Version 2.20

Companion Guide: "Building Fly Baby"
Article 1: Wing Construction

EAA SPORT AVIATION January, 1963, Pages 20-25

By Ron Wanttaja
and the Fly Baby Community

This Companion Guide is written to accompany the first of Pete Bowers' Fly Baby construction articles in EAA SPORT AVIATION magazine. The topic of the article is the initial construction details for components in the Fly Baby wings. Article 2, in February 1963, covers the actual assembly of these components into the wings themselves.

You will need to download these articles from the EAA Archives to actually build the wings. This Companion Guide merely supplies additional background information and some helpful hints on the actual construction. A full Table of Contents is included on the next page.

Photo By Drew Fidoe

There are two kinds of figure references in this Companion Guide. If the reference is "Figure 4-1" (with a hyphen), it's a figure in the original EAA articles. Figures without a hyphen are contained in this document and should closely follow the text which refers to them.

For specific assistance in building the components described, see the Workmanship and Hardware articles on the PB100 Web Page.

Many thanks to Matt Wise, Jim Katz, Jim Hann, and the others of the Fly Baby community for providing some great pictures to illustrate the points in this Guide.

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1 OVERVIEW

Figure 4-1 on page 21 of the EAA article gives a good overview of the wing structure. The usual description is, “It’s built just like a balsa model!”

Perfectly true, and understandable given Pete’s long association with award-winning free-flight models.

However, people who actually BUILD balsa airplanes from scratch are pretty rare, nowadays. Let’s “deconstruct” the wing structure and examine how it goes together.

The main basis for the Fly Baby wing is shown in Figure 1. The basic wing structure consists of two spruce spars, both 13 feet long and ¾” thick. The front spar starts out at six inches high, while the rear spar is 4.5”.

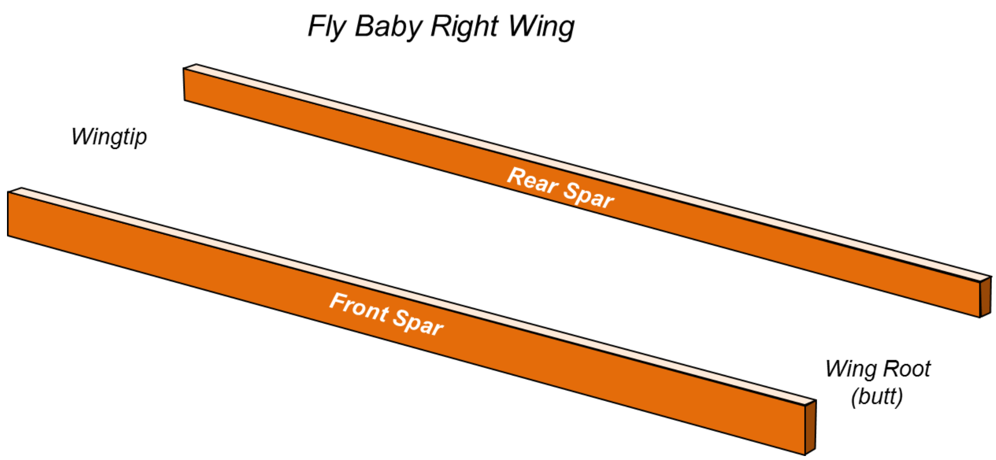
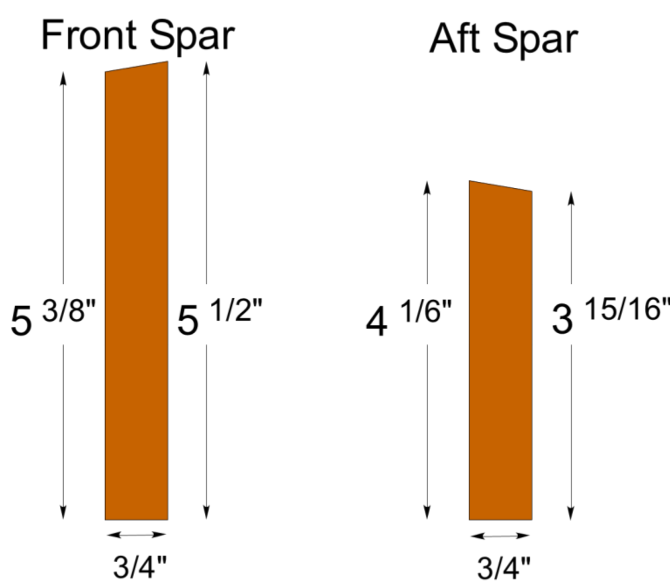


Figure 1: Front and Rear Spars



One of the first things that happens to the spars is they get beveled to match the wing profile. The front spar is cut down to about 5.5 inches, with the front of the spar 1/8” shorter, and the rear spar is cut to 4 1/16” high, with its back side also about 1/8” lower. We’ll talk about how to do this in the Construction section.

Also, keep in mind that the dimensions for the aft spar listed in Article 1 were updated later by Pete. This is address in the Errata section, section 2.2. For what it’s worth, the dimensions shown on this diagram are the correct ones.

And…there’s a theory that says the spars don’t HAVE to be beveled. This would save a bit of hassle. See Section 5.1 for more details

In addition to the beveling of the spar cross-section, the spars themselves are reduced in height on the outboard section, as shown in Figure 4-6 on Page 24 of the EAA Article. The figure below shows the kind of shaping required. Note that the beveling must still continue in this section.

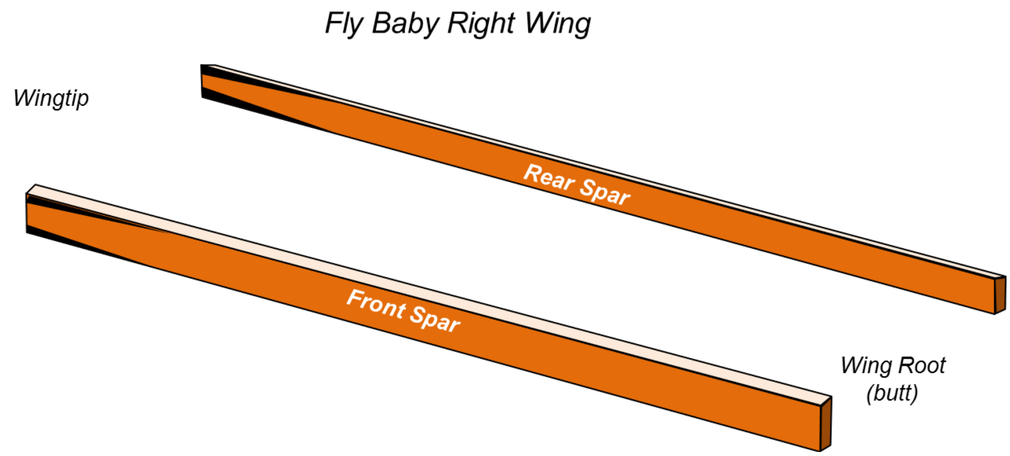


Figure 2: Tapered Spars per EAA Article #1 Page 26

With the spar shaping done, the next step is to actually build the structure of the wing. Wooden mounts are glue to the spars for anchoring the external wing bracing wires, and steel "Compression Ribs" are bolted to the spars to form the main structure. Eventually, cross-brace cables are installed diagonally between the compression ribs to hold everything rigid.

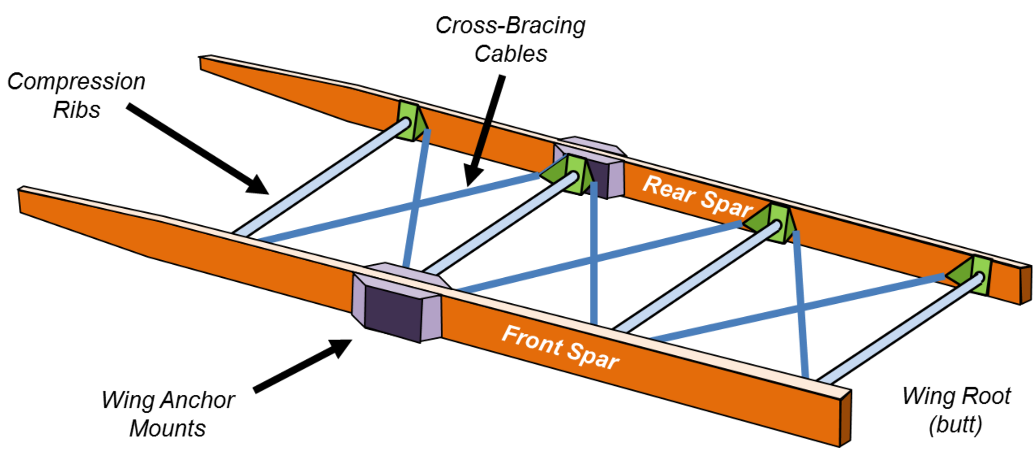


Figure 3: Wings with Compression Struts and cross-bracing

But before those cross-braces are installed, 11 full ribs, made of 1/8" plywood, are installed between, in front, and aft of the spars.

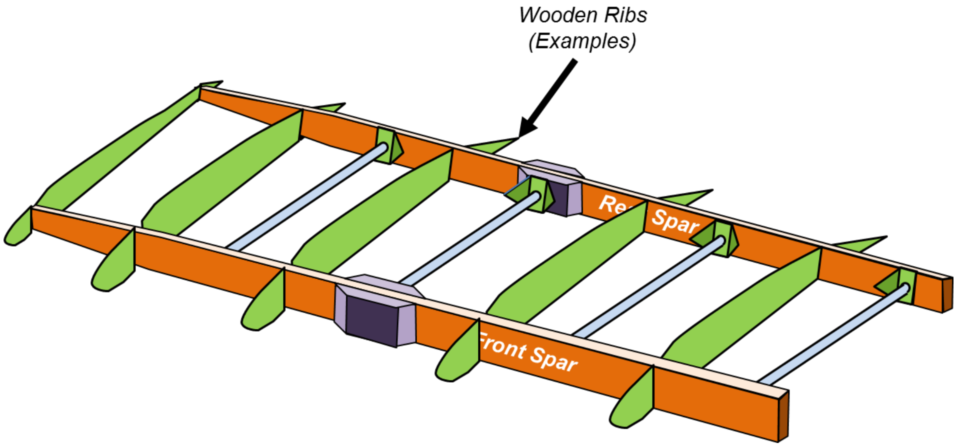


Figure 4: Wooden Ribs (examples)

Finally, a curved wingtip bow is fabricated out of laminated strips of spruce or cedar and the leading edge is wrapped in thin aluminum, plywood, or fiberglass. But in any case, we're well beyond the Article 1 topics…most of this is in Article 2.

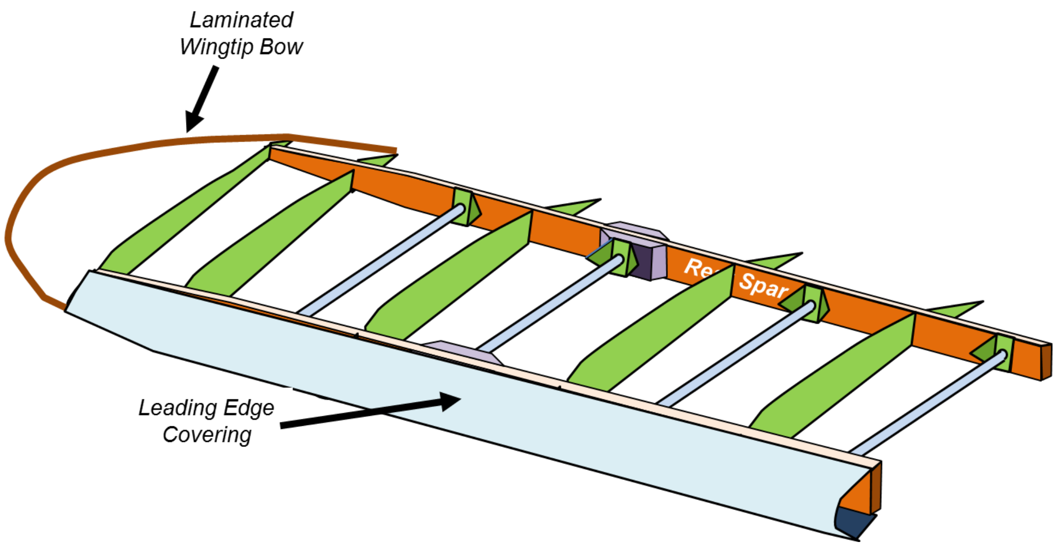


Figure 5: Laminated Wingtip Bow and Leading Edge Cover

2 ERRATA

2.1 Build Sequence

The EAA Magazine series starts with the building of the wings; the plans, when Pete published them, started with the fuselage. There is a big advantage to starting with the wings if you have limited build space: The wings can be easily stored hanging on the walls while the fuselage is built.

However, it should be noted: the wings cannot be completed until the fuselage structure exists. The innermost rib is shaped and glued to match the fuselage. While the fuselage-matching can be approximated, it's better to work with the actual structure.

So: If you have room, skip Articles 1 and 2 and build per Articles 3 (Fuselage Construction), 4 (Fuselage Secondary Structure), and 5 (Landing Gear) first. The Landing Gear isn't necessary to fit the wing to the fuselage, but it does make it easier to move the fuselage around the shop.

2.2 Spar Dimensions

Pete soon altered the height of the forward face of the spar. Figure 4-6 on Page 24 shows the aft spar as 4 inches on the forward face, and 3 $^{15/16}$" on the rearward face. The correct dimensions are shown in Figure 6. This was addressed in Part 11 of Pete's articles.

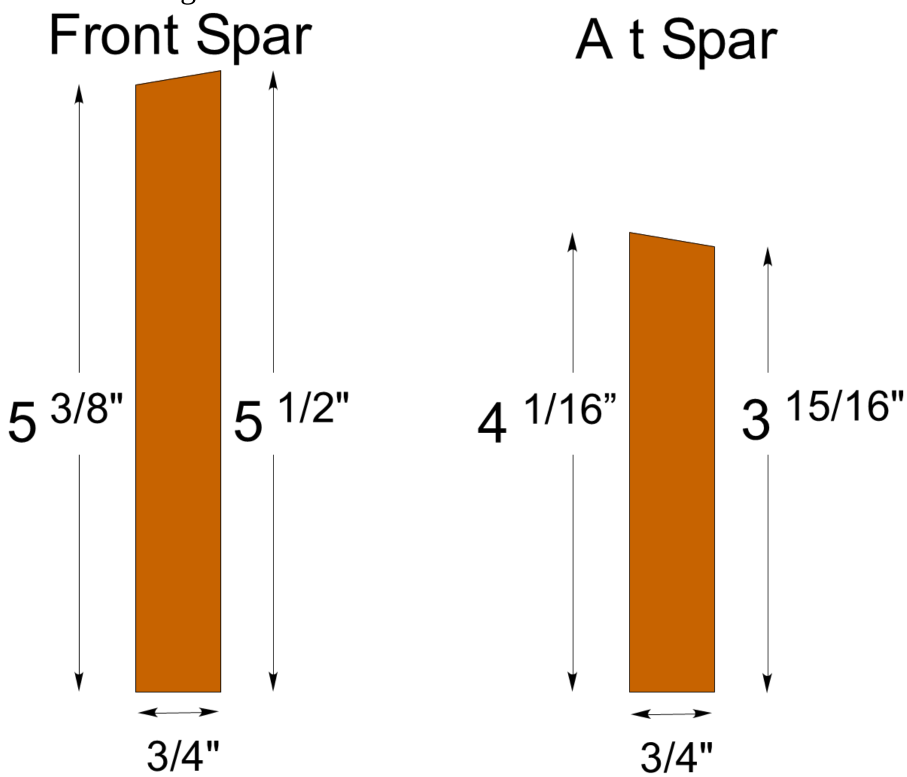


Figure 6: Correct Spar Dimensions

What difference does it make? Very little…it's only a 1/16" change. Doesn't matter structurally, but really, all it does is adjust the shape of the spar to the slanting rib cap strip coming down on top.

The slight amount of additional gap would make a difference if you're using the old glues like Weldwood…but modern epoxies will close that gap without effort.

2.3 Compression Rib Lengths

In Figure 4-4 on page 23 of the article, there is a list of the lengths of the compression ribs. "C4" is erroneously listed as 25 and 3/16ths inches. According to Pete, the correct dimension is 25 and 13/16 inches.

Compression Rib	Face Length
C1 and C3	26 and ¼ inch. (26.25 inches)
C2	25 inches
C4	25 and 13/16 inches (25.8125 inches)

However, there are other issues regarding Compression Rib length. See Section 4.3.

2.4 Compression Rib Ends

Figure 4-4, on Page 23 of the article, provides the dimensions for the ends to be welded to the end of the Compression Ribs. However, Pete doesn't call out the hole sizes.

All the holes should be 3/16", with the exception of the top and bottom of the Compression Rib end for Rib C-4 (the triangular one on the right). The top and bottom holes should be 1/4" to match the holes in the spar fitting.

2.5 Spar Root Fittings

The two plates bolted to the butt of the spars for attaching the wing to the fuselage are illustrated in Figure 4-3 on page 23. However, Pete changed the dimensions of these plates. The actual dimensions are shown in Article 11, "Corrections," dated January 1964. Basically, it's a finer taper…the plates start tapering right at the last bolt hole rather than waiting until the plate is clear of the spar butt.

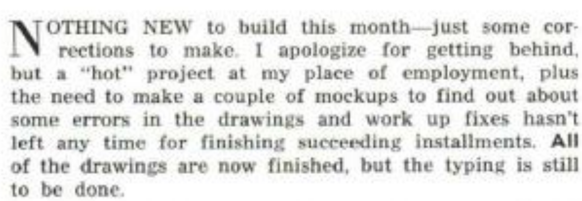

NOTHING NEW to build this month—just some corrections to make. I apologize for getting behind, but a "hot" project at my place of employment, plus the need to make a couple of mockups to find out about some errors in the drawings and work up fixes hasn't left any time for finishing succeeding installments. All of the drawings are now finished, but the typing is still to be done.

Figure 7: Revised Wing-Root Fitting (From Sport Aviation, January 1964)

The same diagram shows some other shapes of the spar fitting. Ignore those; they're for correcting Fuselage problems that we'll address in Part 3.

2.6 Wing Wire Anchor Bolt Availability

With the stock wing-bracing system, anchor plates are bolted to the mounting blocks as seen in Figure 8. These require very long bolts: AN3-54A (5 ½" long), AN3-64A (6 ½" long) and AN3-66A (6 ¾" long). The two longest bolts

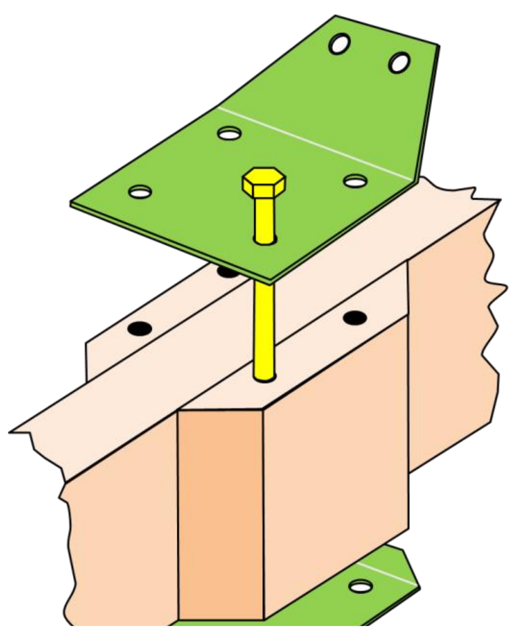


Figure 8: Wing Wire Anchor Pads and Plates

have become difficult to find; they're no longer carried in the Aircraft Spruce catalog. However, a Google search for "AN3-64 Bolt" finds some vendors with them in stock.

If you intend to build the stock wing-bracing system (See the Safety section) you may wish to order theses bolts early. They are rather pricy, about $10-$15 each, and you need 16 of the various sizes.

2.7 Steel Availability

In the article, steel parts are specified as 0.093" 4130 steel. This size is not commonly available nowadays. Use 0.100" instead.

3 SAFETY ISSUES

3.1 Wing Anchor Plates

The wing bracing wires are attached to metal plates, which are bolted through the wing wire mounting pads. The pads are shown on page 22 of the article, Figure 4.2, and two metal plates are bolted the long way through them. Figure 8 in the "Errata" section also shows this attachment method. Figure 9 shows this arrangement in cross-section.

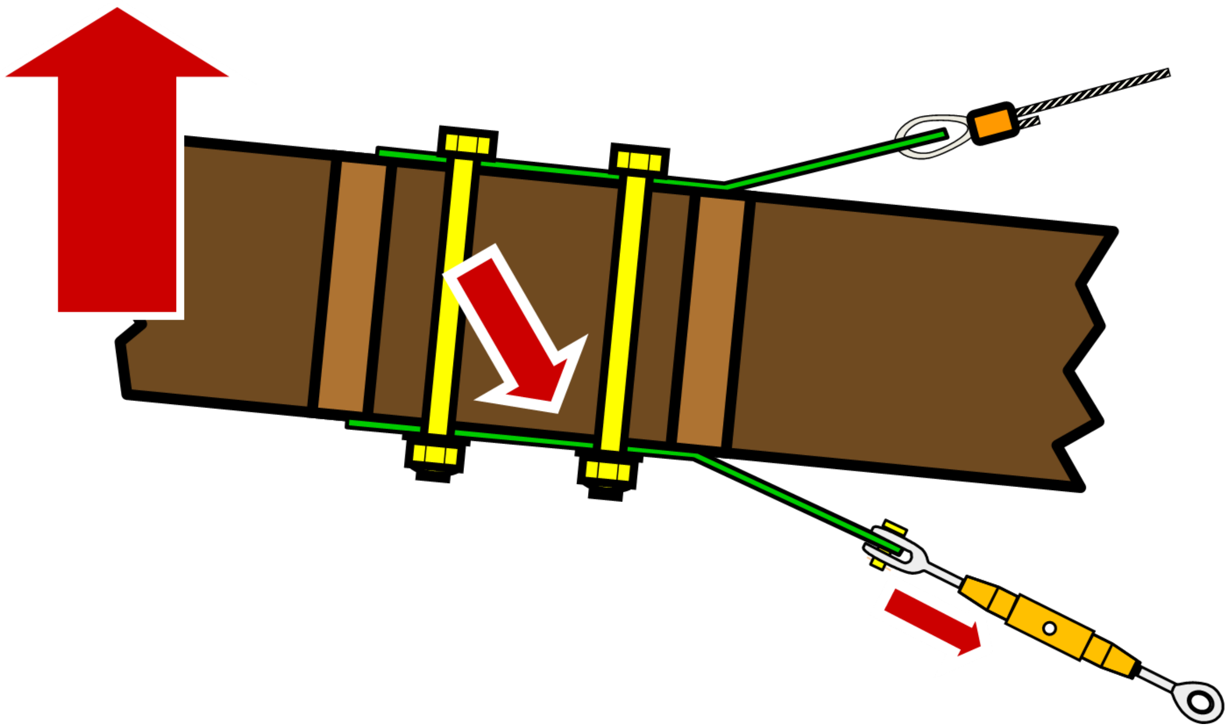


Figure 9: Wing Anchor Cross-Section

This attachment method is adequate, but is not the ideal solution.

- It requires drilling long, accurate holes through the external wood blocks. This is difficult; in fact, in the plans, Bowers recommends having this done by a cabinet shop.
- As mentioned in the previous section, the long bolts through these blocks are becoming difficult to find. You'll need about 16 total, of three different sizes.
- There is the potential for metal fatigue in the anchor plates, due to vibration of the bracing wires. There has been at least one accident caused by metal-fatigue-induced failure of these plates, and a second case where the metal fatigue was detected in time.
    - **HOWEVER**: Both these cases involved modified wing-bracing systems, using solid tie rods rather than the cable/turnbuckle arrangement specified by Bowers. The stock system actually allows a bit of "slip" between the cable and the plates (due to the cable eye through the turnbuckle) and it is believed that this minimizes the situation
- There is also one case where the through-bolts shown in Figure 9 failed in tension. As you can see from the diagram, the wing bolts are in tension as well as shear. The case mentioned happened when the heads of the through-bolts ripped off.

- **HOWEVER**: This also involved a modified bracing system, and the failure occurred while the pilot was flying aerobatics. Bowers allowed aerobatics in the aircraft, but my own opinion is that aerobatics should not be attempted.

Yet hundreds of other Fly Babies have flown with this system without incident.

On later editions of the plans, Bowers did show an optional alternate method for attaching the bracing wires to the wing. Matthew Wise used this system on his Fly Baby. It incorporates a set of four steel straps bolted through the spar. Two pieces of ¾" plywood are glued to the spar to act as the base for the bracing system.

The bolts into the spar are mostly AN4 (1/4"). The lower strap, which attaches to the flying wires (the ones under tension during flight) have an AN6 (3/8") bolt instead.

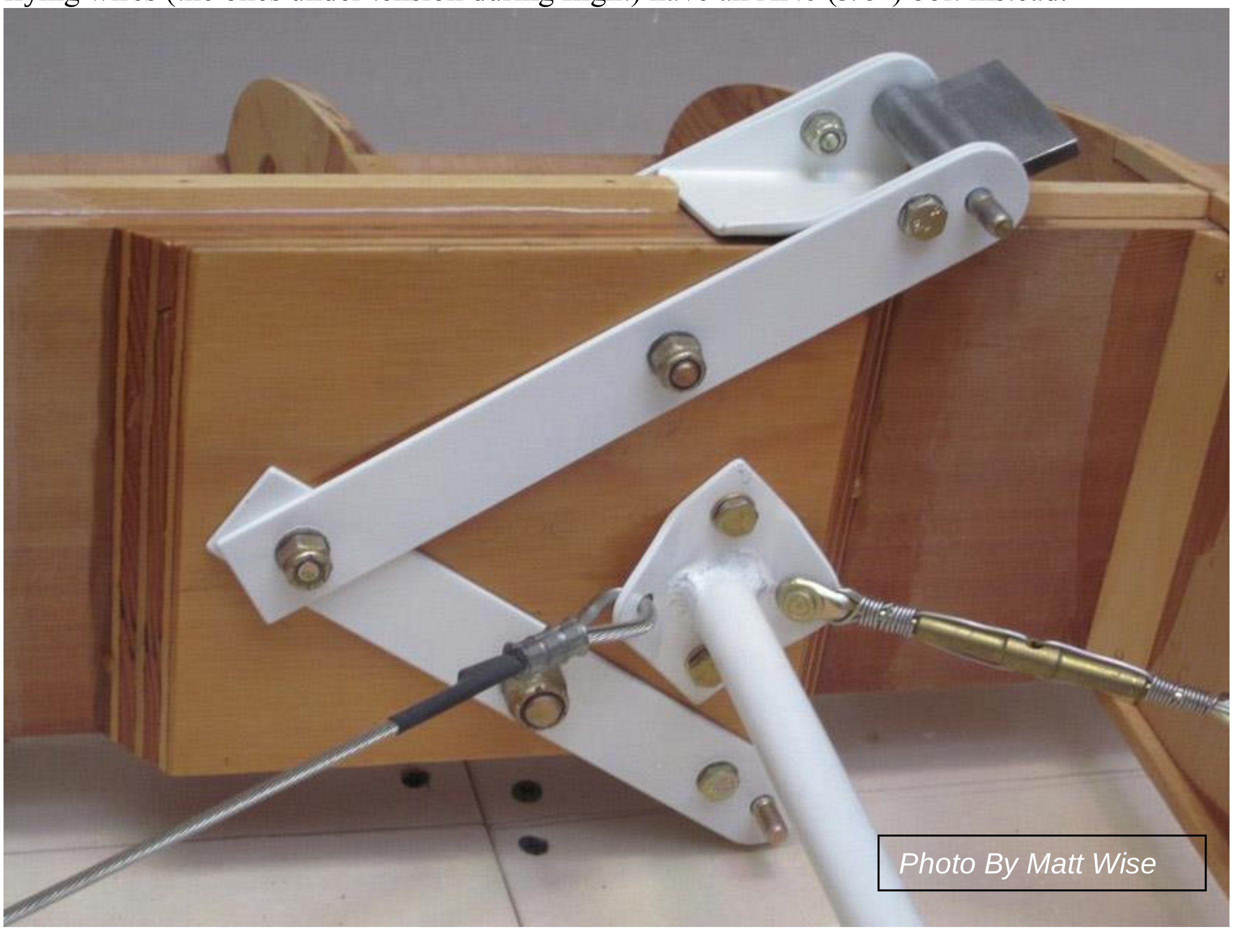


Figure 10: Alternate Wing-Bracing System

At the top and bottom of the straps, a U-shaped reinforcement is inserted into the gap between the two straps. Bowers shows this as welded in; Wise used bolts for his.

Between the two straps is a tab; an AN3 bolt through the straps and reinforcement hold this tab in place. Wise used 4130, 1/2 inch stock and had a machinist mill them out (Figure 11). Bowers shows this tab as bent 4130 steel, which Chuck Baynard implemented

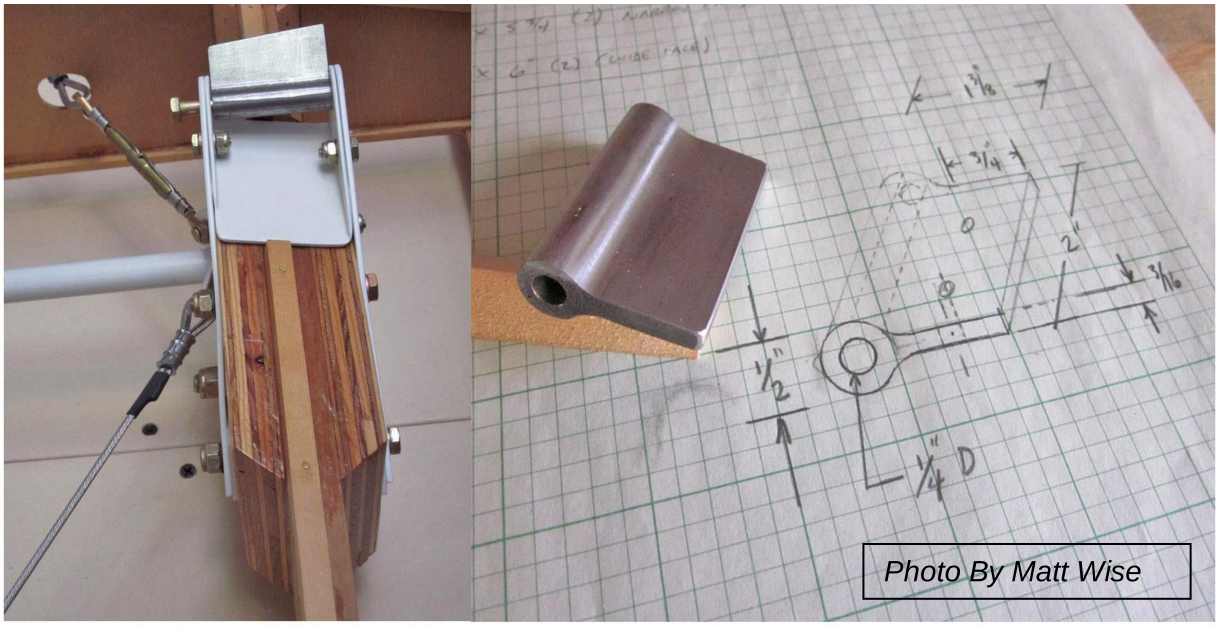


Figure 11: Tab Used in Alternate Bracing System

Figure 12: Bent-Steel Tab Approach

When EAA Chapter 26 rebuilt Pete Bowers' original

3.1.1 Drawings of Strap System

The following drawings show the dimensions that should work for this alternate bracing system. It should be noted that all aircraft are different, and that it may be necessary to alter some of these dimensions. Please test-fit to your aircraft before making anything permanent.

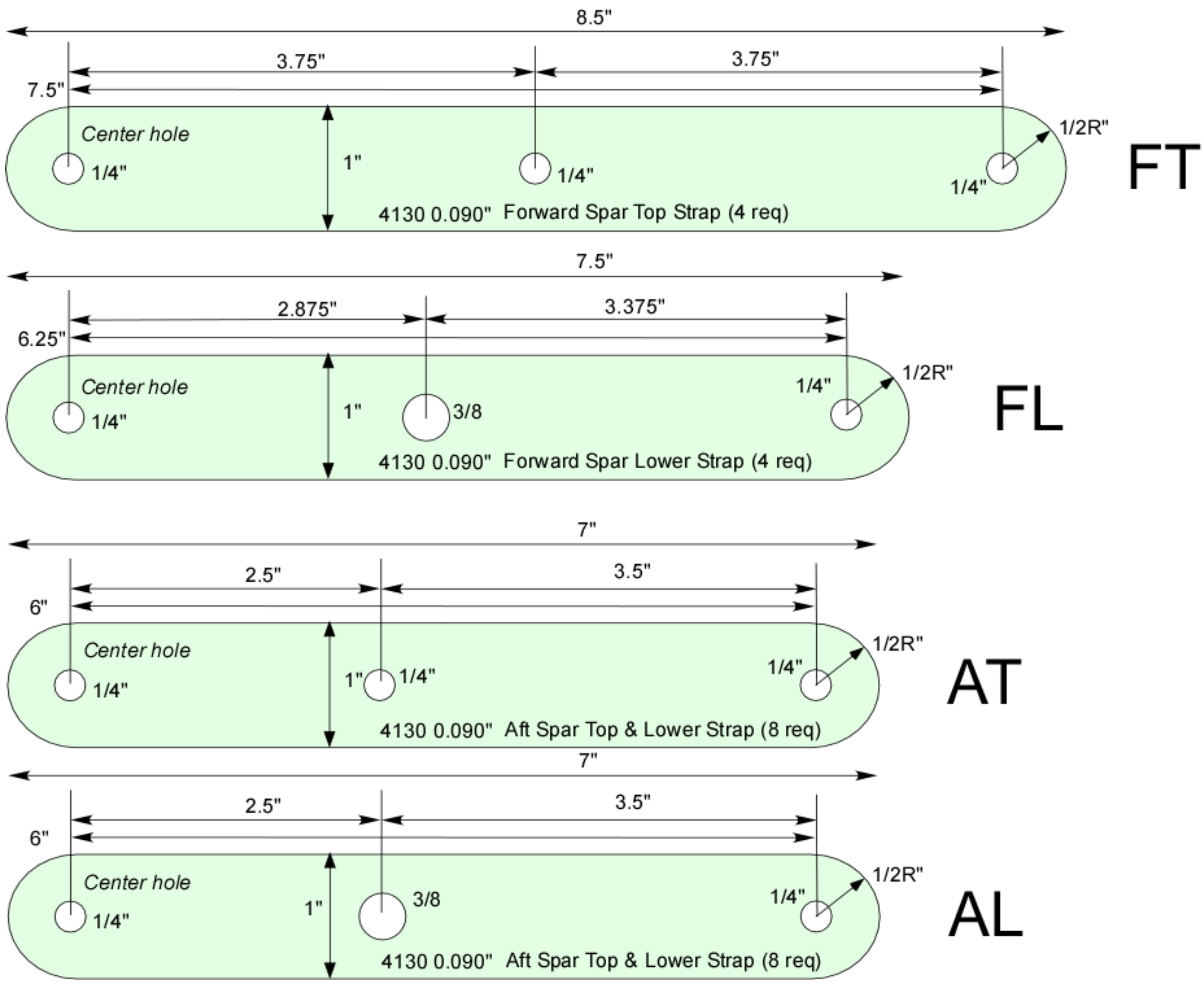


Figure 13: Strap Dimensions

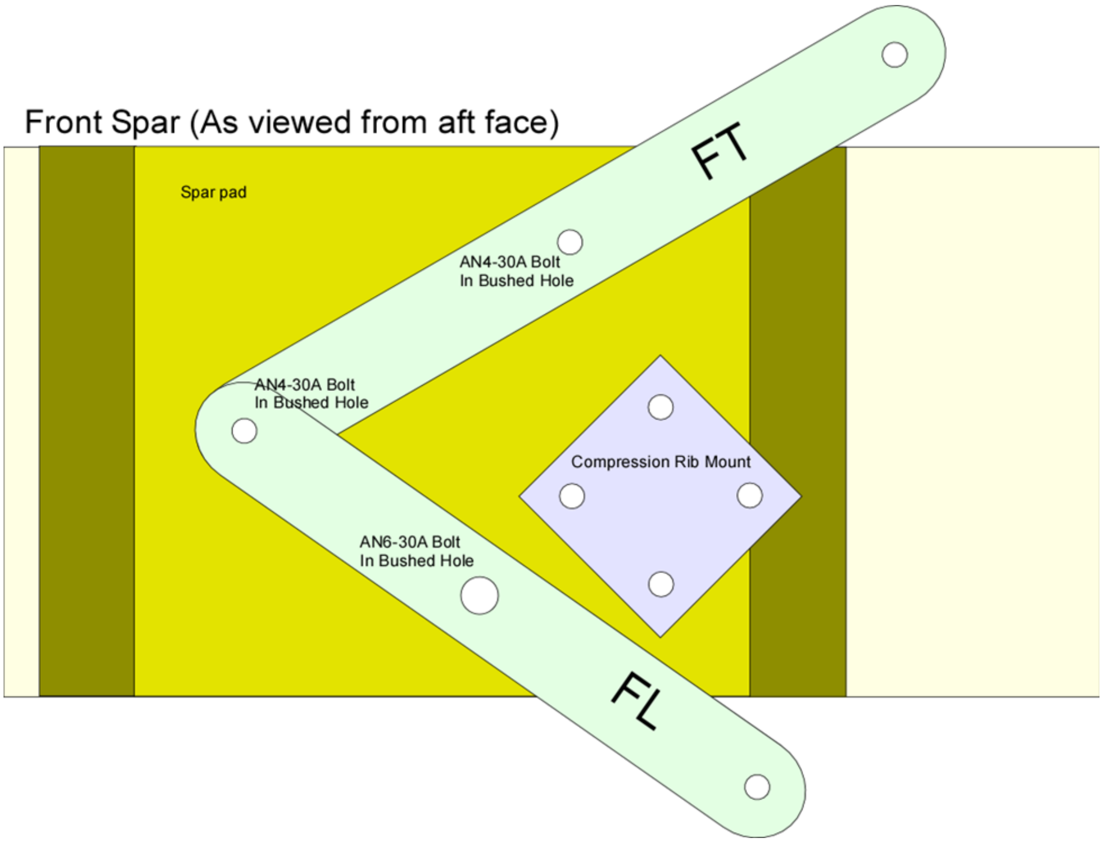


Figure 14: Bracing Straps on Front Spar

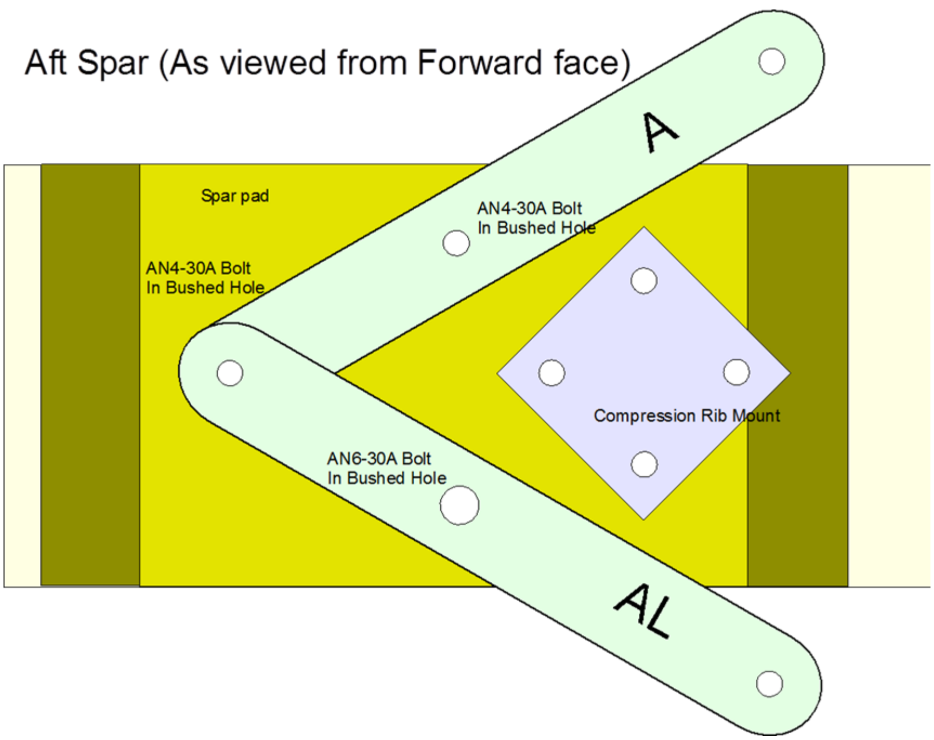


Figure 15: Bracing Straps on Aft Spar

3.1.2 Alternate Approaches

When N500F was restored in 1982, the strap-type bracing system was instituted *on the front spar* only. The stock block-and-plate system was retained on the aft spar. Since ~60% of the flight loads are in the front spars, this is probably an adequate approach.

However, N500F did not include the "tabs" discussed previously. Both of the bracing wires were attached to its own strap, rather than the tab with the through-bolt. This approach appeared adequate. However, the straps peeking out of the wing in Figure 16 don't look like 0.090"…they look closer to 0.125", or 1/8". Little harm in going with the bigger size.

Figure 16: N500F Wire Attachment, without Tab

3.2 Flying Wire Size

The Flying Wires are the cables under the wings that support all the weight of the aircraft in positive-G flight, while the Landing wires are on top of the wings, and support the wings on the ground as well as any negative-G loading. All the wires are 1/8" cable.

However, the front bracing wires must handle about 60% of the flight loads. In some cases, folks have upgraded to 5/32" cable on the front wires only.

Note that this will also require going to the next higher turnbuckle size, as the original turnbuckle would then be the weak point in the system. The AN130-32 series is probably the best pick, though of course the price is higher. On the plus side, only four are needed.

HOWEVER: Before committing to this, make sure your planned wing-wire anchors can accept the larger turnbuckle. If you use the stock anchor plates, there has to be enough space between the anchor plate and the wing to insert the turnbuckle clevis pin.

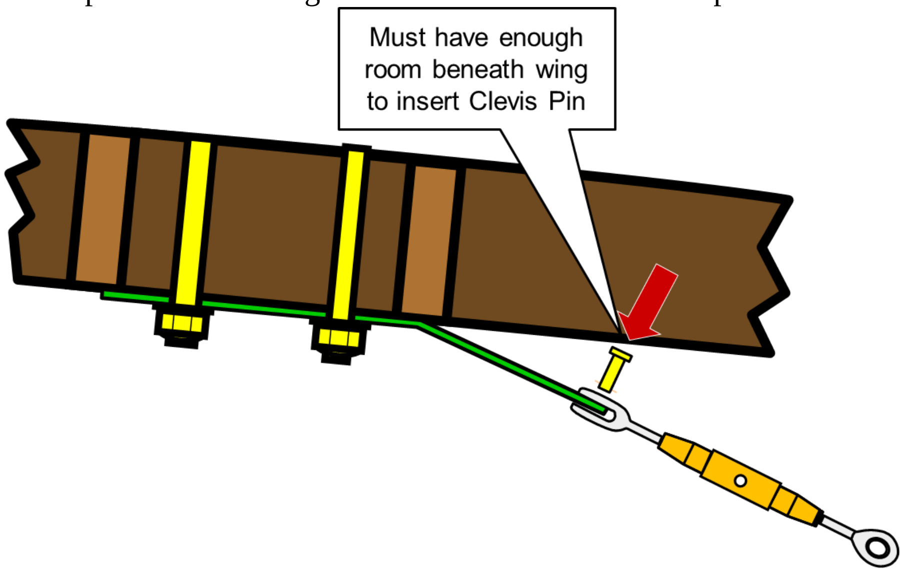


Figure 17: Clevis Pin Clearance

3.3 Internal Bracing Wire Size

In 1982, EAA of Canada released a safety bulletin recommending that the internal bracing cables of the Fly Baby be upgraded to 5/32." Their analysis showed some of the internal bracing, at extreme corners of the flight envelope, might exceed the 2000 lb cable/1600 pound turnbuckle ratings of the standard bracing system:

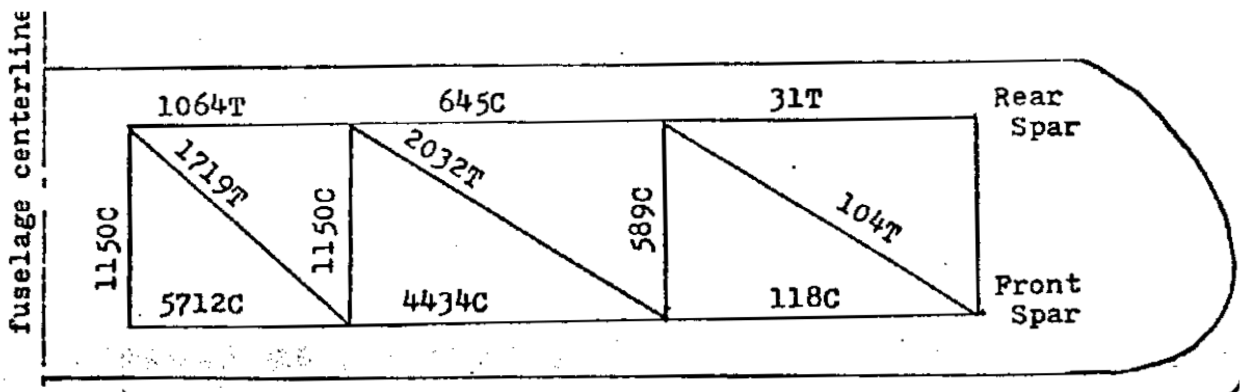


Figure 18: EAA Canada Loading Diagram

There is some controversy over this, with some believing that the methodology used to determine this loading was flawed. In any case, there has not yet been any accidents or known incidents relating to the internal cable bracing size. In addition, the original Fly Baby flew for ~20 years with SMALLER bracing cables…3/32" inch.

However, the cost for this upgrade is pretty minor. You'll need the next-size larger turnbuckle (rated as 2200 pounds), but they don't cost that much more.

4 CONSTRUCTION DETAILS

Article 1 of the SPORT AVIATION series on building the Fly Baby didn't actually CONSTRUCT the wing…it covered making the parts, not actually putting them together! The parts addressed in Article 1 are shown in Figure 19. Information on assembly and other construction details will be included in the Article 2 Companion Guide.

Before starting, read the Errata section and the Alternate Approaches.

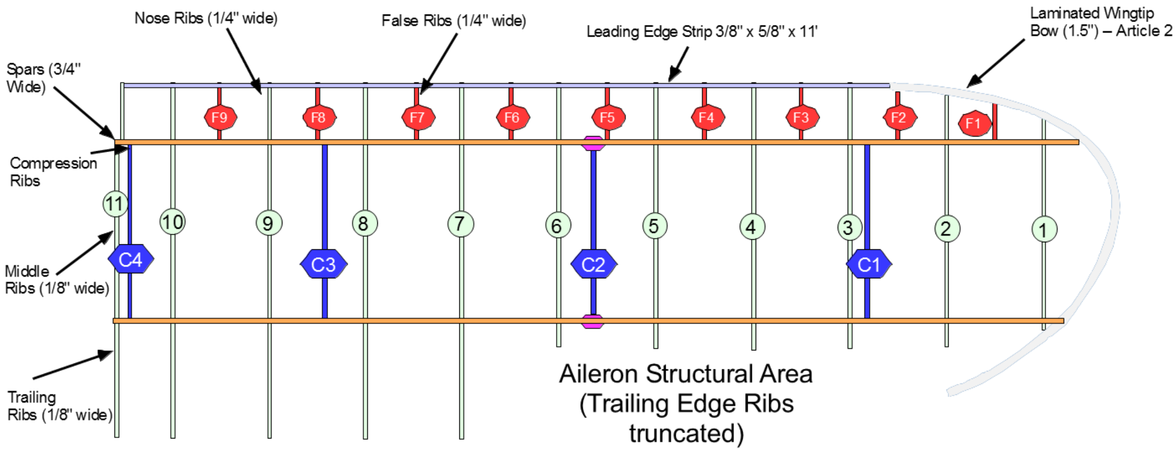


Figure 19: Wing Components in Article 1

4.1 Material

Download the Fly Baby Materials List and sort through the listings to find the Wing material. Most of it will be used in the Article 1 construction, but between Article 1 and Article 2, it'll cover most of the wing stuff.

If you have Microsoft Excel and are familiar with it, the Excel Version of the Material List is best. If not, try the PDF version.

The major purchase will be the wing spars Beyond that, the primary material will be 1/8" plywood for the ribs, 1/2" x 1/4" capstrip, some 5/8"x0.032" steel tubing, and some 0.100 4130 plate to make fittings.

4.2 Metal Components

The article provides the diagrams for making the steel components out of 4130 steel. It is recommended that these be made first, so that the wooden parts can be drilled to fit exactly. The PB100 web page includes two different sets of digital files of steel part templates.

With 4130 steel, you'll need a steel-cutting bandsaw to make these. However, there are many companies who can take a computer file and cut the parts with a water jet, plasma cutter, or a CNC mill. "Racing speed shops" apparently have this type of capability…check your local listings.

When you have them cut out by machine, DON'T have them cut the bolt holes, to the exact dimension. Just have them do a pilot hole, and you can drill to the final dimension once you have the part.

All metal parts must be painted, or otherwise protected from corrosion. There are many good systems for protecting steel parts. Epoxy primer and paint systems are popular and readily available; in some cases, the paint can act as its own primer.

Enamel paint is a traditional solution, but the consumer-grade enamels available at the typical hardware stores is sometimes of questionable quality. Marine-grade enamel might be a better choice.

Finally, powder-coating produces a hard, near-impervious coating. However, it does cost a bit, and there are some concerns that it won't reveal any cracks under the paint surface.

4.3 Compression Ribs

The compression ribs are the key structural element of the Fly Baby wing. Not only do they set the spacing between the wing spars (26.25 inches), they support the cross-bracing that gives the wing maximum strength.

There are eight total compression ribs… four per wing. In a perfect world, they would be identical, and 26.25 inches long. Not the case, of course. Two are that length—Compressions Ribs 1 and 3—but Compression Ribs 2 and 4 are installed upon other components, and that reduces the length of the compression ribs themselves.

The ribs are illustrated on Page 23 of the article, in Figure 4-4. Note that the table of compression rib lengths in that figure has an error. This is the actual required compression rib length:

Compression Rib	Face Length
C1 and C3	26 and ¼ inch. (26.25 inches)
C2	25 inches
C4	25 and 13/16 inches (25.8125 inches)

The dimension shown is the total length of the compression struts, including the 5/8" diameter steel tube as well as the 0.100" thickness plate welded to each end of the tube.

It's important to not make the Compression Ribs too long…they set the separation of the wing spars, and a too-long Compression Rib may cause later problems. It's better to err to the SHORT side, by as slight a margin as possible. A too-short Compression Rib can be shimmed up with thin plywood (available at most hobby stores).

4.3.1 Compression Rib Sizing

The dimensions in the above table are based on the distance required between the spars: 26.25 inches. Obviously, Compression Ribs C1 and C3 are good…but what's up with C2 and C4?

Compression Rib C2 goes between the Wing Wire Anchor Pads on the spars. The nominal thickness of these pads is 5/8ths of an inch. So 25 +5/8 +5/8= 26.25

If your Anchor Pads are another thickness, the length of Compression Rib C2 must be changed as well. It's possible you'll use the much more available 3/4" hardwood instead. In this case, Compression Rib C2 will need to be 26.25-3/4-3/4, or 24.75 inches long.

Compression Rib C4 is interesting. Pete's 25 13/16" dimension was based on the use of 1/8" plywood to reinforce the spar end, and spar attachment plates made out of 0.093" steel. However, that 0.093" steel is no longer available, and 3 mm plywood is slightly thinner than 1/8" (0.118 vs. 0.125).

Incredibly, as Figure 20 shows, the combination of the thicker steel with the slightly thinner plywood totals up to the same total thickness!

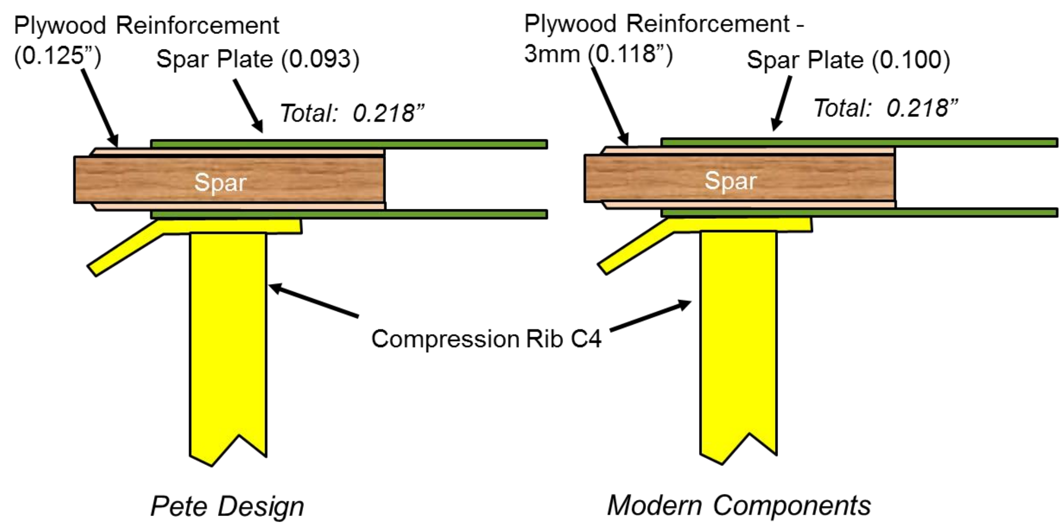


Figure 20: Wing Chord at Compression Rib C4

4.3.2 Compression Rib Construction

As you might gather, getting these ribs correctly sized is important. If you're not interested in it yourself, check with your local EAA chapter for references. In most cases, the shops give you a good discount if you cut and fit the parts together first. In that way, all they have to do is actually weld.

You might consider having the Compression Ribs slightly undersized, and count on using small thin plywood shims to get the spar distance correct.

The plate welded to the end of each compression rib must be bent upward to provide the proper angle for the cross-bracing wires. For compression rib #4 (the one nearest the wing root), this angle is about 45 degrees. Compression ribs 1-3 have them bent at about 30 degrees. Actually, the inward sides of the #3 compression rib should be at about 45 degrees as well, to match the planes on compression rib #4. Figure 21 illustrates this

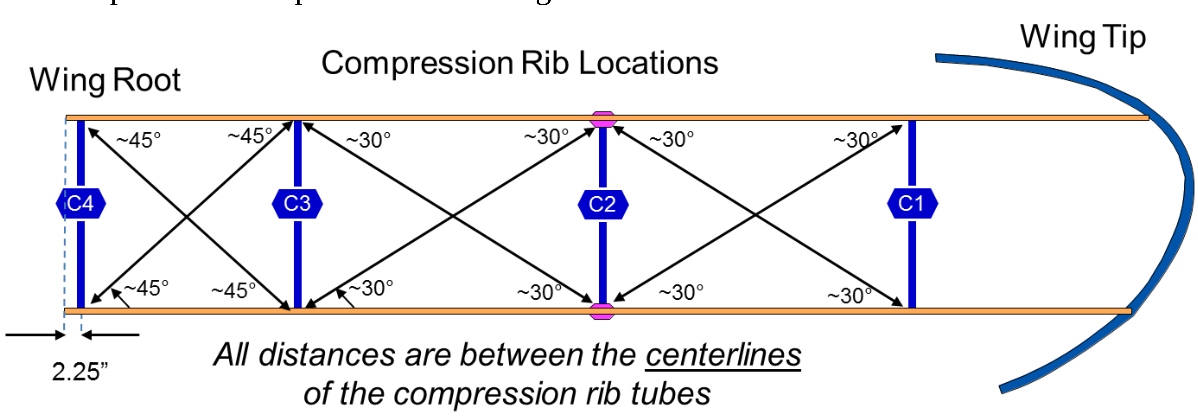


Figure 21: Compression Rib Plate Bend Angles

Now… in 50+ years of Fly Baby discussion and documentation, nobody ever seemed to write down these angles before! The above angles are my own estimates. I suspect the actual angles aren't too critical… builders probably just adjusted the angle once the compression ribs were bolted to the airplane, or the tension of the bracing wires soon had the plates at the proper angle.

4.4 Spar Preparation

The spars, other than the engine, are likely to be the single most-expensive portions of your aircraft. And, also, the time required to order one and get it delivered is likely to be on the order of several months. So you don't want to take risks with the spars.

The first step after getting the metal parts is to prepare the spars. There are three aspects: Beveling, trimming, and drilling.

Needless to say, any shaping of your very expensive spars requires the best saw blades available. You want a blade with 60 teeth or more that is defined as for fine finishing. Narrow kerf is good, too (the kerf is the thickness of the blade). One Fly Baby builder recommends "hollow ground planer blades," but notes that the fence must be very parallel to the blade.

4.4.1 Beveling

Figure 6 in the "Errata" section shows the required final dimension of the spars. Note that the aft spar is slightly different from that called out in Article 1. Pete changed that not long after.

You cut the bevel first, because that's probably the most-complex portion of the job. Hopefully, if a mistake is made, it can be caught early. If you plan on making the front spar first, it's wider than the aft spar and if you botch it, you might still be able to make an aft spar out of the piece.

Why are the spars beveled? To follow the curve of the upper surface of the airfoil. It has nothing to do with the durability or strength of the wing. On option is to NOT bevel… see Section 5.1, "Non-Beveled Spars."

You'll want to cut the bevel first. You'll be starting out with ~6" wide spar stock, so that gives you a half-inch to play around with. Once you get the bevel itself done, it's easy to cut the other side of the spar square.

There are a lot of ways a professional wood worker might apply the bevel, using tools like a planer. However, most spars have been beveled by the humble table saw. Needless to say, you want a GOOD blade in place, for clean cuts.

The cut is pretty simple…the blade is tilted the prerequisite amount. Then run scrap wood through the saw until the angle is right (remember, the actual amount of the bevel is only 1/8" difference.

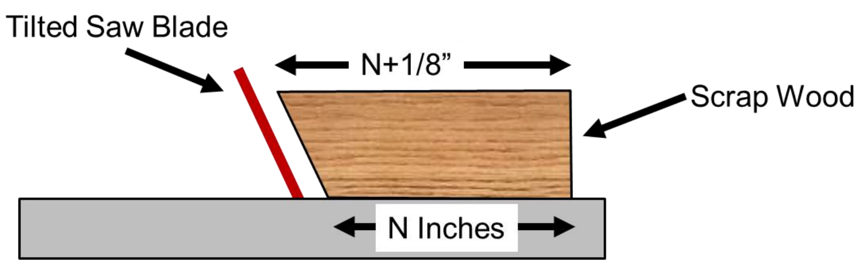


Figure 22: Adjusting the Angle

Once you have the angle right, you're ready to cut the spar itself. Your table saw has an adjustable fence to keep the cuts straight…since you're cutting a piece 13 feet long, add a bit of angle iron or other straight item to make the fence longer. Adjust the position of the fence so that, when the spar blank is run though, it just cuts off enough from the side to apply the bevel and leave most of the rest of the board intact. With a 13-foot-long spar blank, you do NOT want to handle it yourself. Make sure you've got a helper.

Make sure, also, that there's enough ROOM to run the 13-foot-long blank through the saw. That means you need at least a 26-foot free space (13 feet of room BEFORE the blank hits the saw, with 13 additional feet of clearance as the blank passes completely through). THIS is where a set of wheels on the table saw come in handy….

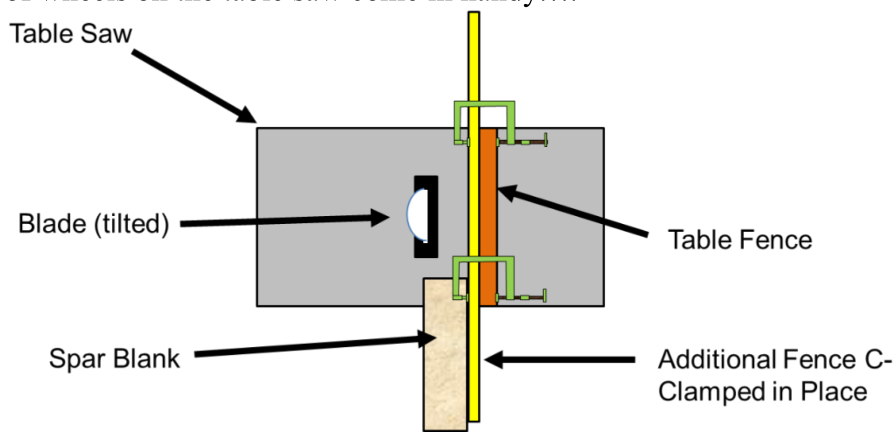


Figure 23: Table Saw Setup for Spar Beveling

Once you run the piece through the saw, check the bevel. Everything OK? Then, without touching the saw adjustments, run the other three blanks through. After then run some scraps through to help adjust the saw later.

Keep in mind that mindless precision here isn't necessary. You want about 1/8" difference in the dimension, as seen in Figure 22. A few 1/64ths off don't make much difference.

However, it is a bit harder to match the angle once the saw blade position has been altered. So make sure you're ready before going on to the final cut.

Make sure you rotate the blade to vertical (and check it with a square to be sure). Set up the fence to the widest dimension of the spar to cut. Run one of your beveled scraps through to make sure of the setting. Then run two spar blanks through, reset for the other dimension, and run the other two through.

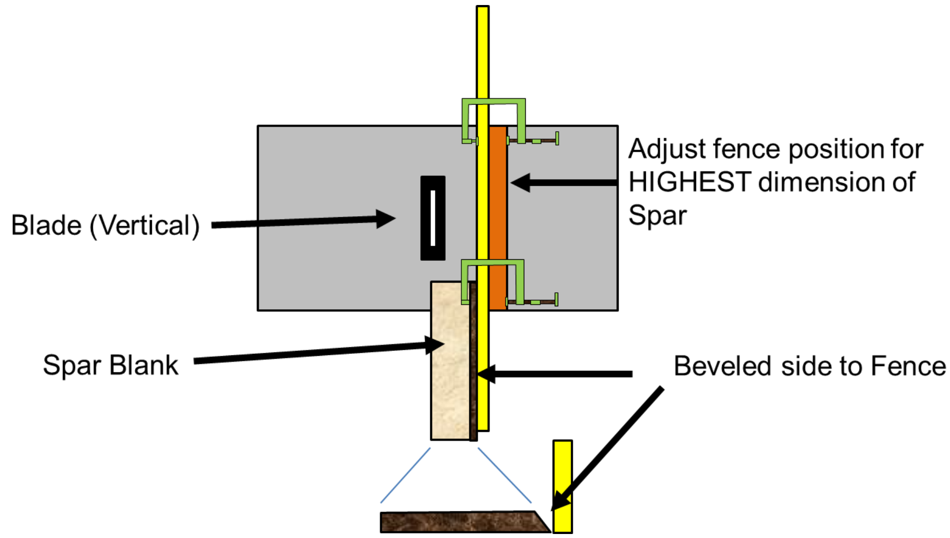


Figure 24: Cutting Spar Blank to Final Size

A final note: DON'T VARNISH THE SPAR YET! You're going to be gluing some important stuff to it, and it won't stick right if there's varnish on the glue line.

Also, don't sand it too much. The sawdust can interfere with gluing. AC43-13 says to buff slightly with 220 grit sandpaper, if needed. Otherwise, use a plane to clean things up.

4.4.2 Marking

Your next step is to mark the position of for the ribs and other major components on the spar. This is actually an Article 2 function, but you need to taper the spars near the wingtip, and the rib locations are used for as the reference. So it's probably better to do this marking before going much further on the spars.

The ribs are numbered 1 through 11, STARTING AT THE WINGTIP, as shown in Figure 25.

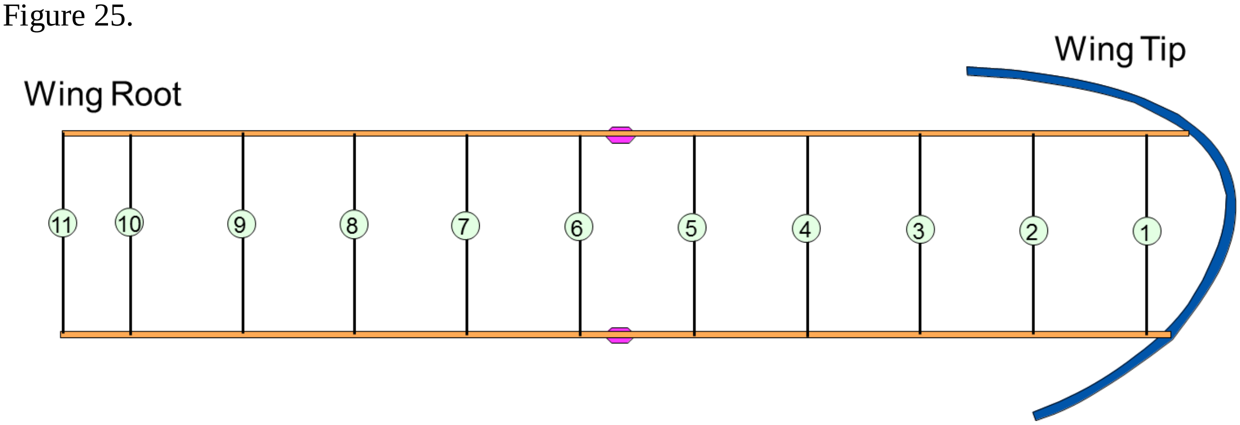


Figure 25: Rib Numbering

Here is a table of the distances from the wing spar roots for each rib:

Rib	Inches from Root
11	0
10	9
9	24
8	39
7	54
6	69
5	84
4	99
3	114
2	129
1	144

Using a carpenter's square, draw a line on the front and back side of each spars at the proper rib location, along with the rib number. Compare the lines front-to-back to ensure you've got them properly lined up. Write the rib number by the line

Do the same thing for the compression rib locations, per the following table.

Compression Rib	Inches from Root
4	2.25
3	32.25
2	74.25
1	116.25

Again, the compression ribs are numbered one through four, STARTING AT THE ONE NEAR THE TIP. This figure illustrates the numbering

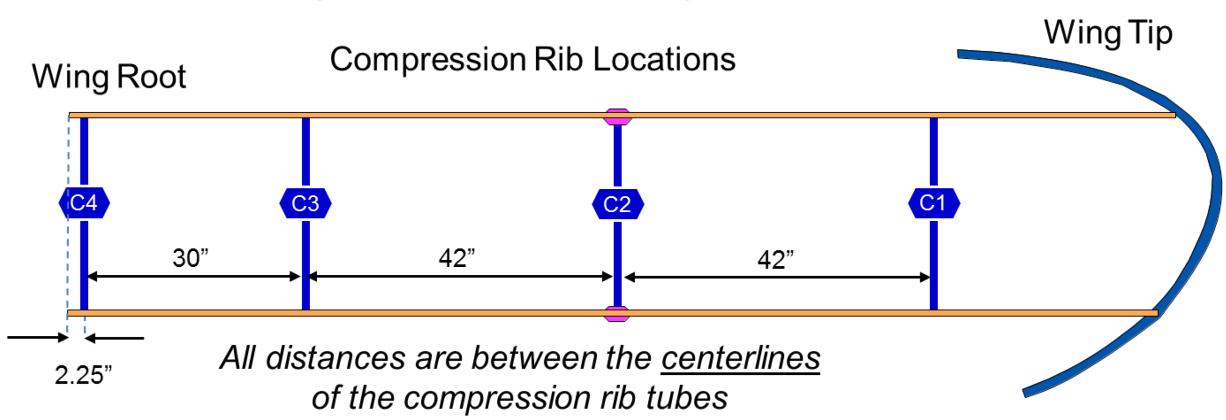


Figure 26: Compression Tube Spacing

Note that the location for compression rib C4 is on top of the spar plates attached to the root of the spars. It uses the same holes drilled for the spar plates. Remember that, so you don't try to drill separate holes for it.

Then, draw a line the full length of the spar two inches above the bottom (i.e., the non-beveled side). Note that on the rear spar, this will be nearly down the middle (just 1/32" off, in fact), but it will be significantly biased toward the bottom of the front spar. The sketch in Figure 27 gives an idea of what this will look like.

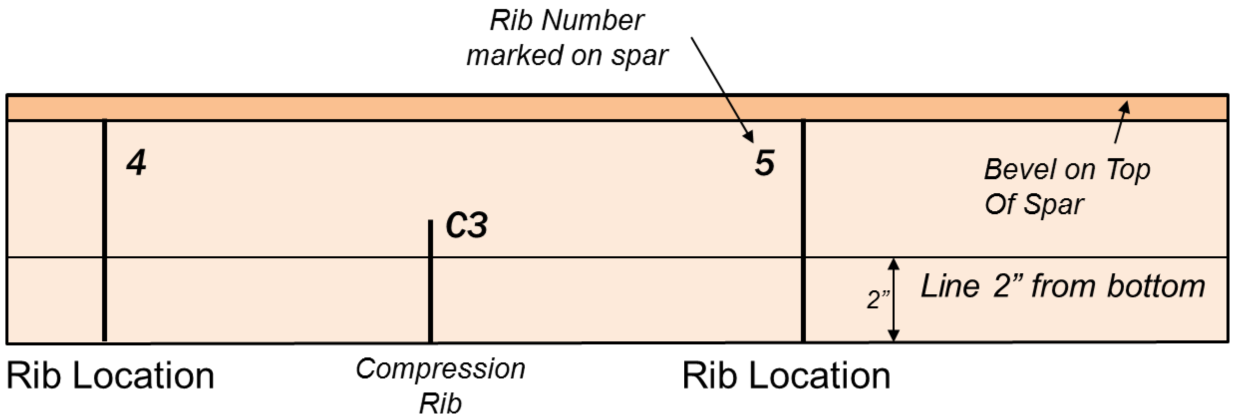


Figure 27: Sample Rib and guideline markings on both sides of wing spars

Will address the actual drilling of the mounting holes in the Companion Guide for Article #2.

4.4.3 Trimming

As of this point, you have four 13-foot spars with a lot of pencil marks. These now need to be trimmed to final shape.

The main trimming is the shortening of the spars to the final length, and the tapering of the spars in the wingtip area.

You determine the final length of the spars using the overall wing plan in Figure 4-1 (page 21 of Article 1). Look at the distances showing the rib spacing…the numbers just under the front spar. It starts out as nine inches, then there are nine at 15-inches. Then, it just leaves twelve inches to the tip.

Now, examine Figure 4-6 on Page 24 of article 1. It shows the required taper for both the front and rear spars, based on the locations of Ribs 1, 2, and 3.

WORKING ON THE FRONT FACE of the spars, mark the required spar thickness as the offset from the 2" guide line at the Rib 2 and Rib 1 positions. Then continue the shaping towards the ultimate end of the spar. Use a straightedge to connect all the locations and draw the required shape at the end of the spar.

Check and recheck the lines…compare their appearance to the original in Figure 4-6. Then, cut the spar end to shape. Personally, I'd try to use the bandsaw for this, but manhandling that 13-foot plank would be awkward. You'll definitely need someone to help you. A handheld jig saw with a fine blade might be an option, if you're working alone.

In either case, take care to stay outside the line and NOT remove too much material. Once the machine-cut trim is complete, you can work the remainder down with hand tools, such as a draw knife or a plane.

The last step is to renew the bevel over the newly-cut area. This, again, can be done with the draw knife or plane.

Finally, the root of each spar has to be cut at a 5-degree angle, per the illustration on the upper right of Figure 4-6. This, basically, gives enough clearance for the wing dihedral.

4.4.4 Protection

Do NOT varnish or otherwise protect the wooden spar (or any other wooden parts) at this phase. Varnish will interfere with the bonding of the glue used to attach other components.

4.5 Wing Wire Anchor Pads

The wing wire anchor blocks are a key component of the wing structure. They run the height of the spars, front and back side. You can find them on the same page as the nose-rib patterns, page 22 of Article 1 (Figure 4-2).

Bowers wants these made out of a hard wood, like oak, birch, or maple. Oak can usually be found at the "big box" home improvement stores.

Bowers specifies 5/8" thickness for these pads, and the big box outlets usually have just 1/2" and 3/4". You could find a friend with a planer to shave the three-quarter size piece down, but there's little harm in going with the 3/4" size.

HOWEVER, THIS WILL AFFECT THE REQUIRED LENGTH OF COMPRESSION RIB NUMBER 2.

That's not really a problem…as long as you remember to make C2 a quarter-inch shorter than the specification, if you go with 3/4" pads.

The dimensions of the pads are provided in Figure 4-2; they're the height of the spar at that particular point. That means you have to drill long, straight holes the long way through each pad. The holes are designed to take an AN3 bolt, which is 3/16" in diameter. Bowers does suggest that the hole be slightly oversized to take a piece of thin steel tube (3/16" inside diameter) as a bushing. Otherwise, after a few years, the wood generally tightens down hard on the bolt and makes it almost impossible to remove.

The nice thing is, you drill these pads BEFORE they get glued to the wing (Figure 28). So you can experiment and ruin a lot of nice (but fairly cheap) wood before you get it right. The actual positioning will be set by the mounting holes for Compression Rib #2; the bolts will go between the pairs of vertical holes.

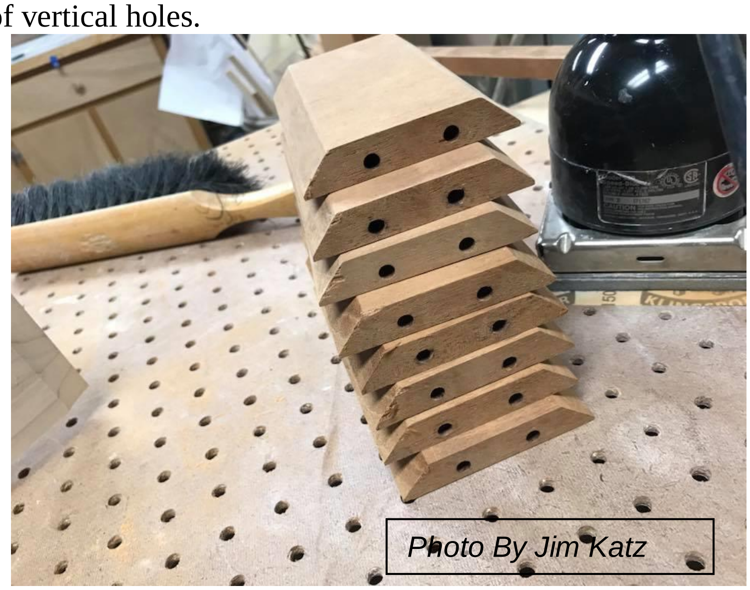


Figure 28: Wing Wire Anchor Pads are drilled prior to installation

4.5.1 Note for Alternative Bracing System Users

If you're going to use the alternate bracing system described in Section 3.1, this will affect the design of the pads, and, potentially, the length of Compression Rib 2 (again). A 1/2" pad thickness will probably be adequate for this system, especially if the U-shaped insert is not used (see Section 3.1.2). A good approach would be to make a scrap pad of the proper thickness and experiment with the strap positioning. Once you understand how wide a pad is going to be necessary, you can cut the final pads to the right dimension.

4.6 Wing Ribs

There are three sections for each rib… the nose, the middle, and the trailing edge.

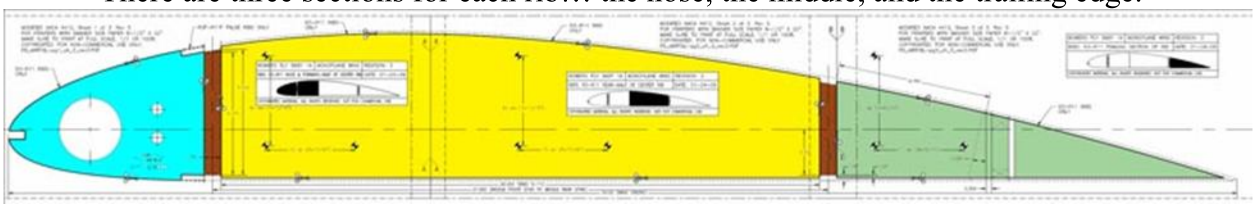


Figure 29: Wing Rib

The middle and trailing edge ribs are made from 1/8" plywood, but the nose ribs are 1/4". Templates for these ribs are available for download on the PB100 web page. There are also "False" nose ribs; these are nose ribs that are installed between the full-chord ones to help support the leading-edge covering.

As you can see from the above diagram, the ribs actually stick up beyond the spar dimensions. The three sections of ribs are held together by a "cap strip"; 1/2" x 1/4" spruce that composes the actual top and bottom of the ribs.

Figure 30: Typical Ribs

The stock cap strips is readily available from the usual sources. A slot must be cut in the bottom, 1/8" square, as shown in Figure 31. Use the table saw to rip the 1/8" wide by 1/8" slot down the bottom of it. Usually, the saw blade itself is 1/8" wide, so this is a fairly simple cut.

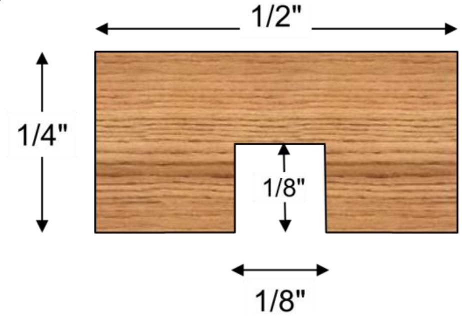


Figure 31: Rib Cap Strip Cross-Section.

4.6.1 Cutting out the Ribs

Electronic templates for the ribs can be found on the PB100 web page. Using the templates, the ribs can be cut from the plywood in several different ways.

- *Individually*: Print out a template for each rib, attach the template to a piece of plywood a bit larger than the rib size (the "blank"), then cut the shape out using the bandsaw.
- *Gang-Sawed*: Pretty slow, doing these one at a time. Many folks stack a bunch of blanks on top of each other, attach a template on top, and cut the whole stack at the same time on the bandsaw. Make sure you have a sharp blade, or it'll try to tilt a bit and affect the sizes of ones further down. Consider just doing ~4 at a time, rather than all ~18 of the standard size.
- *Router*: This method is pretty slick. Use the templates to cut a single pattern out of heftier plywood (~half inch or so), then put the pattern on top of a blank and use a router with a pattern bit (Figure 32). Join the pattern and the rib blank(s) with a pair of countersunk screws to keep them together.

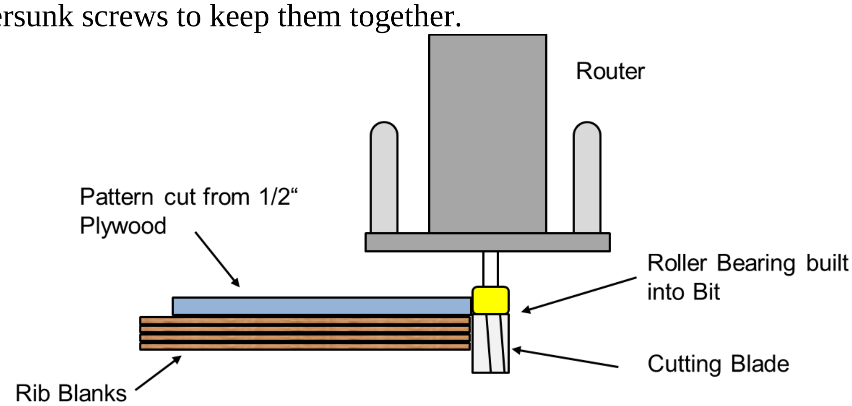


Figure 32: Cutting Ribs with a Router and a Pattern Bit

While templates are provided for the trailing edge ribs, a look at Figure 4-1 in the article shows that there aren't that many "intact" trailing edge ribs. Most are trimmed or altered some way due to the aileron installation and the wingtip taper.

4.6.2 Rib Assembly

There's a lot of information on Rib assembly in the EAA articles. There's not much more in the plans themselves.

And in both cases, I think Pete's instructions are quite lacking. How the ribs go together varies from rib to rib, and he doesn't really address that.

This mostly affects the trailing edges of most of the ribs. It becomes obvious later on during construction, but that will mean that you'll need to rework several of the ribs, possibly even have to repeat them. Again, this isn't just the EAA articles—the same issues are in the plans as well.

So let's take a look at rib construction and assembly, rib by rib. The nominal sequence for assembling all ribs is shown in Figures 4-8 through 4-13 in Article 1. Basically, the capstrip is attached to the top of the nose rib using glue (with nails or staples to pin them in place until the glue cures), then a second piece is attached the same way to the bottom of the middle and trailing edge ribs. The rib is assembled around two pieces of 3/4" wood standing-in for the wing spars, with the top capstrip beveled to match the bottom one. Leave a little leeway for those ~3/4" stand-in blocks, so the ribs will be able to slide onto the spars later. They're going to be glued into place using triangular blocks, so the ~1/8" plywood doesn't have to be real tight to the spar.

There is one small thing to keep in mind when gluing the capstrips to the nose ribs. The capstrips have a 1/8" slot in one side, into which corresponding tabs on the middle and trailing edge slide into for gluing.

However, the nose ribs are all 1/4" plywood, and don't fit into the capstrip slot! On the nose ribs, the capstrip itself is just glued directly to the rib, with a couple of staples or nails to hold it while the glue cures.

One small problem with this: As Figure 33 shows, since nothing goes into the slot on the nose rib or spar, that ~1/8x1/8 slot is empty for several inches at the end of the capstrip run.

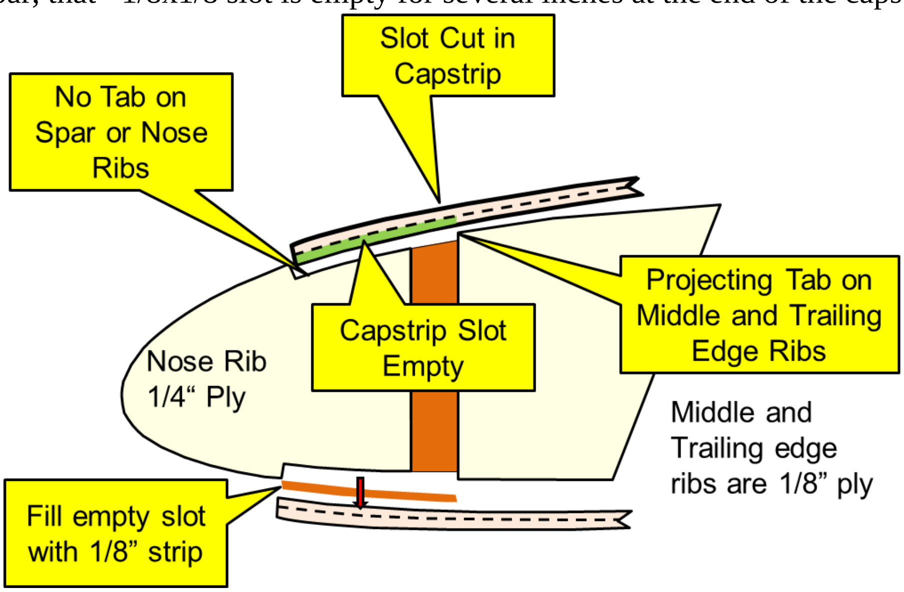


Figure 33: Filling the Capstrip Slot

Pete says to fill the gap with glue. Instead, I suggest cutting a short strip of scrap 1/8" ply that fits the slot, and glue that in place. It doesn't have to fit the entire slot exactly; you're just adding a bit more material in there for the glue to hang onto.

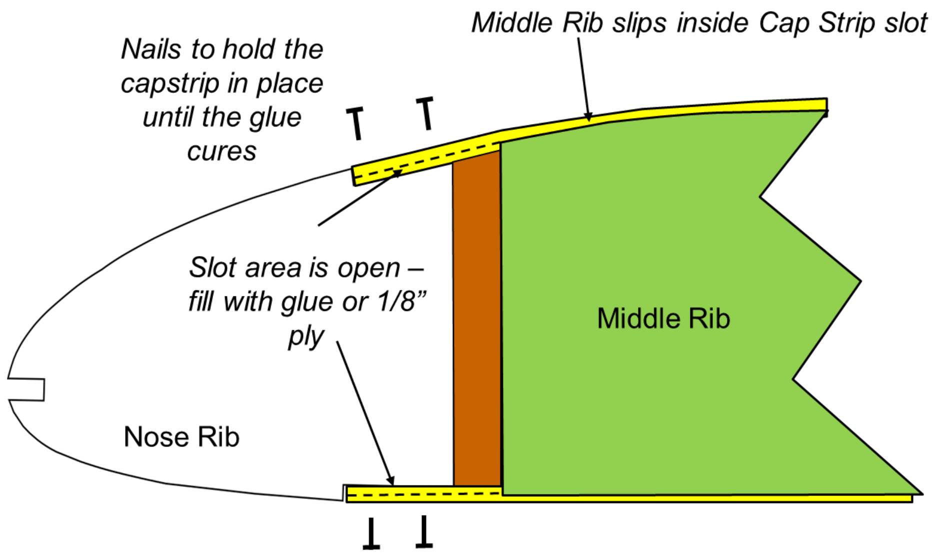


Figure 34: Cap Strip Attachment at Nose Ribs

Before you glue these sections together, you might be tempted to cut out some lightening holes in the middle section. Nothing wrong with that…but I suggest you wait until the wing gets assembled in Article 2. There are some holes that will be needed to be made in the ribs to accommodate the bracing cables, and you don't want them to be affected by existing lightening holes.

4.6.2.1 Rib 1

Rib 1 is the outermost rib. As such, it is one of the most affected by later wing construction—specifically, the wingtip bow. The trailing edge of this rib will basically have to be adjusted later to fit within the area between the spar and the curving tip bow…so you DON'T want to glue the trailing edge rib in place. Nose rib, middle rib are fine.

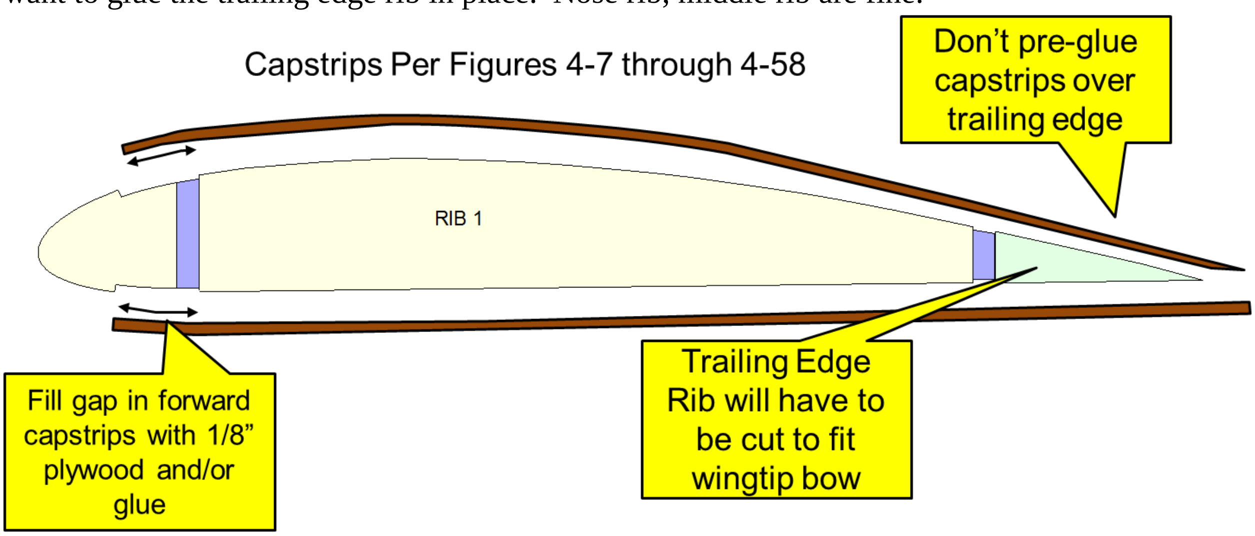


Figure 35: Rib 1 Construction

You might even consider shortening the top capstrip so it ends just a few inches beyond the aft spar. That will make is easier to slip in a modified trailing edge. Then glue a new section of capstrip to the top of the completed trailing edge rib.

4.6.2.2 Rib 2

Like Rib 1, Rib 2 will need the trailing edge adjusted to match the wingtip bow. However, Rib 2 is also used to form a small structural "box" (Figure 36) to support the aileron structure. So don't attach any capstrip aft of the spar.

Figure 36: Aileron Support Box

As part of that box, a short parallel section of the trailing edge will be installed about 2.5" outboard of Rib 2 proper. Rib 2A will be similar to the Rib 2 trailing edge, but will again have to be custom-fit to the wing.

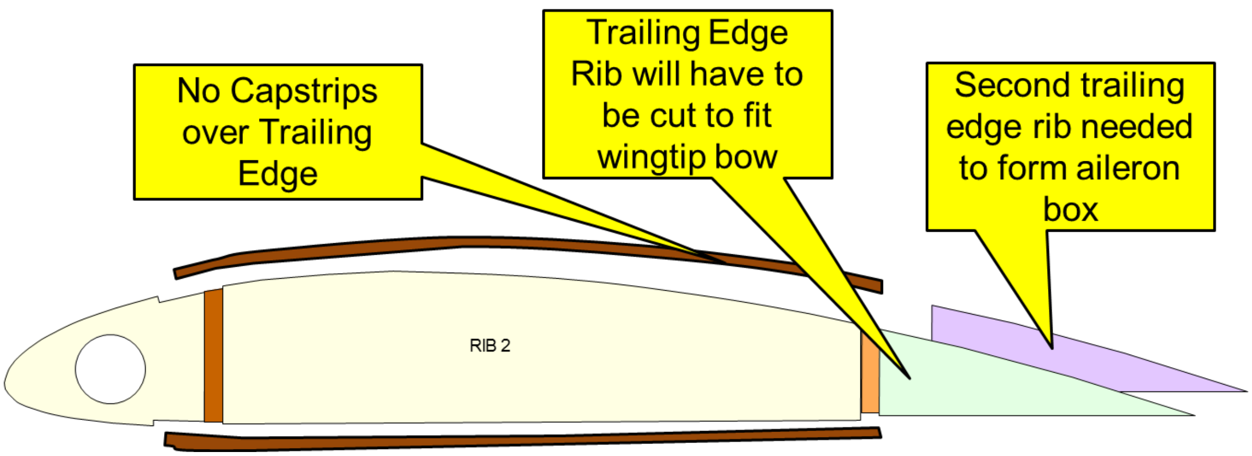


Figure 37: Rib 2

Both the Rib 2 and Rib 2A trailing edges will have small strips of spruce attached to facilitate closing the "box". Instructions on these are given in Article 2.

4.6.2.3 Ribs 3 through 6

Ribs 3 through 6 are identical, with the trailing edges truncated to form the aileron well. They are assembled nearly conventionally, though the cap strips are left off for the last two inches. This, again, is for the aileron structural box.

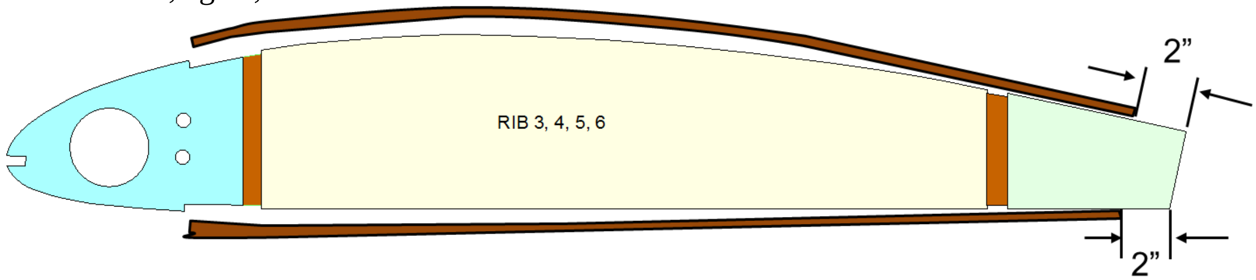


Figure 38: Ribs 3-6

4.6.2.4 Rib 7

Rib 7 is the first full-size, complete rib…but, like Rib 3, it does not have capstrips on the trailing edge. For the same reason as Rib 3: It's part of the inner aileron box, and there will be plywood applied in Article 2.

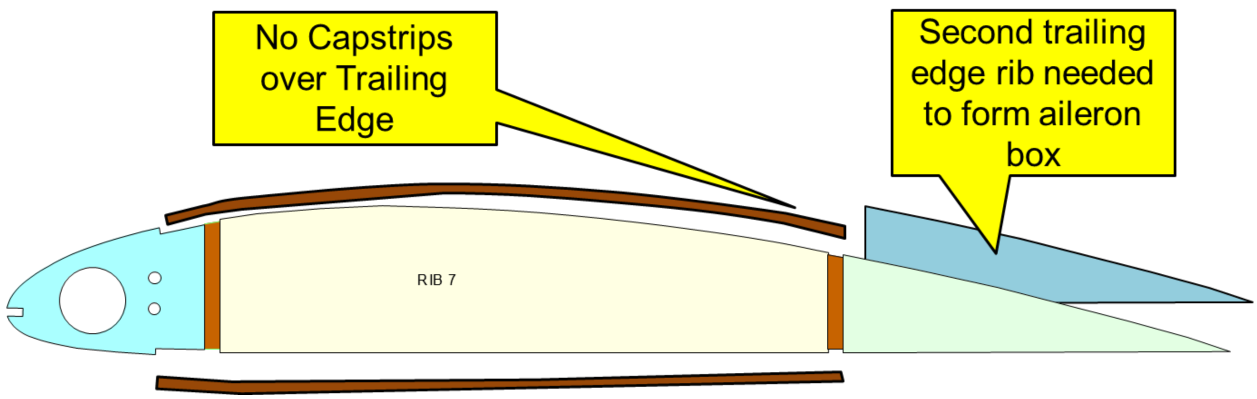


Figure 39: Rib 7

4.6.2.5 Ribs 8 and 9

Ribs 8 and 9 are the only "standard" ribs on the whole airplane. They're built just like Figures 4-8 through 4-13 illustrate.

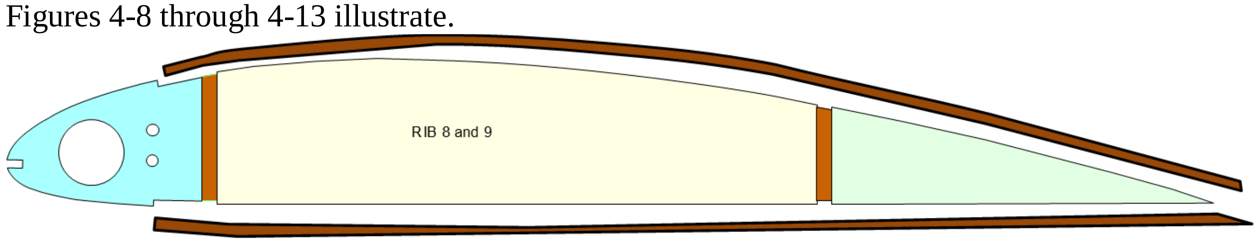


Figure 40: Ribs 8 and 9

4.6.2.6 Rib 10

With Rib 10, we start getting weird again.

Rib 10 and the root rib (Rib 11) support the wing-walk plywood. This gives the pilot a solid surface to stand on when climbing into and out of the cockpit.

But if Rib 10 had capstrips, it would hold the wingwalk plywood too high. So instead of capstrips, it has a small strip on the OUTSIDE of the rib, as seen in Figure 41.

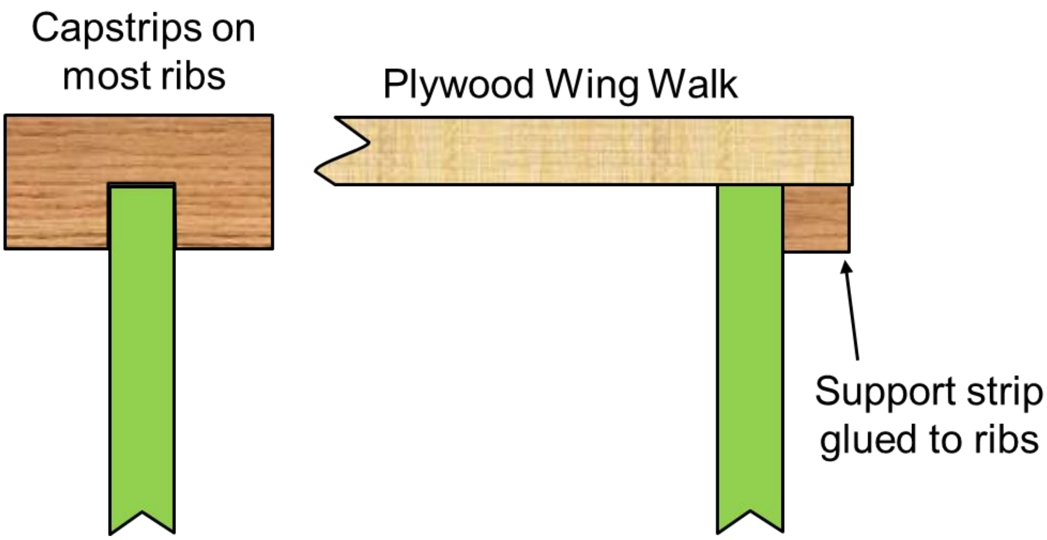


Figure 41: Change for Ribs 10 and 11

What's more, for the first time, ribs will be <u>different</u> based on which wing they're installed on. Figure 42 shows a schematic view of the ribs in cross-section. Note how Ribs 1-9 have the 1/2" x 1/4" capstrips on the top and bottom, while Ribs 10 and 11 have the 1/8" square strips on just one side. But the Rib 10s have the strips oriented AWAY from the root, and Rib 11s have it TOWARD the root.

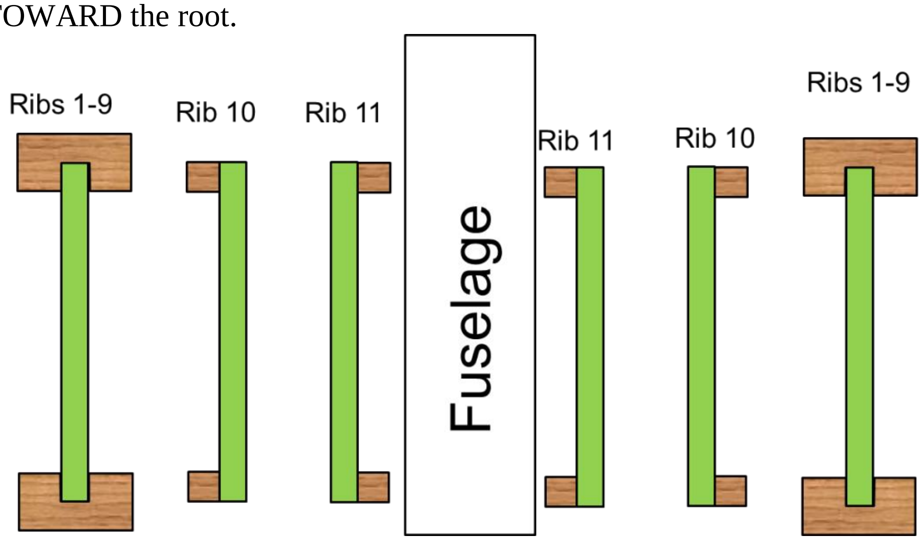


Figure 42: Cross-sectional View of Ribs

It's going to be more awkward to install this long strip. Try the lower side first. Nails or staples are going to be useful here.

Make the front part of the strips long enough to reach over the spar and an inch or so into where the nose rib will be, but don't bother to attach the nose rib. Fill the gaps with plywood and glue when they're attached to the wing structure.

As mentioned, the change in the capstrip system is because Ribs 10 and 11 support the wing-walk plywood. If the strip sticks up a bit far in some places, fine…use sandpaper to take off the excess, once the glue cures. Just make is smooth enough that the wing-walk plywood will be nicely attached. The wing walk plywood is visible on the right side of the wing in Figure 43.

Figure 43: Wing Walk Plywood

4.6.2.7 RIB 11 (THE ROOT RIB)

Most of the ribs follow the main chord line. However, the trailing-edge Rib for the wing root (Rib 11) has a ~2$^{3/8}$" reflex upward at the extreme end.

Why? It's pretty simple: Pete wanted a smooth interface where the wing actually met the fuselage.

Take a look at Figure 44. If a standard rib trailing edge is used, the trailing edge of the wing ends below the bottom of the fuselage. This leaves a kind of jagged interface. It's not good aerodynamically (probably not a big worry), but it actually, esthetically, is pretty ugly.

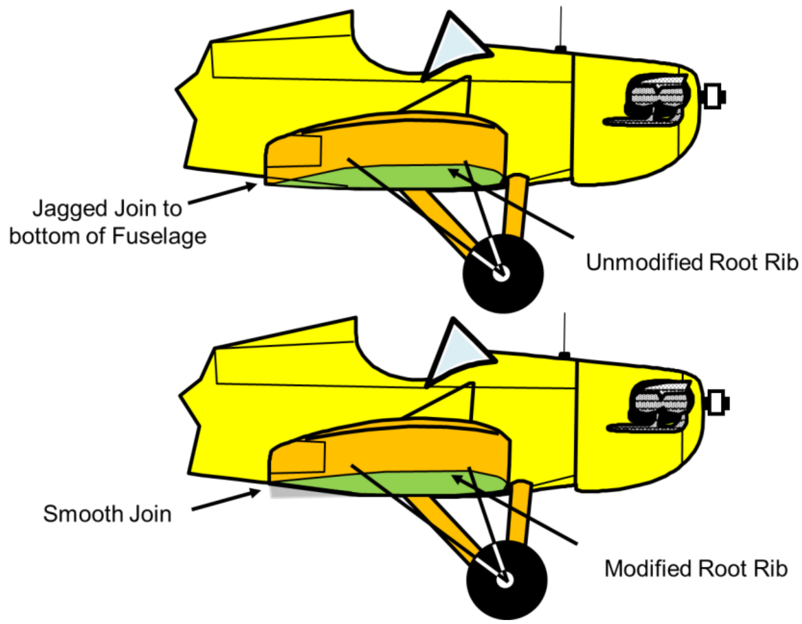


Figure 44: Effect of Root Rib "Reflex"

So the very end of the trailing edge rib at the wingtip is raised so that the wing matches the shape of the fuselage. This makes a bit of a discontinuity, but it actually is more pleasing than continuing the main line of the trailing edge. Figure 45 illustrates this on my own airplane. It is a much smoother line, and it not really noticeable. From this angle, it looks like the root rib is shorter than the others, but it isn't—the wing is the same chord.

Figure 45: Trailing Edge with Reflexed Rib

Rib 11 is included in the trailing edge template, and is also shown as Figure 46. However, Pete recommends that this rib be made to match the fuselage shape.

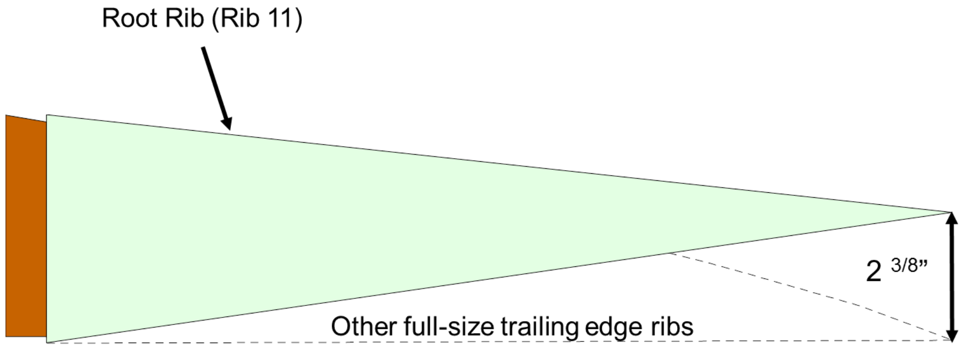


Figure 46: Trailing Edge Template

So, do you have to reflex the rib? No. Most builders do, though others, like Tom Staples (Figure 47), have left the reflexed rib off entirely, and ran a panel diagonally from the root of the aft spar to Rib #10. There doesn't appear to be much of an aerodynamic penalty either way.

So, do not assemble Rib 11 at this point. If you're including the wing-folding mechanism in for the wings, the nose rib will actually be installed slightly offset from the main rib. See Article #2.

Figure 47: Tom Staples' modified wing root

As I mentioned at the start of this article, Pete's magazine series started with the wing, while the commercial plans started with the fuselage. Pete never provided a template for the reflexed root rib. Instead, he had the builder fit the wing to the fuselage and cut the trailing edge rib to match the fuselage itself,

The $2^{3/8}$" reflex is what I physically measured on my own airplane. You might want to wait on Rib 11 and match it to the fuselage, too. In that case, though, be careful when you varnish the wing (in Article 2). You do not want to varnish the areas where the trailing edge rib will be glued.

Again, since it supports the wingwalk, it does not receive any capstrips. Small strips at the edges are used, instead.

4.6.3 Aileron Ribs

The trailing-edge templates include patterns for the ailerons. As Figure 48 shows, they are basically just continuations of the main wing ribs.

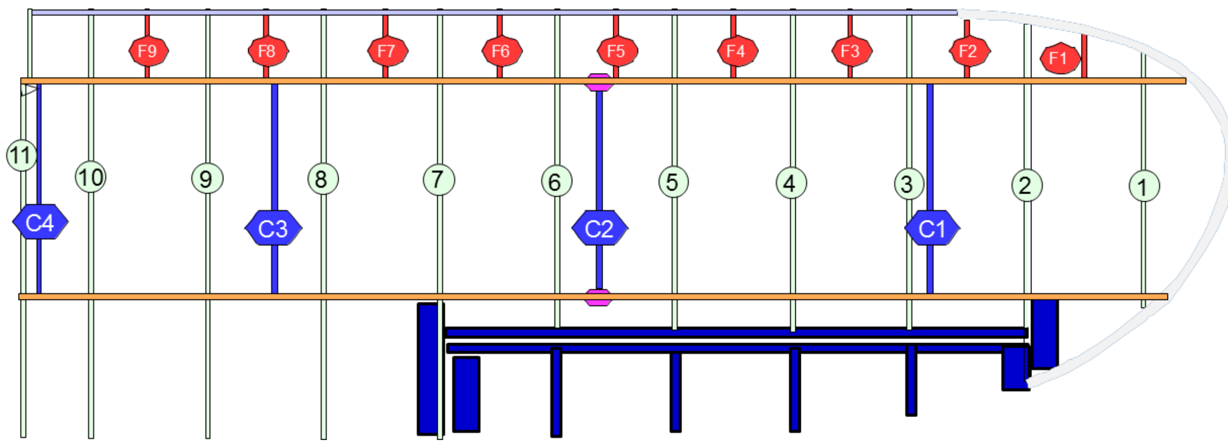


Figure 48: Ailerons share trailing edge rib blanks

As you can see above, the aileron ribs 2 and 3 will require some adjustment to accommodate the wingtip bows.

You may have wondered about the funny angular end for ribs 3-6. Figure 49 shows why. It leaves the gap for the downgoing aileron.

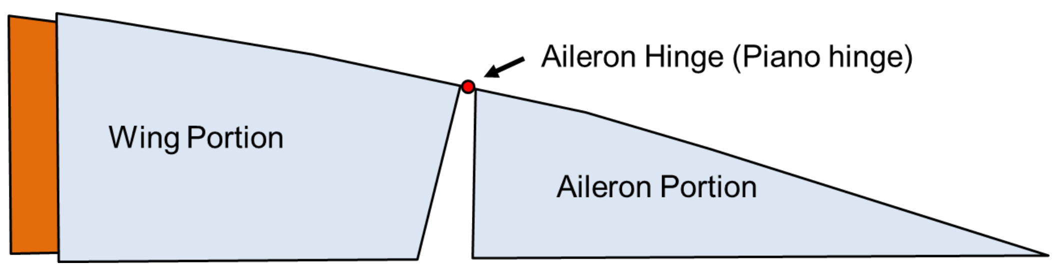


Figure 49: The trailing edge ribs 3-6 are used for both the wing and the aileron

5 ALTERNATE APPROACHES

The following topics have been discussed within the Fly Baby community. They may provide advantages to the builder, but have not been verified as viable.

5.1 Non-Beveled Spars

One of the major steps required for building Fly Baby wings is to apply a bevel to the tops of the four spars. This beveling requires feeding the full 13-foot length of the spars through a table saw to perform a relatively small diagonal cut.

Eliminating the bevel has been discussed. The 1/8" difference between the front and rear faces of the spars is not necessary for strength, but to make it easier to glue the wing ribs to the tops of the spars. It is extremely minor, but considering the cost of the spars, it may be worthwhile to avoid the beveling.

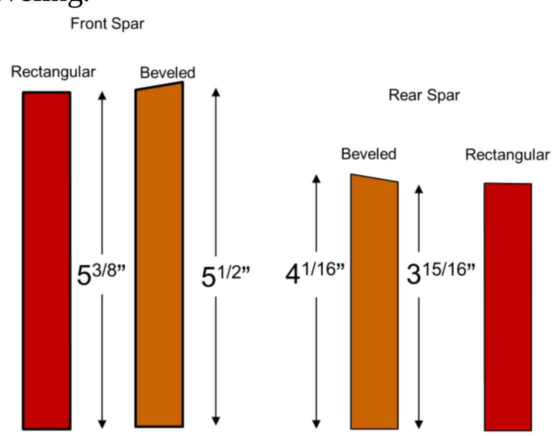


Figure 50: Non-Beveled Spars

The main effect of removable of the bevel can be seen in Figure 51. A small gap is opened under the rib cap strip. This could easily be filled will a small wooden wedge and epoxy.

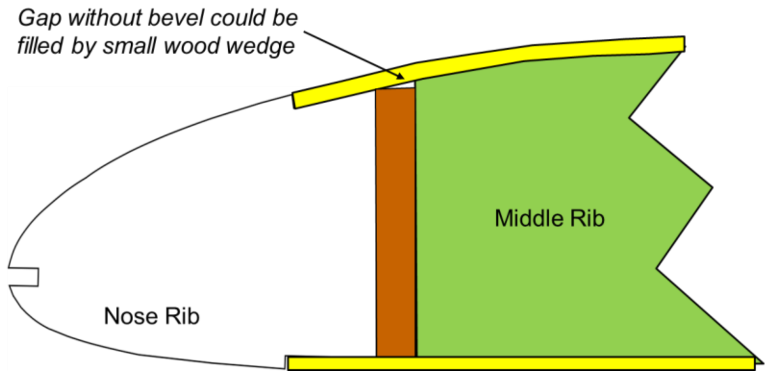


Figure 51: Effect of Removal of Spar Bevel

When the forward part of the leading edge is covered by metal, the top of the spar receives a strip to attach the leading-edge material to. Similarly, the rear spar gets a similar fill strip (See Figure 4-22 on Page 8 of Article 2). Without the bevel on the spar, these strips should be wedge-shaped as well… 1/8" difference. That should be high enough to match the cap strip height at the front and rear of each spar.

Finally, if the builder is using the traditional wing-wire bracing system, the anchor pads must be the height of the original spar-face height where they're glued. Otherwise, the bolt tension will force the anchor plate flat to the top of the spar and it will dig in to the fabric on the aft side.

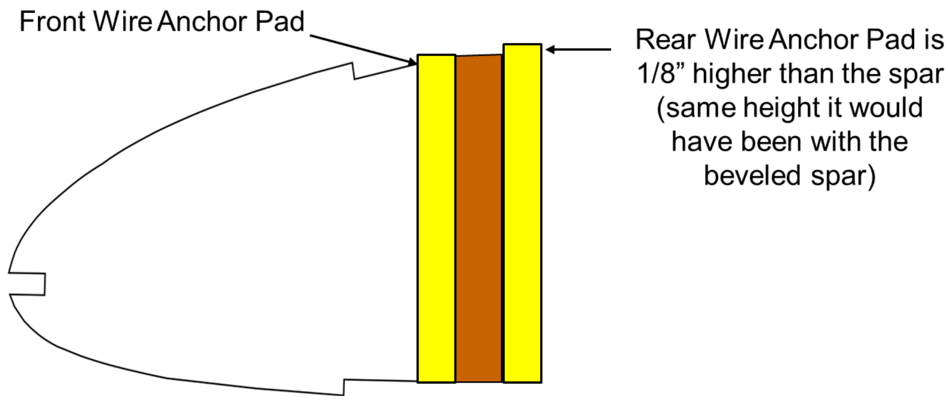


Figure 52: Anchor Pads are the Original Height, even with the Non-Beveled Spars

It may well be easier to do the bevel on cheap non-structural wood rather than the spars themselves.

5.2 Non-Cable Internal Bracing

The standard internal cable-bracing of the Fly Baby wing is great. It's easy and quick to make, easy to adjust to get everything square, and, if you make a mistake, it's simple to cut the cable off and re-use the turnbuckle for another try.

Back when Pete designed the Fly Baby, the whole thing was cheap, too. World War II had sent tons of airplane parts to surplus sales outlets. He bought turnbuckles by the bag, back then. He just gave me a bag of leftover turnbuckles, back in the '90s.

Things have changed quite a bit. Those turnbuckles go for $35 EACH…and the Fly Baby uses 40 of them.

Almost a third of those are for internal bracing of the wings.

So…what about some cheaper alternatives?

Many small aircraft, including production aircraft, use diagonal steel tubes in the wings. A ~half-in, 0.035" wall thickness tube has the ends flattened, and they are bolted to the same kind of tangs that the Fly Baby wire braces attach to. Figure 53 shows an example.

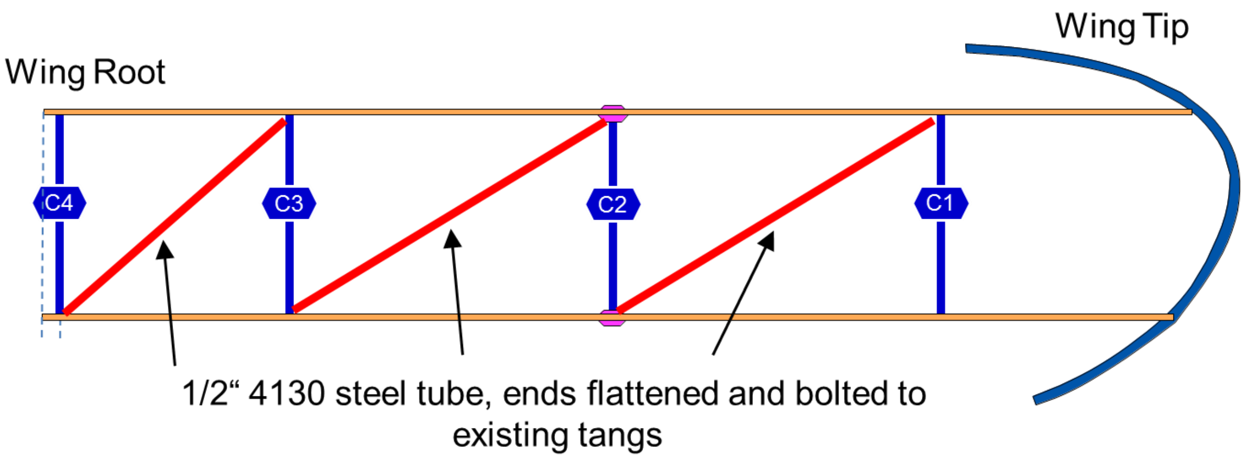


Figure 53: Steel Tube Internal Bracing

You don't really need "X" bracing if you're using solid tubes, hence there's just the single diagonal in each bay.

Some of the Fly Baby folks prefer to have the "X" bracing, though, and it certainly would be a bit safer. The trouble is, you can have cables cross each other without a problem, but half-inch tubing won't cross without bending.

One suggested solution is shown in Figure 54. The plates for the compression ribs are changed to incorporate two tubes on one side, and one on the other.

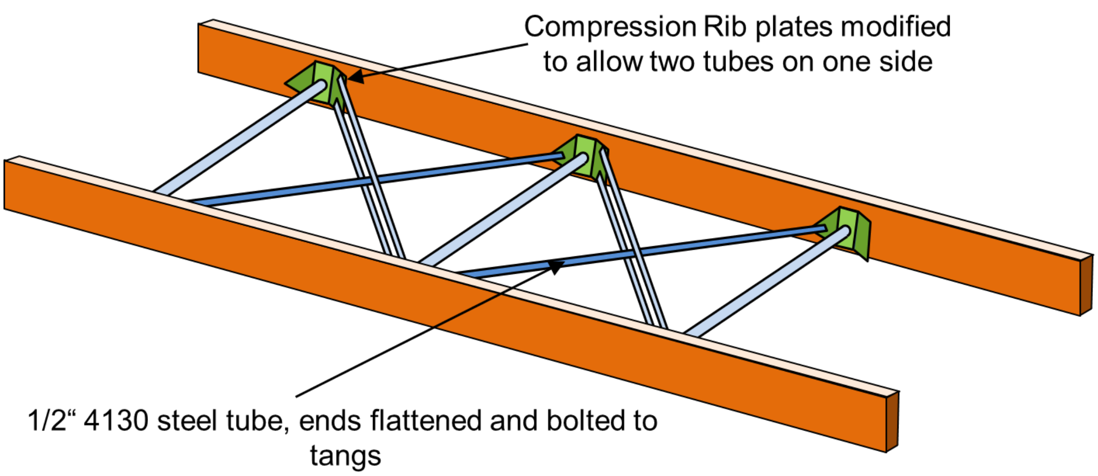


Figure 54: Twin-Tube Diagonal Bracing

Another suggestion was just to stagger the holes on the opposite side of the compression rib plates to ensure the tubes don't contact when the cross.

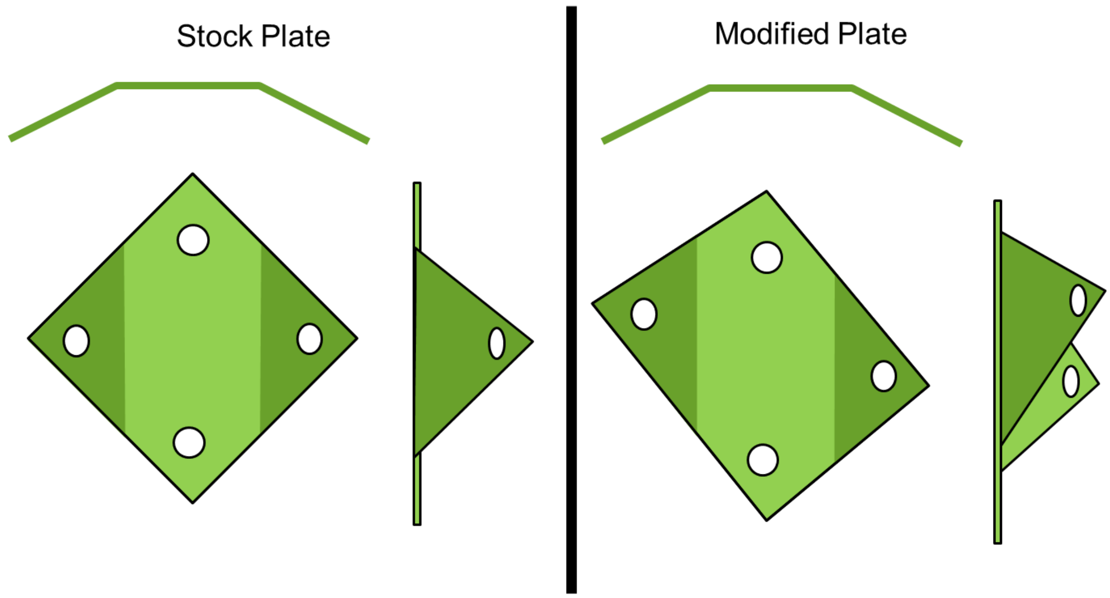


Figure 55: Compression Rib Plate modified to separate diagonal tubes

Finally, many homebuilts (and, again, production airplanes) just use threaded rods for the diagonal braces. They can cross with no problem. By using a custom strap, they will even attach to the tangs on the compression rib fittings. Figure 56 illustrates this method.

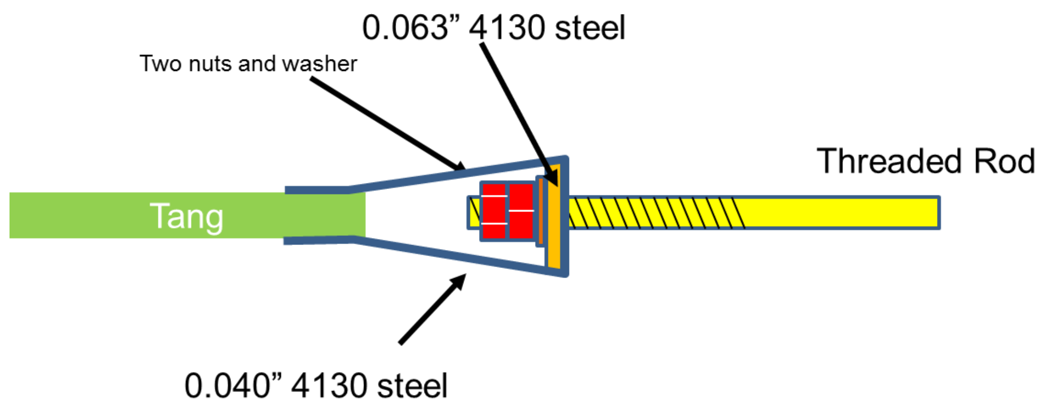


Figure 56: Threaded Rod Termination

Tony Bingelis addresses these units on Page 50 of "Sportplane Construction Techniques."

The Drawbacks

All right, let's state the negatives.

None of these methods are a simple and easy to execute as the cable and turnbuckle system. For schemes using sold tubing, "Trammeling" is an issue….getting the wing structure exactly square. It's fairly simple with the cables and turnbuckles, when the solid tubes require, at some point, a hole be drilled to hold things in position. When that is done, extreme care and multiple clamps and structural braces will have to be used to ensure the holes are drilled with the structure in exactly the right position.

And, finally…they might be cheaper, but for the most part, they're heavier.

5.3 Non-Wood Wings

Spruce for spars of wooden airplanes is getting hard to find. What are some alternatives?

About forty years ago, a Fly Baby flew with a Luscombe wing. That wing was all-aluminum. So an aluminum wing for a Fly Baby is certainly doable. Several companies sell extrusions that are the same sizes as the Fly Baby spars. Several small homebuilts, such as the Vans RV series and the Zenith CH-701 and -750, have all-metal wings whose designs could be adapted to the Fly Baby.

However, just replacing the spar isn't enough: The builder would have to develop appropriate spars and aileron support structure, as well.

The consensus in the Fly Baby community is that this is doable, but the fact is, other than the single example forty years ago, it hasn't been done. So no previous information is available to help a builder who wishes to try a metal wing.

5.4 Cantilever Wings

I've been asked several times about modifying a Fly Baby to not need the external bracing wires…a Cantilever wing. So, what about it?

Well, one way to answer is to look at the Warner Spacewalker/Revolution/Sportster, or whatever name it has, now. It's basically a Fly Baby with a steel tube fuselage and a cantilever wing.

Figure 57 shows a Spacewalker wing under construction. The aft spar looks like a 3/4" - 1" spruce plank, like the Fly Baby, but the front spar is a thick, high, wooden block. Looks to be about 6-7 inches tall, and ~3.5 inches wide. I actually think this is a box spar, not solid, but obviously it would need to be built up (and built straight!). That wing is at least 8" deep, compared to ~6" for the Fly Baby.

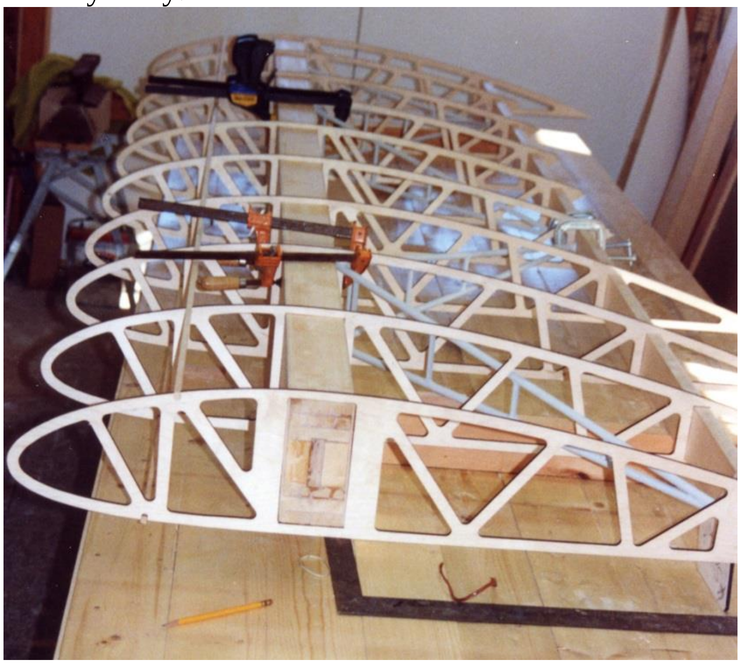


Figure 57: Cantilever Wing for a Spacewalker

The other factor is, what does that been ol' beefy spar bolt onto? Not a stock Fly Baby center section, of course, since the two bulkheads are only ~3/4" wide to match the stock spars (Figure 58). So you'd have to beef up Bulkheads 3 and 5 to make them just as wide as the box wing spars, AND move the opening higher to that the lower part of the bulkhead matches the height of the wing. This opening is what your legs stick through when you fly, so it'll make the cockpit a bit more awkward.

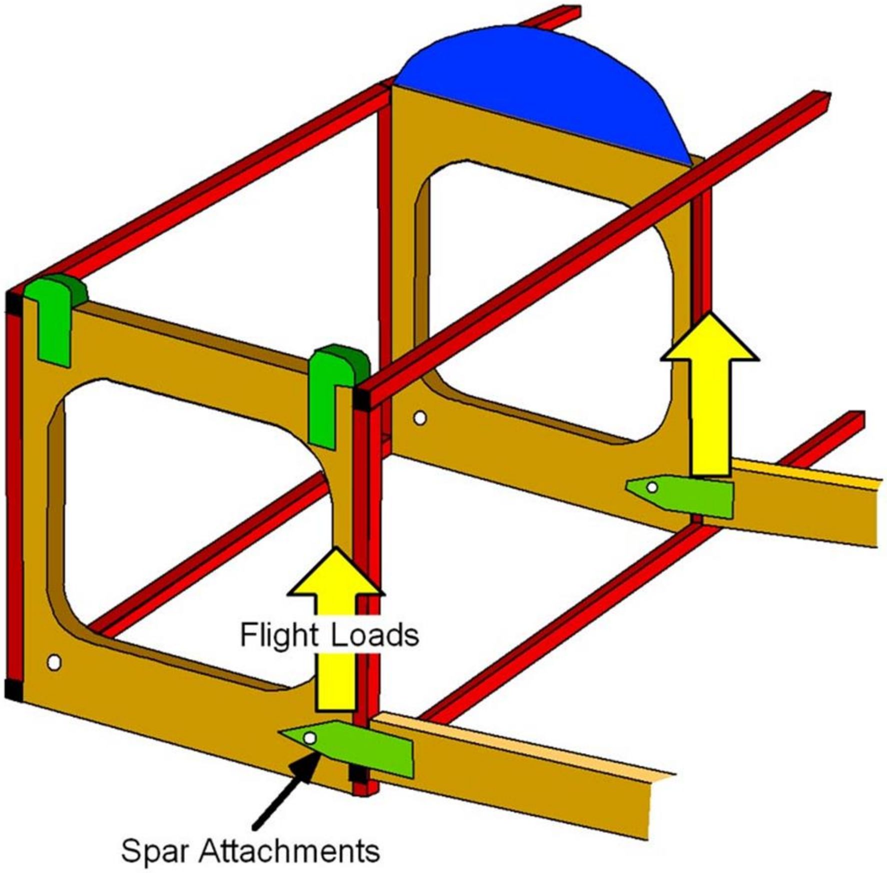


Figure 58: Fly Baby Spar Attachment

In short, there's a lot of changes that would be necessary to eliminate the external bracing for the wing. It's not just a simple fix.

5.5 Strut-Braced Wings

Fly Babies have been built with strut-braced wings, with the struts either below or above the wings. Bowers didn't like the iterations with the struts below the wings; the loads on the landing gear get passed into the wing-bracing structure.

Miguel Tschopp of Argentina engineered a strut-braced wing with the struts on top (Figure 59), and has been flying for a number of years. Additional supports are added to the inside of the fuselage to transfer the flight loads to the fuselage. More information can be found on the Fly Baby Facebook page, or Señor Tschopp's own blog: http://flybaby.tschopp.com.ar/.

Figure 59: Strut-Braced Wing

5.6 Eliminating the Wing Fold

One of the criteria for the EAA contest in 1962 is that the plane had to have folding wings, so an owner could tow it home and store it in their garage.

The Fly Baby has folding wings (yay!). However, this is NOT a fancy pull-one-lever-and-the-wings-fold back system. It's actually a kind of hassle to fold the wings, and few people have ever done it routinely.

Check out Figure 60. It is certainly a long process. You can get a detailed description at http://www.bowersflybaby.com/tech/FOLDING.HTM.

All right, it's a pain, and you're not likely to ever do it very much. Why not save time and effort while building and eliminate the folding-wing gear?

Now, even if you leave the wing-folding hardware off, it's STILL going to be fairly easy to remove a Fly Baby's wings if you need to put the plane on a trailer. The main change is deleting a bit of unneeded ironmongery in the wing root and using standard bolts to hole the wing instead of fabricating 1/2" thick pins.

I'll address this more in Article 2, as that's where the primary impact of the decision will be. For now, though, consider NOT making the "Hinge Supports" shown in Figure 4-3 on page 23 of Article 1.

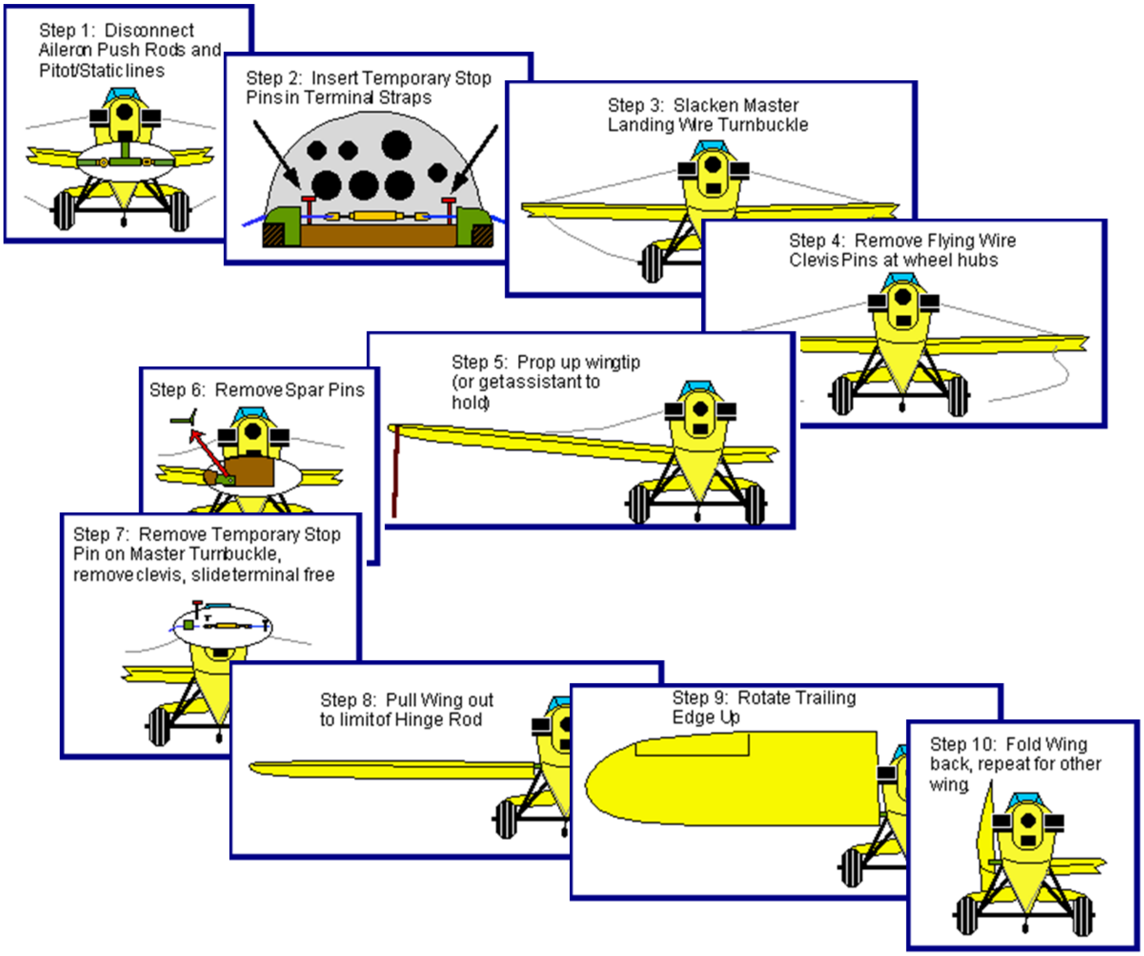


Figure 60: Fly Baby Wing Folding Process

5.7 Stick-Built Ribs

The Fly Baby uses plain-vanilla ribs cut out of 1/8" sheet plywood. Many other small homebuilts use "built-up" ribs made from spruce sticks. These are thought to be lighter.

Perhaps. Some time I'm going to build a couple of sample ribs, side-by-side, and compare their weight.

But the Fly Baby's stock ribs don't weigh that much. And their big advantage is how fast they can be made. The stick-built ribs are made one at a time, and Fly Baby ribs can be cut out five, ten, even twenty at a time using the gangsaw method or a router.

5.8 Rectangular Wings

The graceful semi-elliptical curve of the Fly Baby wingtip is one of my favorite features of the airplane.

However, it must be said that this takes a lot of work. The builder will be making laminated wing bows, each made up of 12 separate strips of spruce or cedar, then carving them to match the taper required for a wingtip bow. In addition, there's the required tapering of the spars, and the special tip ribs (Ribs #1 and #2) that are required.

Figure 61: Semi-Elliptical Wing of the Fly Baby

Now, depending on how much of a fan of the Fly Baby shape you are, there are some opportunities for a minor design change that will eliminate tens of hours of work.

Back in the ‘70s, 13-foot spruce spar stock became rare. Twelve-foot planks were still available, but the shorter wing would reduce the total wing area and affect the handling of the airplane.

The solution was to switch to a rectangular wing, rather than a tapered one. A sample is shown as Figure 62.

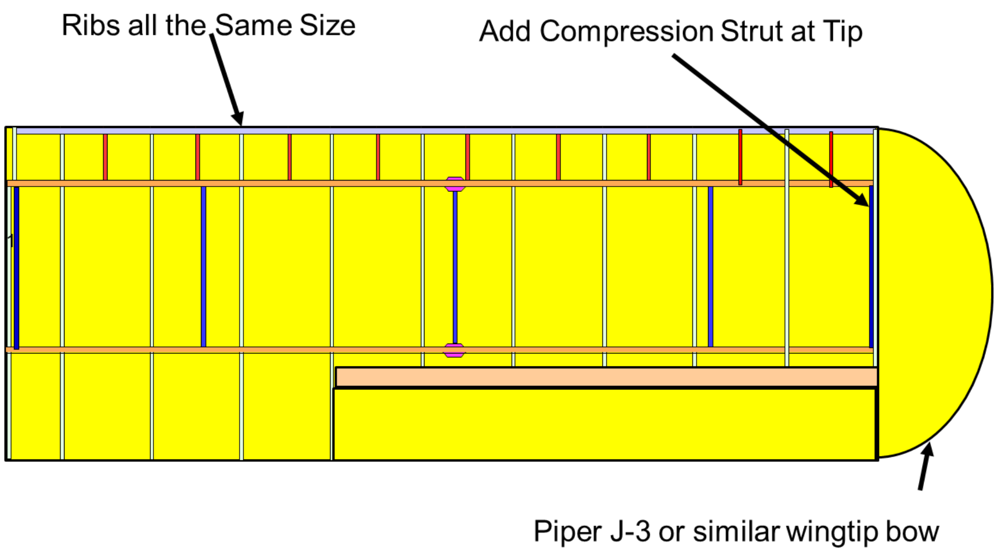


Figure 62: Rectangular Wing

There's a lot of simplicity in this approach. The spars don't have to be tapered at the end. All the ribs are the same size. The aileron area is actually a bit larger. And another scheme can be used for the wingtip bow. It could be commercial bow, or just narrow section of tubing like the Fly Baby biplane.

Lew Mason's Fly Baby shows this approach. He was building a Junkers CL-1 replica, and the square wing a feature of that design. It went with his other cosmetic modifications, like the change in the rudder shape. Notice Lew didn't make the ailerons go all the way to the tip, unlike how I show in the previous figure.

Figure 63: Lew Mason's Junkers Replica

Anyway, it's something to consider.

END OF COMPANION GUIDE FOR ARTICLE 1

See Article 2 for Wing Assembly