

STEEL STRING BRACING

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THE ART OF BRACING

TOP BRACES

Braces reinforce the top and back of the guitar. Without top bracing, string tension would distort the top plate, eventually pulling the bridge from the soundboard.

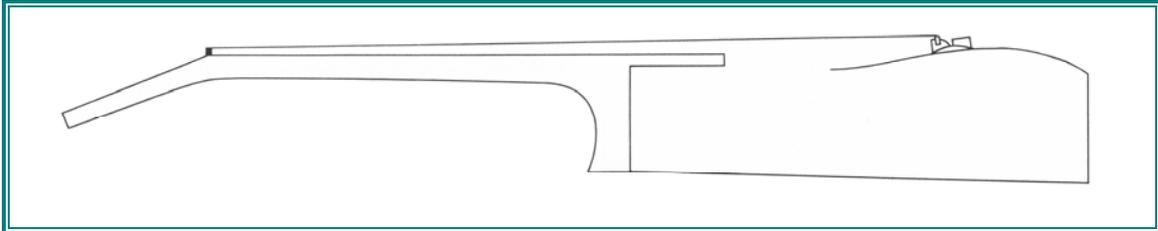
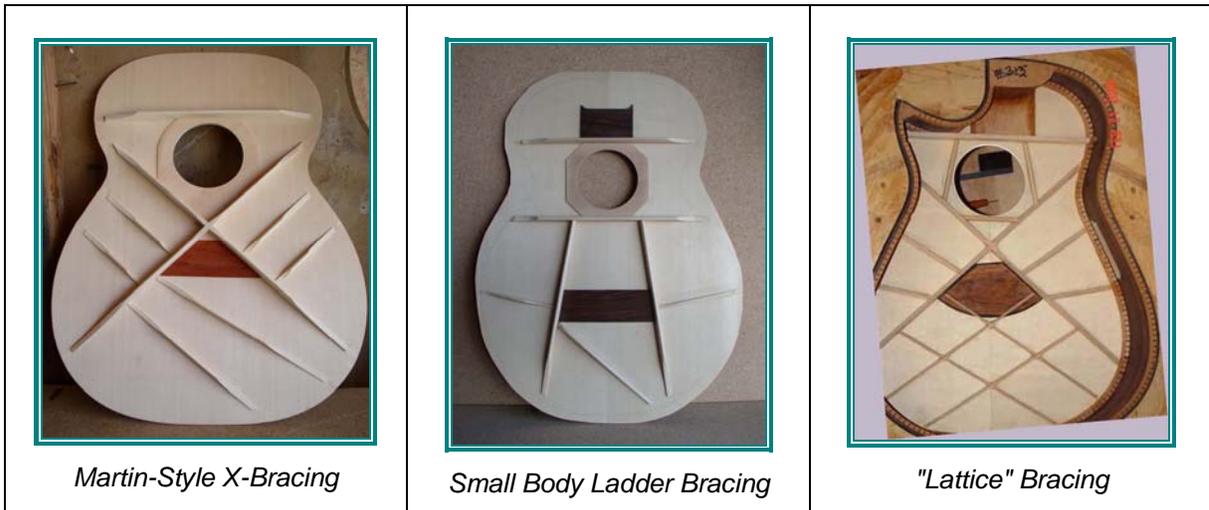


Figure 1. String Tension Wants To Deform The Top Around The Axis Of The Bridge
([American Lutherie, Summer, 1995](#))

Tonally, braces stiffen the top and raise the pitch of the soundboard. Braces also add mass, which slows response. The art of guitarmaking is optimizing the contributions of the tonewoods and the structural and tonal effects of the bracing to get the best sound from the instrument.



BACK BRACES

Traditional back bracing consists of three or four cross braces, depending on the particular instrument, and a center seam graft, which covers and reinforces the center seam glue joint.

Bracing procedure: all back braces are milled square to oversize dimensions; thickened, radiused; and glued using the go-bar deck and the appropriate radius board. The brace ends are then scalloped, the profile shaped, and the center seam graft is glued in.



Modified Standard Back Bracing

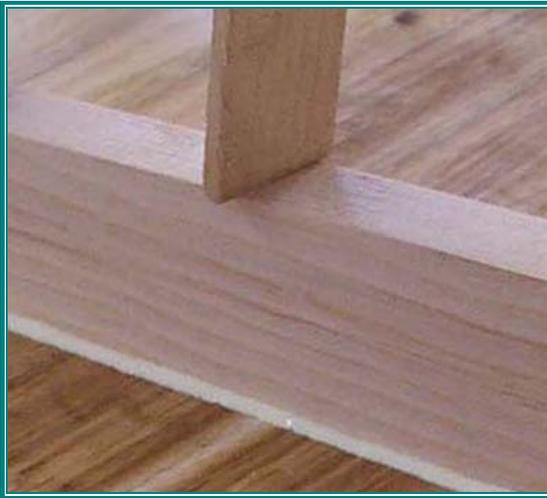


"X" Back Bracing
(Shane Neifer)

GLUING – Using The Go-Bar Deck



Appropriate Squeeze-Out



Too Much Squeeze-Out

- Set-up the go-bar deck and position the proper radius form in it. Check the length of the go-bar clamps. *"If the clamps are too short, small blocks of scrap wood can be placed at the upper end as shims. Clamping pressure will hold them in place. Be very careful in removing such clamps; a falling block can leave a divot,"* suggests luthier Ira Caul.
- As a general rule with all new operations, begin – in this case gluing the braces – with those furthest from the soundhole first. You will get a feel for what you are doing and any 'missteps' can't be seen. Also true for carving the braces.
- Use The World's Most Convenient Glue Applicator - a pinkie - to evenly cover the radiused edge of the brace with glue. *"Use the pinkie and save the other fingers for positioning the clamps, et cetera,"* offers Bud Inski
- Position the brace between the layout lines. Slide the brace back-and-forth just a bit to insure complete glue coverage. Hold the brace in position for a moment, letting the glue begin to tack, or set-up.



*Place The 1st Clamp In The Middle Of The Brace.
Check The Brace Ends Against The Witness
Marks.*

(photo by Len Poche)



*Work Outward From The Middle With Subsequent
Braces. Check The Ends.*

(photo by Len Poche)

APPLY GO-BAR CLAMPS

- Place the first clamp in the middle of the brace. Place the second clamp as a mirror image of the first clamp. This way –each pushing against the other – the brace will tend to stay put (a little better, maybe) Work toward the edges with subsequent braces. Be aware that the brace will still likely squirm in the slippery glue, possibly obscuring penciled witness marks. Check the position of the brace after adding each new clamp. Expect to use 5 or 6 clamps for each brace.
- Ten guitar makers will have ten different glue clean-up techniques. One school of thought: clean up squeeze-out after each brace is glued down – at least before the next brace gets in the way of easy access. Immediate clean-up proponents like to use a moist cloth or paper towel to "lift" the squeeze-out away from the surface(s). Smearing the glue will leave a stain. Luthier Mike Easter opines, "Some novice makers are enamored of using a plastic soda straw with one end clipped at an angle for this approach. I think it's over-rated, but that's just me." Luthier Howie Vasive likes the John Bogdanovich method, as outlined in his book *Classical Guitar Making*: set your egg timer for 8 minutes. At that point, the glue coheres to itself more



*Plan On Using 5 Or 6 Clamps Per Brace
(photo by Len Poche)*

than it adheres to the wood. Lift it off; with a chisel. Or a soda straw?

- The glue will dry in 1 hour or less, depending on temperature.



(photo by Len Poche)

MAKE TEMPLATES

Templates insure consistency and efficiency in shaping braces by laying out the initial shape of the brace for carving. Templates may be made out of any number of materials. Plexiglas is the preferred material, but, tempered hardboard, cardboard, or even paper, will suffice. Templates made from wood or wood products may be carefully shaped on power sanders.

- Use the simplified template making technique - photocopy the blueprint, fix the photocopy to the template material with spray adhesive or white glue, and shape to the line. Do not use power sanders to shape Plexi templates; the plastic melts and clogs the abrasive.
- To ensure proper brace height of radiused braces, the templates should also be radiused.



Figure 2. Mahogany Template For Back Braces Radiused, With Different Scallops At Each End

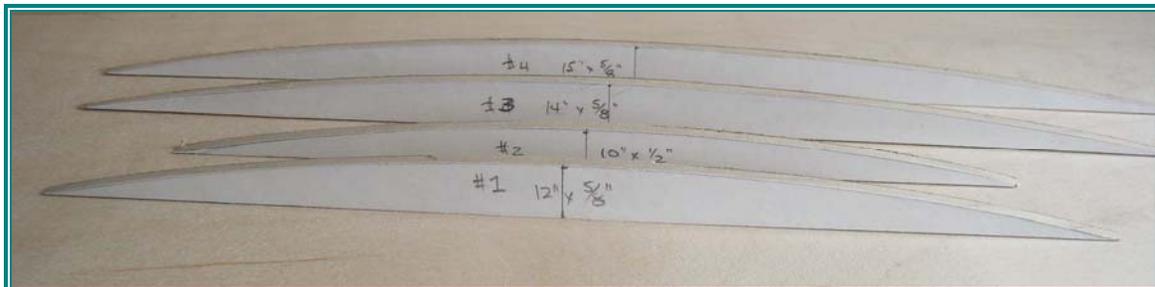


Figure 3. Hardboard Templates For Steel String Parabolic Back Braces

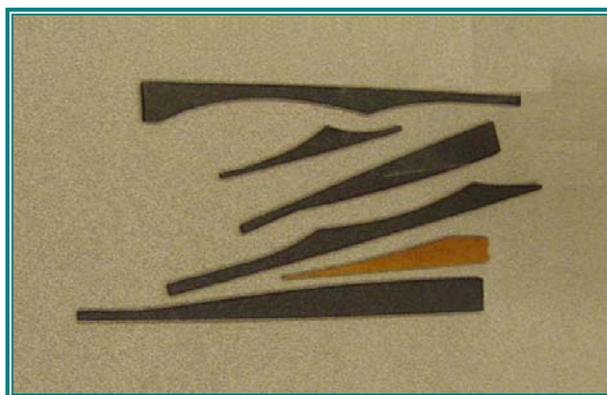


Figure 4. Plexiglas Templates For Steel String Top Braces

PREPARE THE BRACE STOCK

MILL THE BRACE STOCK

Everything comes together more easily when you begin with square and true stock. So, it's time to get familiar with the jointer, band saw or table saw, and thickness planer. Safety glasses are required while using all power tools. Use push sticks whenever possible.

MATERIAL AND GRAIN ORIENTATION

To provide maximum strength with minimum weight, use quartersawn - aka vertical grain - stock to make all bracing. Sitka spruce has the highest strength-to-weight ratio of commonly available woods, and accordingly is a preferred top bracing material. In addition to spruce, back bracing is also commonly made from mahogany or Spanish cedar.



Figure 5. Vertical Grain Spruce Bracewood

MAKE A CUT LIST

The following is a partial cut list for a modified OM guitar. The "Measured" length is the longest length taken from the blueprint. Additions to height are for carving away any dents left by the go-bar clamps. Additions to X-brace length is to allow for registering the braces into the linings for alignment purposes; face braces and finger braces are not registered into the linings. Note that the upper bout transverse brace - not included here - is also registered into the linings.

SAMPLE / PARTIAL CUT LIST FOR MODIFIED OM TOP BRACES

	X - BRACE (cut 2)			FACE BRACES (cut 2)			FINGER BRACES (cut 4)		
	Thick	Height	Length	Thick	Height	Length	Thick	Height	Length
Measured	1/4"	9/16"	17"	1/4"	3/8"	10-1/4"	1/4"	1/4"	4-3/4"
Add (a)		1/4"	1"		1/8"			1/8"	
Blank	1/4"	13/16"	18"	1/4"	1/2"	10-1/4"	1/4"	3/8"	5-1/4"

(a) *Additional height for radius and margin for carving away go-bar clamp marks, etc. Additional length for braces indexed into the linings.*

RIP AND MILL THE BRACE BLANKS

1. Mill the brace wood billet so that brace blanks taken from the edges are quartersawn; rotate the billet, if necessary. Surface – on a jointer, hand plane or sand - and square one side and the adjoining edge. If using a jointer, square the fence, adjust the depth of cut, and use push pads. Ditto if using a table saw and drill press planer or thickness sander. Wear safety glasses whenever using power tools.
2. Rip (saw with the grain) one brace blank from each of the squared-up edges.
 - BANDSAW - Because it has a narrower kerf than a table saw, a bandsaw wastes less wood than a table saw. Brace blanks may be either cut free-hand along a line drawn the length of the billet, or against a fence. Luthier Ira Caul advises, *"Using a fence with a bandsaw doesn't guarantee a true edge. The blade may 'drift' during the cutting operation. Expect to re-visit the jointer or sandingboard to true the billet edge before ripping the next brace blank."*

- TABLE SAW - The table saw may be used only by those are specifically checked-out on that machine. Although the table saw has a wider kerf, it cuts more precisely than the bandsaw, eliminating the need to go back to the jointer to square up the edges before ripping subsequent brace blanks.
3. Square the ripped face of the brace blank with a surface planer, Saf-T-planer or thickness sander. Thickness the blank to the brace's final thickness. Feed alternate faces through thicknessers for best results. Recall that a surface planer removes material from the top of the piece. Accordingly, feed bracewood pieces through a thickness planer with the 'smooth' side down. Observe all shop safety rules, as well as machine specific safety rules. Safety glasses are required. Hearing protection is recommended.
 4. You should now have a couple of braces – one cut from each edge - that are slightly longer and taller than their final dimensions, but which have two flat, parallel sides that are of final thickness.
 5. Repeat for the remaining braces. For those using the bandsaw, begin by re-squaring the outermost sides of the bracewood billet on the jointer.

RADIUS THE BOTTOM OF THE BRACE BLANKS



(photo by Len Poche)



MARK 'EM

Place the milled brace stock on the appropriate radius form at the same relative position that it will be glued onto the top/back plate. With a pencil that has been cut-down to about 1½" and flattened on one side ("Mr. Pencil Meets Mr. Sandingboard") mark the radius of the back onto the brace by sliding the pencil along the curve of the radius form. If the lead in the pencil doesn't reach the brace, put a little block under the pencil.

ROUGH 'EM OUT

Plane, file or sand – using the disc sander or stroke sander – the brace nearly to the marked line.

FINE-TUNE 'EM

- Finish shaping the bottom of the brace to the contour of the form by sanding against 100# - 120# grit sandpaper placed on the radius board. Luthier K. Serra opines, *It may be splitting hairs, but I like to sand in the same position that the brace will be glued down and*

	<p><i>keep the sides of the brace perpendicular to the radius form – It makes the braces stand up straight!."</i></p> <ul style="list-style-type: none">• Remove the sandpaper and check the brace for "light tight" contact to the form. This means that, with very slight pressure applied to the center of the brace, no light leaks out between the bottom of the brace and the form. Except where lap joints are required, the brace is now ready to be glued into position.
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BACK BRACES AND CENTER SEAM GRAFT

Although many guitar makers lay down the center seam graft first, then cut slots in it for the cross braces, for 'newbies', we advocate gluing down the radiused cross braces first, then filling-in with center seam graft segments.

CUT OUT THE BACK



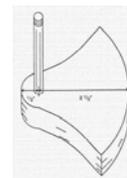
Optimize The Location Of The Back On The Show-Face.



Mark The Back On The Brace-Side, And Add 1/2" Margin For Bandsawing.

CUT OUT THE BACK

- Determine the 'show-face' of the back plate. Consider grain, figure and defects.
- Mark the centerline from top to bottom of the back plate. A white art pencil shows up well on dark hardwoods.
- Determine the position of the back on the show-face by sliding the template along the centerline. Be sure to look at both left and right panels. Mark the endpoints of the template on the centerline.
- Clamp a straightedge to the centerline. Clamp the template to the straightedge at witness marks, and trace the outline of the guitar onto the backplate. Before marking the mirror-image, use the drawing tool guide or a flat washer to make a second – 1/2" larger - outline.



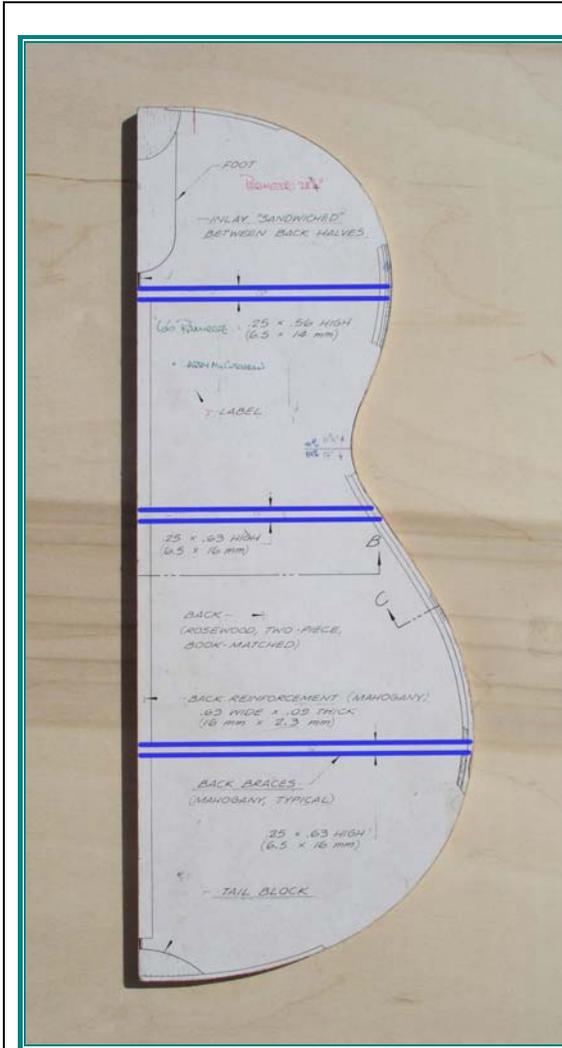
Drawing Tool Guide



*Back Plate Bandsawed To The Shape Of The
Guitar With 1/2" Margin*

- Bandsaw the back plate to the outside profile. Wear safety glasses.
- Place witness marks at the points where the outline of the template intersects the centerline.

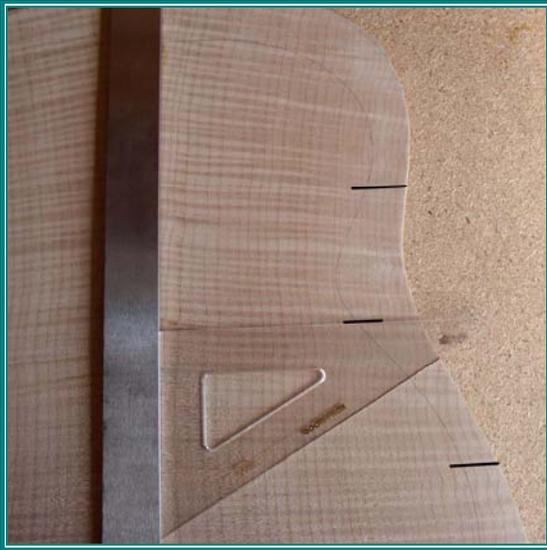
CROSS BRACES



Mark Brace Locations Directly From Template

LAYOUT THE CROSS BRACES

- For those who left the photocopy of the blueprint on the guitar half-template (left), mark the location of the back braces directly from the template. If the template is tempered hardboard, use a small layout square to extend a brace location line onto the edge of the template. If the template is Plexi, use a scribe.
- Bracket the location of the brace ends, either with (low tack or de-tacked) masking tape or pencil lines, placed just outside the outline of the guitar. Position a plastic drafting triangle at the brace location line on the template, and lay down a piece of masking tape along the edge of the triangle that lies outside the outline of the guitar. ("Plan B", for those who removed the photocopy of the blueprint from the template, uses the same drafting triangle, but instead of the template clamped along the plate centerline, uses a straightedge. Locate brace positions by measuring down from the neck-joint. Otherwise, everything else is the same.) Repeat for the remaining braces on this half of the plate, then locate and bracket the brace ends on the opposite half of the back plate.



Transfer Brace Locations From Blueprint



Tape Is Used To Mark Brace Locations

- Set aside the template and drafting triangle. Position the appropriate milled and radiused brace along side the masking tape location marks, and lay down masking tape on the free side of the brace, so that the brace end is bracketed by masking tape on either side. Repeat for the opposite side, and the remaining braces

Luthier Bud Tugley opines, "*I like masking tape better than pencil marks to locate the bracing for a couple of reasons. First, because pencil marks tend to disappear just when you need them the most – when you are gluing the braces down and the squeeze-out covers the line. Second, the tape has a tiny bit of height – the brace "drops-in" to the proper position with no sideways movement. When you may not be able to see the right spot, you can feel it. Remove the tape before the glue dries – I like to do it after I have positioned the last go-bar clamp and everything looks right.*

Just as an aside - You might think that running masking tape the entire length of the brace would make cleanup easier, with glue squeezing out onto the tape, but somehow it just doesn't work out that way. Better to bracket just the ends and cleanup the squeeze out along the length of the brace."

GLUE THE CROSS BRACES

- Be sure that all the braces are radiused on the bottom. Luthier Ben Thayer suggests, "*Mark the top edge of each brace with a position number so that they go in the right place.*" Because the braces will be carved in place, there is no need for clamping cauls.



A Fully Braced Back

APPLY GO-BAR CLAMPS

CENTER SEAM GRAFT

The center seam graft reinforces the back centerline glue joint on the inside of the back plate. This graft is more important when a decorative centerline accent is routed into the show-face, and less important when there is no routed channel. Opinions vary about grain orientation; we recommend that it be cross-grained to the back plate.

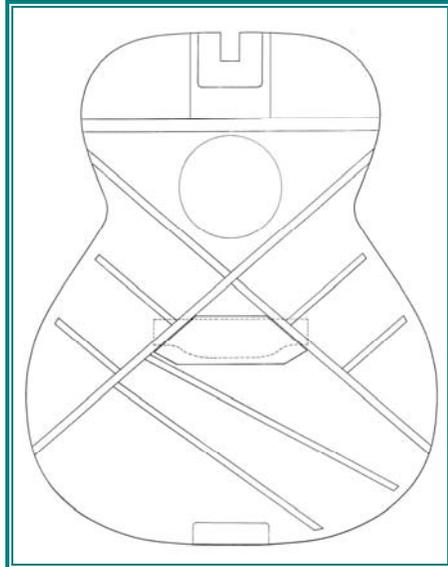
For precise fit, the two ends of the center seam graft - those that fit between the cross braces and the end blocks - may be glued down after the back has been glued to the sides.

	<h3>CENTER SEAM GRAFT</h3> <p>The Frugal Luthier uses a strip of quartersawn spruce cut from excess soundboard material for the center seam graft. Mahogany is also a commonly used graft material. For uniformity of the graft, mill a single length of stock to final height and width, round-over the edges, and cut segments from this piece sequentially. Due to its thinness, there is no need to radius the bottom of the graft.</p>
	<h3>SHAPE THE CENTER SEAM GRAFT</h3> <ul style="list-style-type: none">• To round over the edges of the center seam graft, use double sided tape to mount the graft onto the edge of a piece of scrap, secure the scrap in bench vise, and ease the square edges off the graft with a piece of sandpaper and a "shoe-shine" action. Symmetrically round both edges. Use a thin putty knife to carefully lift the double sided tape away from the scrap.

	<h3>FIT THE GRAFT SEGMENTS</h3> <ul style="list-style-type: none">• Determine the exact distance between braces with two pieces of paper with straight edges - each a bit smaller than the distance between the braces - and a piece of adhesive tape. Place the straight edge of one piece of paper against one brace. Place the other piece of paper on top of the first, with its straight edge against the opposing brace. Tape the pieces together. Remove and mark the exact distance between the braces directly onto the milled graft stock.• Number them for easy reference; indicate orientation (heelblock end vs. tailblock end) as well as sequence. (first, second, third etc.)
	<h3>ALIGN THE SEGMENTS</h3>
	<h3>GLUE DOWN THE GRAFT</h3> <p>Retired luthier Les Digits opines, <i>I know that some prefer to glue all the grafts down before the rims are attached. That way the grafts that will abut the endblocks help to index the rims on the back. But I prefer to glue them down after the</i></p>

	<p><i>back and rims have been glued together. That way I know that they will be straight, and I'll know exactly how long to make the grafts that about the endblocks for a clean fit."</i></p> <ul style="list-style-type: none">• Glue the graft with the go-bar deck on the appropriate radius form.• Les has more, "Put a little glue on the back along the center of the graft area, and dab it a bit, keeping the glue just in the center. Then put glue on the bottom of the graft; thinly but from edge to edge. I get complete coverage – I know, 'cuz I've had to carve 'em off – and no squeeze-out."• Use cam clamps to secure the back to the radius form.• Use cauls made from scrap to protect the soft graft material.
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TOP BRACES



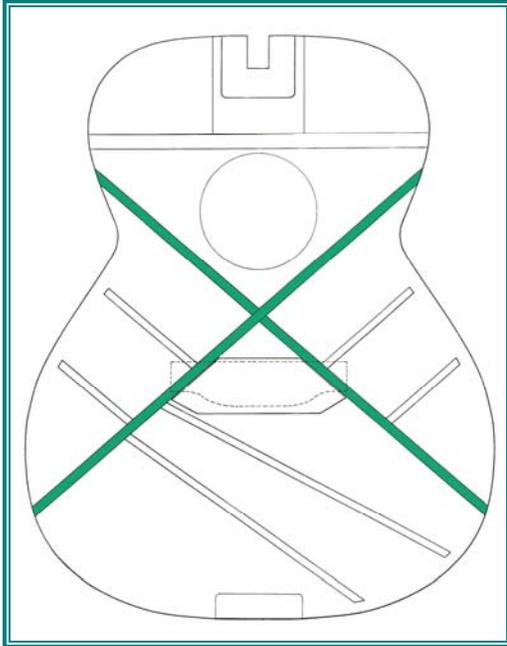
**Figure 6. Steel String Bracing
Large Body Guitar**
*(drawing by W. Cumpiano,
adapted)*



**Figure 7. Steel String Bracing
Small Body Guitar**
(photo by Len Poche)

<u>STEEL STRING TOP BRACING</u>				
REQUIREMENTS AND GLUING SEQUENCE				
<u>BRACE / GRAFT</u>	<u>RADIUS THE BRACE</u>	<u>GLUE ON RADIUS FORM</u>	<u>CAUL</u>	<u>INDEX TO RIM</u>
1. X-Brace	✓	✓		$\frac{3}{32}$ "
2. Bridge Patch	✓	✓	radiused	
3. Face Braces	✓	✓		
4. Finger Braces		✓		
5. Cross Brace		flat		$\frac{3}{32}$ "
6. Soundhole Graft		flat	flat	
7. UBRP		flat	flat	

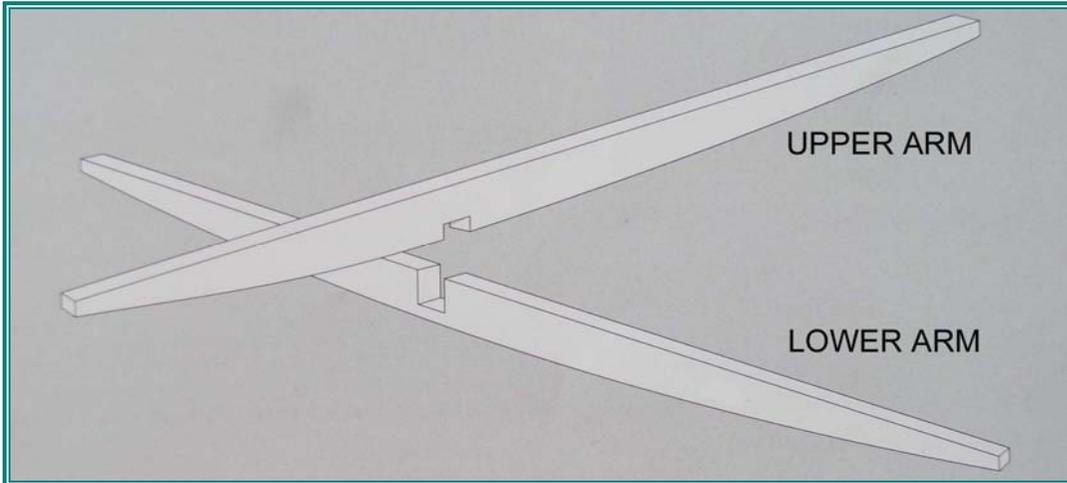
1. X-BRACE



THE JOINT

For structural and acoustic purposes, this joint needs to be as snug as possible.

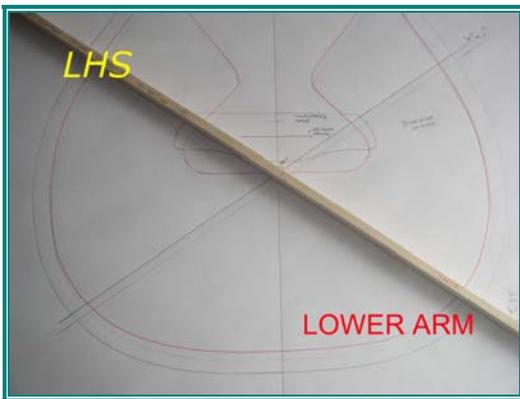
The compressibility of the bracewood is the luthiers' secret weapon in making a successful joint.



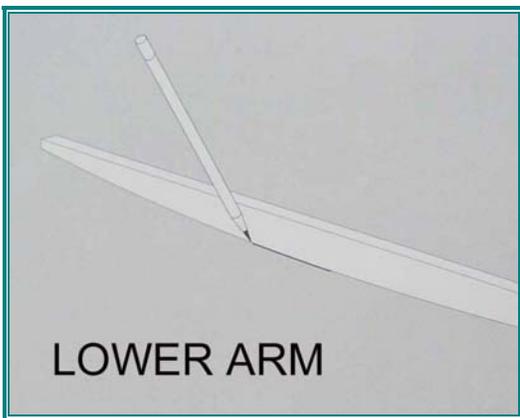
The Basics
(Making An Archtop Guitar, R. Benedetto)



Upper Arm Labeled "**RHS**" For Easy Orientation, But Not Yet Cut To Length



Lower Arm Labeled "**LHS**" For Easy Orientation, Not Cut To Length



(Making An Archtop Guitar, R. Benedetto)

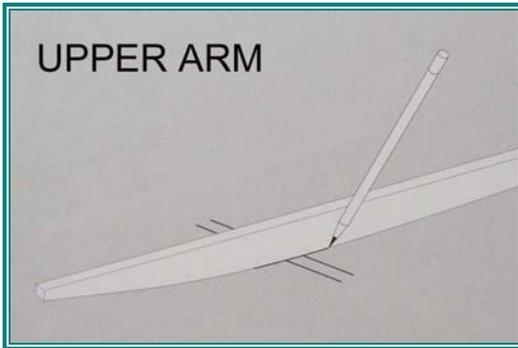
MILL & LABEL THE BRACE ARMS

- **HEIGHT** – Allow about 1/4" extra to the plan's height. This allows extra margin for stiffer bracing, if necessary, and carving away any dents that may result from go-bar clamping.
- **LENGTH** - The X-brace is indexed to the linings at all four ends. Therefore, the ends of the X-brace should extend beyond the outline of the guitar by about 1/2".
- **LABEL THE BRACE ARMS.** Guitarmaker Hugh Jim Bissell recommends, "*I always mark the top edge of the braces in the upper bout 'RHS' on the right-hand side, and 'LHS' on the left-hand side – no figuring-out to do!*"

LAYOUT

Layout the X-brace using positive geometry – that is, use the brace arms themselves for thickness measurements – either directly on the top itself or on a full-scale drawing.

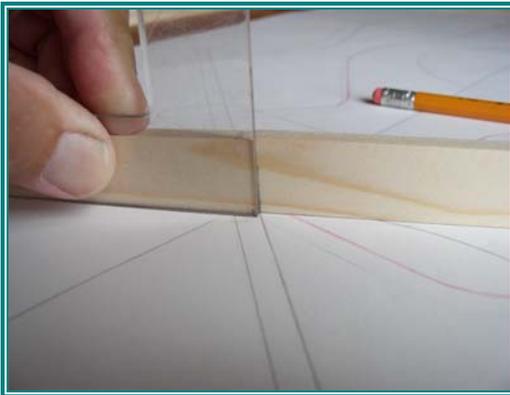
1. Mark the Lower Brace Arm (up-facing excavation) first, set aside, and then
2. Mark the Upper Brace Arm (down-facing excavation) so that the center seam bisects the diamond-shaped lap joint.



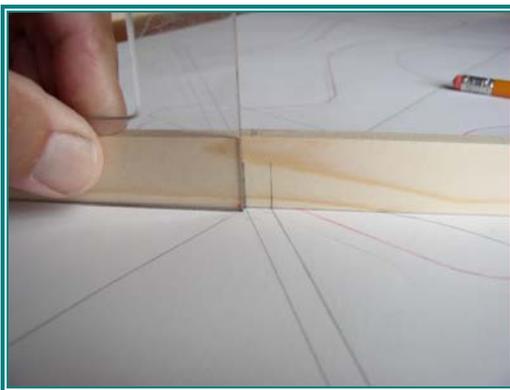
(Making An Archtop Guitar, R. Benedetto)



*Example of layout on a full-scale drawing.
Note length of arms.*

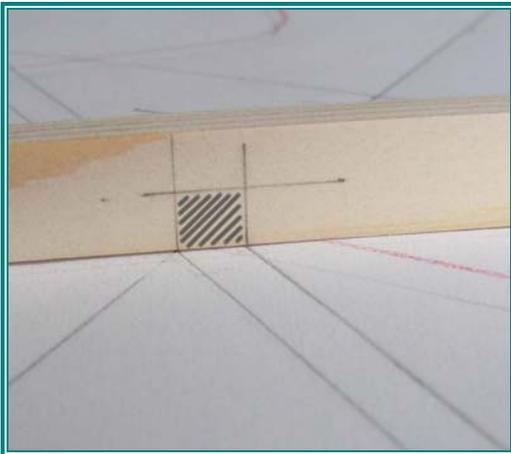
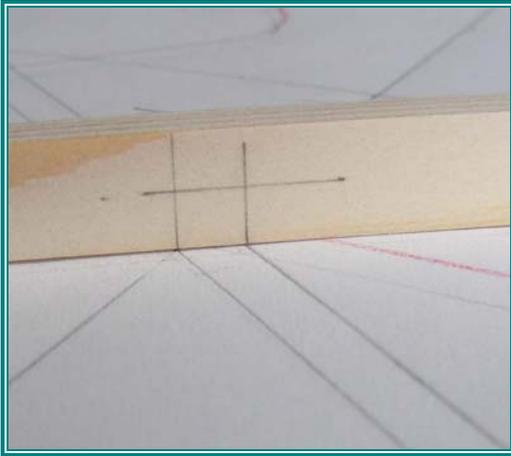


*Drafting Triangle Used To Map X-Brace
Intersection*

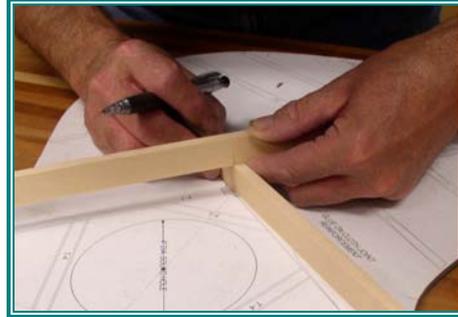


MARK THE INTERSECTIONS – UPPER ARM

1. Very accurately map onto the Upper Brace Arm the 4 points where it crosses the footprint of the Lower Brace Arm. Extend these lines about three-quarters of the way up the brace. Draw a perpendicular line between each pair of lines half-way up the side of the brace. Cross-hatch this enclosed area to indicate that it is to be cut-away.
2. Connect the vertical lines on each side with its counterpart across the bottom edge. *Be precise.* Cross-hatch this area for removal.
3. Double check –
 - Are the vertical lines parallel with each other?
 - Do the lines meet precisely at the edges?
 - Are the angles parallel on the edges?



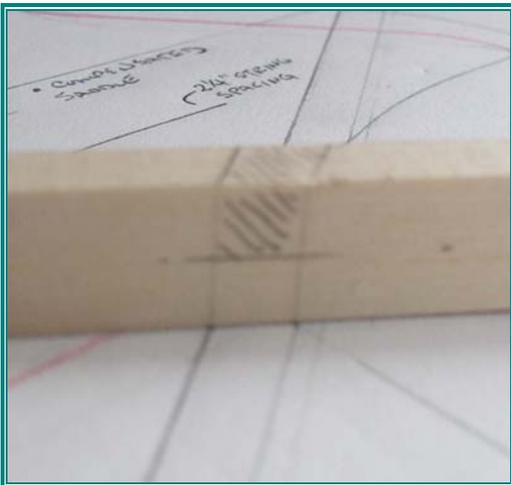
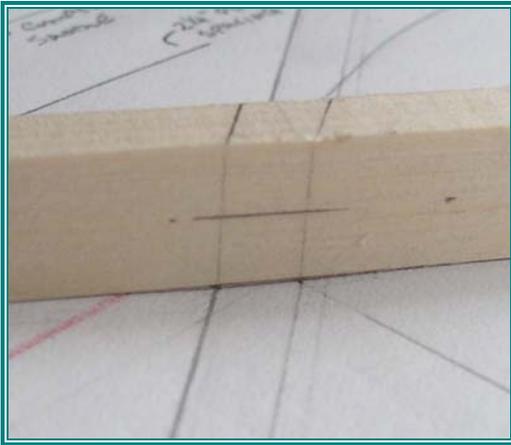
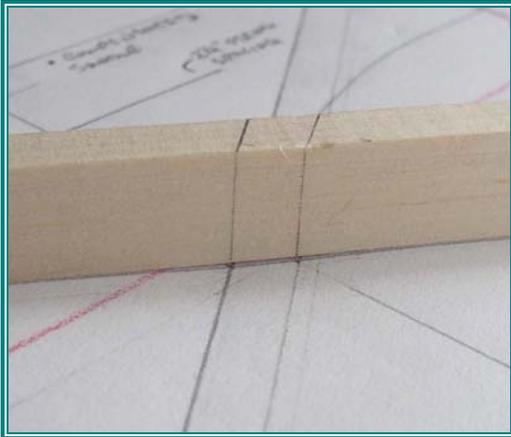
- Does it look *RIGHT*?



Positive Geometry Can Also Be Used To Insure Exact Thicknesses.

MARK THE INTERSECTIONS –LOWER ARM

1. Place the Lower Brace Arm onto its position on the full-scale drawing. As before, map the four points of intersection with the footprint of the other X-brace onto this brace. Extend these four lines to the top of the brace
2. Draw a perpendicular line between each pair of lines half-way up the side of the brace. Cross-hatch this enclosed area to



indicate that it is to be cut-away.

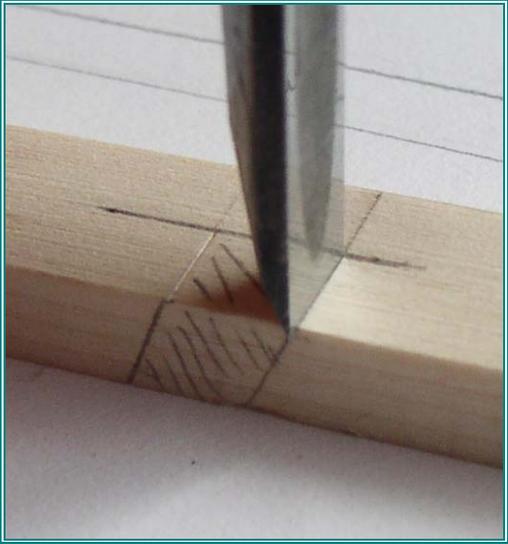
3. Connect the vertical lines on each side with its counterpart across the top edge. Cross-hatch this area for removal also.

4. Double check -

- Are the vertical lines parallel with each other?
- Do the lines meet precisely at the edges?
- Are the angles parallel on the edges?
- Does it *LOOK* right?
- *Alternative check* – flip the upper arm over and line-up the marked edges: they should be identical!

SAW THE LAP JOINT

1. Put the arms in a vise – woodworkers, mechanics, or drill press vise – for

	<p>stability during sawing and carving. Be careful not to compress or mar the brace material in the vise.</p>
	<p>SAW THE LAP JOINT – cont'd</p> <p>2. Some choose to score the inside of the pencil line with a sharp chisel. This cuts the surface wood fiber and prevents tear-out and a ragged saw cut. This step is not necessary if you are using a Japanese cross-cut saw (<i>dozuki</i>) or a razor saw. It IS a good idea if you are using a dovetail saw or a back saw.</p>
  <p><i>Check The Opposite Side Frequently To Ensure That The Kerf Tracks The Witness Mark. Take your time.</i></p>	<p>SAW THE LAP JOINT – cont'd</p> <p>3. Carefully cut the notches, keeping the kerf just inside the scored pencil line. Take your time. Check your accuracy – on both sides of the brace - after every few strokes. Cut through, but not beyond, the pencil mark at the half-way point on the side of the brace.</p> 



SAW THE LAP JOINT – cont'd

4. Cut a few parallel saw kerfs between the outside ones – these will allow you to "pop" the waste from the excavation.



REFINE THE JOINT

Luthier Ben Dover advises, *"Strop your chisel before you begin this step. A well-sharpened chisel is essential for cleanly paring a miniature softwood joint."*

Refine the joint, as necessary, with a sharp chisel and/or a double-cut file. Be very careful in test fitting the X-brace lap joint, particularly in 'un-doing' the joint. The result should be an intentionally overtight lap joint.



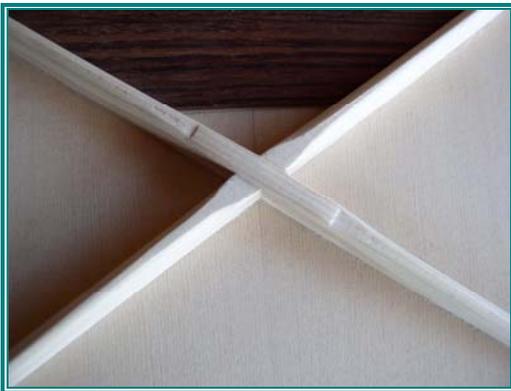
Touch-Up The X-Brace On The Radius Form

GLUE-UP THE BRACE

1. Glue the X-brace lap joint. Make sure that glue covers all surfaces of both sides of the joint. Clamp with a spring clamp.
2. Touch-up the radius of the completed X-brace on the appropriate radius board.



Sand The Top Of The X-Brace Joint Flat



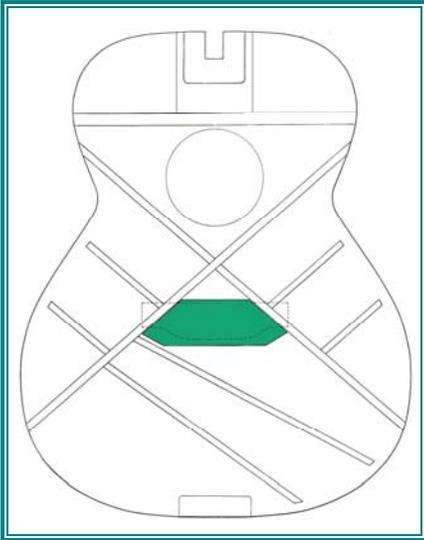
Carved Wood Patch Added To X-Brace For Strength

X-BRACE REINFORCEMENT

Because the lap joint reduces the strength of the X-brace, you may need to reinforce that area with a wood patch, depending on the "tightness / looseness" of the top.

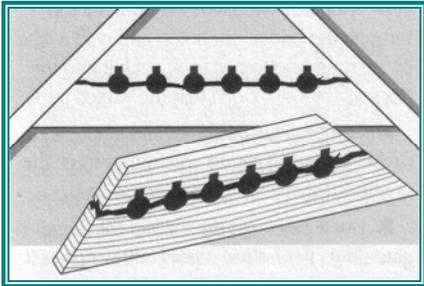
1. Flatten the top of the X-brace with sandpaper and a hard block.
2. Use the radius form and go-bar deck to add a piece of spruce over the X-brace. Carve to 1/8" – 3/16" thickness. Taper and shape as appropriate.

2. BRIDGE PATCH

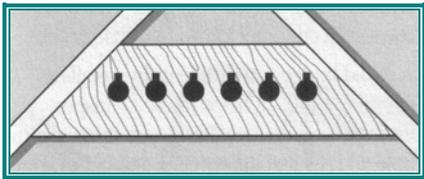


BRIDGE PATCH AND CAUL

The steel string bridge patch is usually made from hardwood, frequently maple or rosewood – the Frugal Luthier uses a back / sides remnant, if possible - thickened to about .090"



*(Guitar Player Repair Guide
by D. Erlewine)*



*(Guitar Player Repair Guide
by D. Erlewine)*

GRAIN ORIENTATION

- Whether the bridge pins are parallel to the front edge of the bridge, or parallel to the compensated saddle, avoid orienting the grain of the bridge patch – AND THE BRIDGE - parallel to the line of the bridge pins: a split bridge patch is a common repair problem.
- For best strength, the grain should be diagonal.

NOTE: THE FOLLOWING PHOTOS USE A NON-STANDARD BRACING PATTERN: THE BRIDGE NORMALLY GOES BELOW THE X-BRACE!

LOCATE AND CUT THE BP TO SHAPE

- Determine the position of the bridge, and make a paper pattern for the pad - and caul. The top and bottom edges should be perpendicular to the center seam; the left and right edges abut the legs of the X-brace,



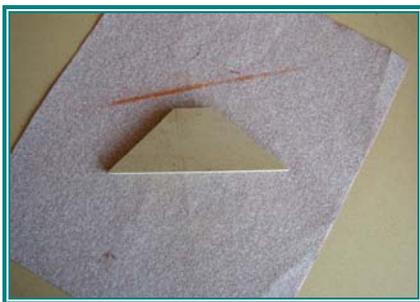
Make A Paper Pattern With 3" x 5" Cards



Tape Them Together And Snip To Fit



Caul made from 1/4" pressed hardboard



but are not tucked into the X-brace.

- Apply the pattern to the hardwood patch material, and cut to shape with a hand saw, and refine on the belt sander (or bench top with sandpaper.)
- Be sure to make the caul slightly smaller than the patch; glue clean-up will be much easier, and you won't glue the caul to the patch!

RADIUS THE BP AND CAUL

- Radius the bridge patch and caul on the appropriate radius form. Noted British luthier Isaiah Olchap suggests, *"Use the old pencil lead trick – use the side of the pencil to cover the back of the caul with lead; then, sand on the radius form until the lead is gone. You'll have your radius."*



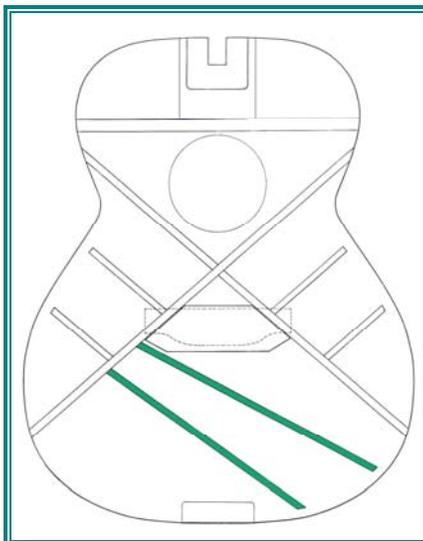
Almost Done!



GLUE THE BRIDGE PATCH

- Save this caul. It will be used later to glue down the bridge.

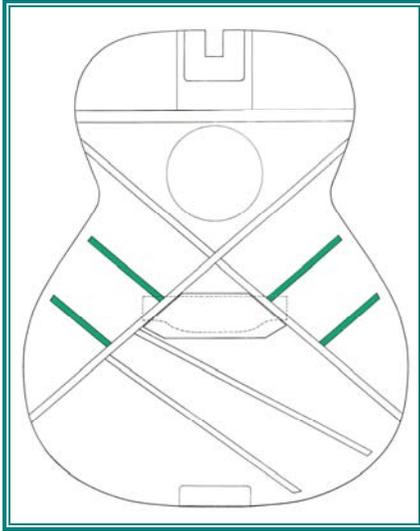
3. FACE BRACES



FACE BRACES

- These braces add strength to the top, unify the sound, AND provide cross-grain reinforcement to the center seam at a couple of places in the lower bout. Where two face braces are indicated, we recommend non-parallel placement of the braces and similar, but not identical, profiles for each.
- These braces are radiused and glued into place on the radius form. They are not indexed into the linings.

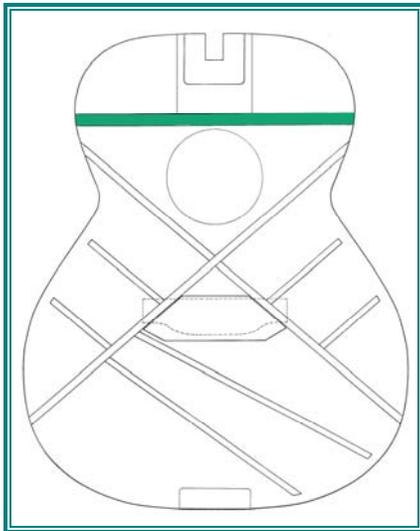
4. FINGER BRACES



FINGER BRACES

- In most blueprints these braces are tall in the middle and scalloped to nearly nothing at the ends. Because their primary purpose is to help to unify the sound, and only to a lesser degree to provide strength to the soundboard, carve these braces lower to reduce weight and improve response.
- Because of their short length, these braces are not usually radiused, but they are glued into place on the radius form. These braces are not indexed into the linings.

5. CROSS BRACE

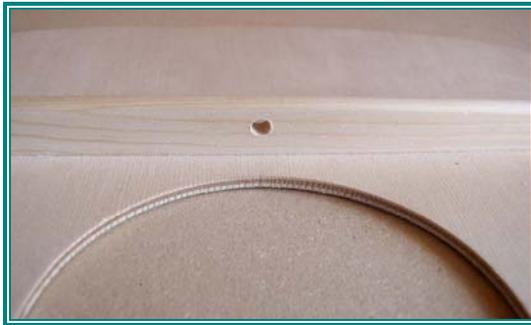


CROSS BRACE

- The cross brace is notched into the linings for strength to support the top under the fretboard. Make the notches about $\frac{1}{4}$ " tall.
- Those who have chosen truss rod access through the soundhole must drill a hole through this brace large enough to pass the truss rod tool, typically a long-shank $\frac{1}{4}$ " HHS bit (Home Depot, et al). Drill the hole from the heelblock side, half-way up the brace.



Back-up the brace with a piece of scrap to avoid blow-out. Lay a ruler on the centerline as a visual guide.



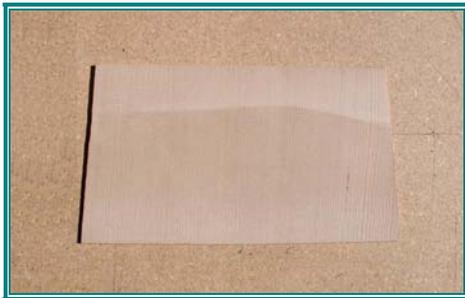
The completed access hole.

6. SOUNDHOLE GRAFT



SOUNDHOLE GRAFT AND CAUL

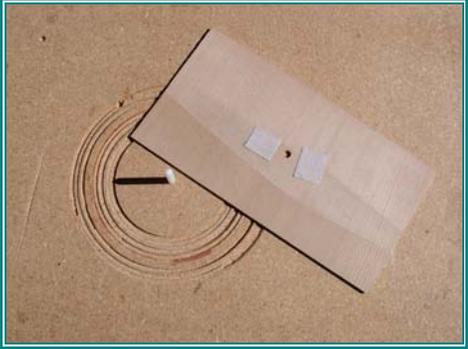
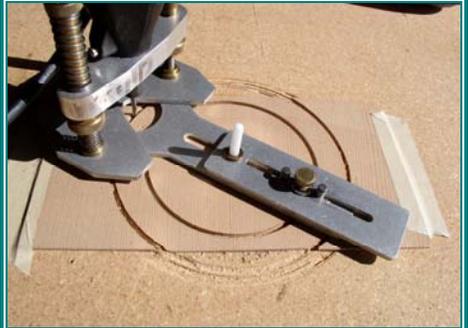
- Most steel string guitar blueprints indicate soundhole braces. We recommend a soundhole patch like those used in classic guitars, an alternative that adds strength uniformly around the soundhole.
- The soundhole graft is best made from spruce and mounted cross-grain to the top. The Frugal Luthier uses excess material from top plate to make soundhole graft, gluing segments together as necessary to make an oversized blank.
- The plan here is to use a circle cutter to shape the graft; to both remove the inner soundhole area, and to define the outside shape of the graft.

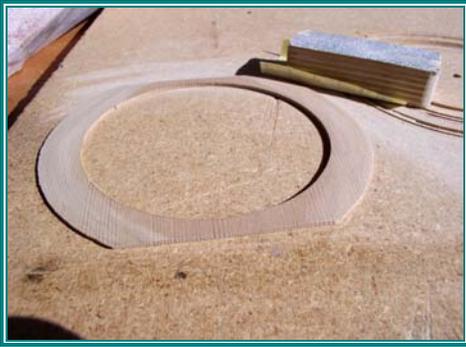


- The soundhole graft is made from soundboard cut-off and mounted cross-grain to the top.
- Thickness the piece to about .075" / 2mm.



- Fit the soundboard cut-off between the braces using the "two-pieces-of-paper-and-piece-of-tape" technique.

	<ul style="list-style-type: none">• Use masking tape to tape the fitted cut-off in place.• Flip the top over and with a sharp pencil, trace the soundhole onto the cut-off.• Remove the cut-off and set the top aside.• Determine the center of the soundhole with a compass and drill a 3/16" pilot hole with a bradpoint bit at that point.
	<p>Set-up the circle-cutting workboard.</p> <ul style="list-style-type: none">• To prevent the "soundhole" excess from rotating (and interfering) while cutting the graft, attach a couple of dime-sized pieces of double-sided tape on the patch portion of the blank. Mount the blank onto the circle cutting pivot post.
	<ul style="list-style-type: none">• To prevent the "outside" excess from rotating (and interfering), tape the edges of the blank to the workboard.• Adjust the router depth-of-cut to cut through the blank in a couple of passes. As with cutting a rosette: the inside of the bit cuts the outside of the patch, and the outside of the bit cuts the inside.



- Remove the thickened graft from the block by VERY carefully working a putty knife under both the tape and the tonewood and taking them up together. Don't try to lever the pad up. Gently roll the tape off the blank.



- Glue the patch to the soundboard with a gluing caul (It doesn't have to be round. It only has to fit between the braces) and the go-bar deck on a flat surface. Put wax paper between the caul and the graft, and between the top and the flat gluing surface. Secure the top to the flat workboard with cam clamps to prevent it from wandering under the go-bar clamp pressure. Pencil a couple of position references marks on the top with the patch in place. A thin, even coat of glue is sufficient.



- After the glue dries, carefully feather the edges of the graft.

7. UPPER BOUT REINFORCEMENT PATCH (UBRP) AND CAUL



The Graft



The Caul

UPPER BOUT REINFORCEMENT PATCH (UBRP) AND CAUL

- The purpose of this patch is to prevent the soundboard from cracking along the edges of the fretboard, a frequently mentioned repair problem. Because the UBRP abuts both the headblock and the cross brace, the layout, fab and installation of this graft takes place after the top has been indexed to the rims.
- Make this graft from the same material – and to the same thickness - as the bridge patch.
- This graft is glued into place using a flat caul on a flat surface
- **Save the caul.** When it comes time to glue the fretboard down, it will serve as an interior fretboard caul.