write down the breaking PSI, board serial number and date right on the broken sample as well as in the log.

Testing for Density

The density of the wood board is the weight of the board divided by its volume (**L**ength times **B**readth times **D**epth):

$$\text{Density} = \frac{\text{Weight}}{(L \times B \times D)}$$

The density should be 30 to 33 lbs/cu-ft for Fir, and 28 lbs/cu-ft for Spruce. Your wood's density should be within this range. If it is outside of this range, the wood <u>may</u> still be suitable for secondary structure. Read R. S. Hoover's excellent article for further info.

For the calculations:

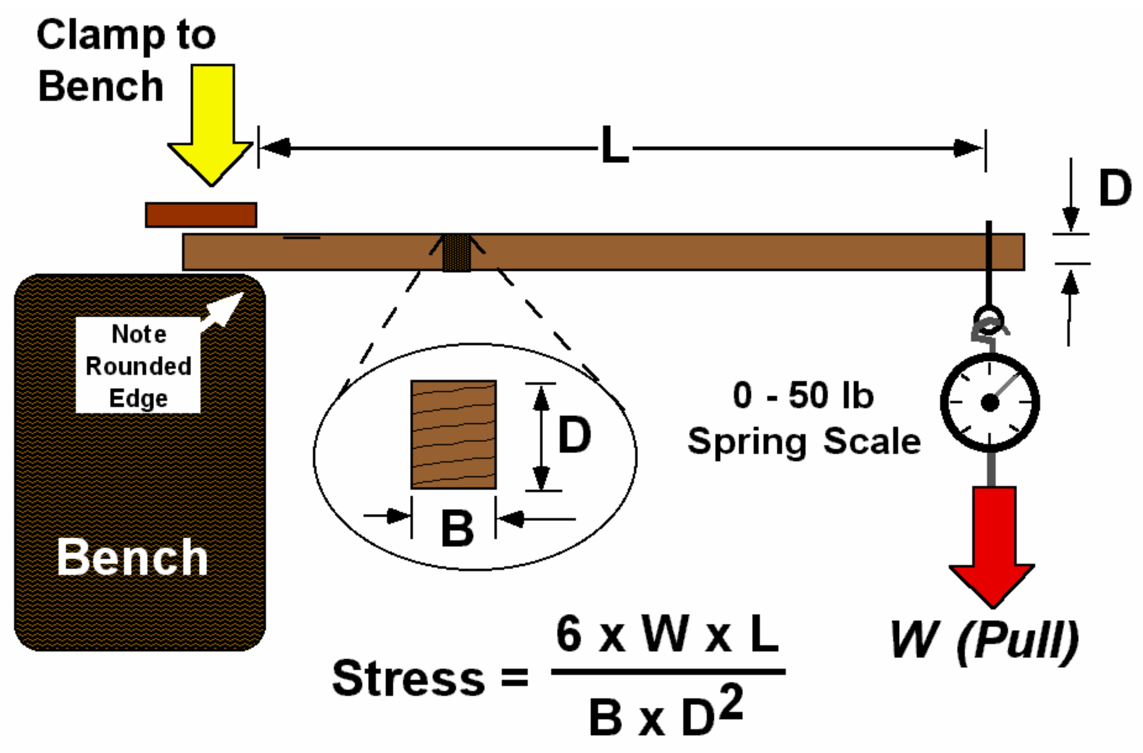
- Weight (W) is in pounds (lbs). I use a good 0 to 50 lbs dial spring scale to weigh the wood.
- L x B x D (aka "volume," **L**ength times **B**readth times **D**epth) is in cubic feet (cu-ft), so a 1" Breadth board will be $1/12^{th}$ or 0.08333 of a foot, and 6" will be 1/2 or 0.5 foot.

Example: Assume a 13 foot Douglas Fir spar, with a 3/4" Breadth and a 6" depth, that weighs 12.5 lbs. The Breadth is 0.0625 feet, the Depth is 0.5 feet. Thus, the density is:

$$\textbf{Density} = \frac{12.5}{13 \times 0.0625 \times 0.5} = \textbf{30.7 lb/cu-ft}$$

Testing my wood: Determining PSI BREAKING STRENGTH

Here's the set-up I use for determining the breaking strength of my wood:



I test at least one sample from each board to destruction to find its strength, using the same 0 to 50 lbs dial spring scale. They cost about $15, nothing fancy.

$$\text{Breaking Stress} = \frac{6 \text{ X L X W}}{\text{B X D}^2}$$

Breaking Stress (in PSI) = 6 times **L**ength times **W**eight (the Force used to break the wood)] divided by: **B**readth (a.k.a. width) *times* **D**epth squared]

Length = length of lever arm, in <u>inches</u>, between edge of shop bench and dial scale hook;

Weight = breaking weight of wood sample;

Breadth = width of sample, in inches clamped to bench (looking end onto the sample its width);

Depth squared = the Depth of the sample (how high the sample is), in inches multiplied by itself

I clamp a length of wood to the shop table, and mark a **L**ength, to the nearest whole inch, from the table to where I will apply my **W**eight (force) with my scale.

The lip of the tabletop should have a slight round down to prevent the sharp corner from digging into/damaging the wood fibres. If the sample piece to be tested isn't square in cross section put the wide side face to face with the table.

I normally break a piece between .5" and .75" wide and about .5" deep. Use a 0 to 50 lb dial spring scale on your measured and marked **L** line and slowly pull downwards on the scale, taking note of the reading. As soon as you see a 'yield' or 'give' in the W force applied by the scale (the wood starts to splinter and permanently deform) you have your reading **W**.

This yield is technically referred to as "Modulus of Rupture". You can add more **W** to determine its ultimate breaking strength but I don't think this necessary myself. To get a better feel for the testing procedure, I would recommend cutting all testing pieces consistently to the same **B** and **D** dimensions, and make **L** an even number, such as 24 inches each time.

It is a good idea to wear safety glasses when doing this...

Wood "facts" that I can't really confirm

- The wood strength (Stress) - to - mass (D) ratio for a species of wood should be a linear line. If the mass (D) of the wood sample is higher or lower from the ideal published values, then the PSI breaking strength (Stress) of the sample should be proportionally higher or lower as well. If the sample doesn't fall reasonably within the ratio the wood may be defective!

- Samples which stray above/below the ideal published values but are still within the within the published strength - to - mass ratio may still be useful for small components where the weight penalty would be minimal, lighter wood may find useful service in secondary structure... you have to make this determination yourself :-)

- Rings Per Inch values are recommended minimums. You can stray above this number, but do stay with the mass/density range for weight considerations. As far as I can tell, rings per inch do not give a determination of the wood sample's strength, only Density (D) and PSI breaking strength (Stress) will determine the true strength of the sample.
- Wood structures have a design safety factor of 2 compared to aluminum, which has a design safety factor of 1.5
- Port Orford Cedar is supposed to be *the* ideal wood for aeroplane construction
- I believe that a laminated spar is as good as a solid one, possibly stronger too. One local Fly Baby built here in my area back in the middle '60s was constructed using off-cuts. The main spars were laminated and this aeroplane and it amassed well in excess of 1000 flying hours, including extensive aerobatics (it is now retired in a local museum). Aeroncas, Fleets and Stearmans among others have all been factory produced with laminated spars at one time or another.

Assorted References

Here are some references for wood inspection and wood testing:

- Dec 1998, and January, February, March and April 1999 "Sport Aviation" contains an excellent series of wood articles, including wood, theory, aircraft structures and selection/inspection. Articles by Ron Alexander;
- March '96 Experimenter has the article "Selection and Evaluation of Wood for Aircraft Use";
- April '96 Experimenter has an excellent article called "Sitka Spruce and Other Woods";
- May '96 Experimenter has a great general knowledge conclusion of these series of articles;
- June '96 Experimenter has a good article on glue laminates and plywoods (laminated and I-beam alternative spars);
- August '96 Experimenter Light Plane Heritage article "Clearing the Workbench" has very good article on wood laminations in propellers and spars (box, laminated, I-beam) and their general strengths;

- September '84 Sport Aviation "A closer look at some alternatives to Sitka spruce in aircraft construction";
- C.A.M. 18/ FAA Advisory Circular AC43-13b
- EAA Building Custom Aircraft series books "Wood, Volumes 1 and 2";
- EAA "Building the Wooden Airplane" page 13;
- EAA "Aircraft Homebuilding Tips" Vol 1 and Vol 2
- An excellent common sense write-up may be found on Ron's Sea and Sky Aviation Page, Tech Links http://www.wanttaja.com/avlinks/index.html#tech, R. S. Hoover's Construction Articles, including "The Pee-Chay Catastrophe -Alternatives to expensive certified wood, and how to grade it."
- Some great tech info on wooden aeroplane construction and maintenance may be found on the Jodel.com website. A good write-up on the use of Okume plywood may be found under Tech: Construction - Plywood Specs. I've kinda taken a shine to those little Jodels
- "Understanding Wood: A Craftsman's Guide to Wood Technology" by R. Bruce Hoadley
- Other useful SPORT AVIATION references:
    - Building One-Piece Cantilever Box Spars - January 1981, pg. 34
    - Aircraft Plywood - How To Use It -September 1978, pg. 35
    - For a complete education on working with and inspecting wood, see Ron Alexander's Aircraft Building five-part series in Sport Aviation, beginning in December 1998 and concluding in the April 1999 issue.