

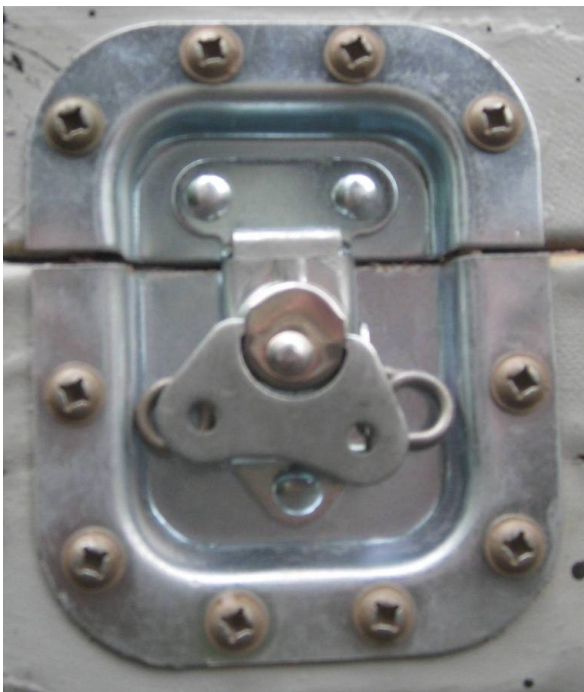
## Hard Flight Case

These instructions are for a durable hard flight case I make for clients that must travel by air frequently with their instruments. It costs about \$350 in materials and takes me about 15 hours of labor to complete a 34 lb case for a harp like the Luchair.



I think there are four conflicting requirements that make it very hard to produce a successful flight case.

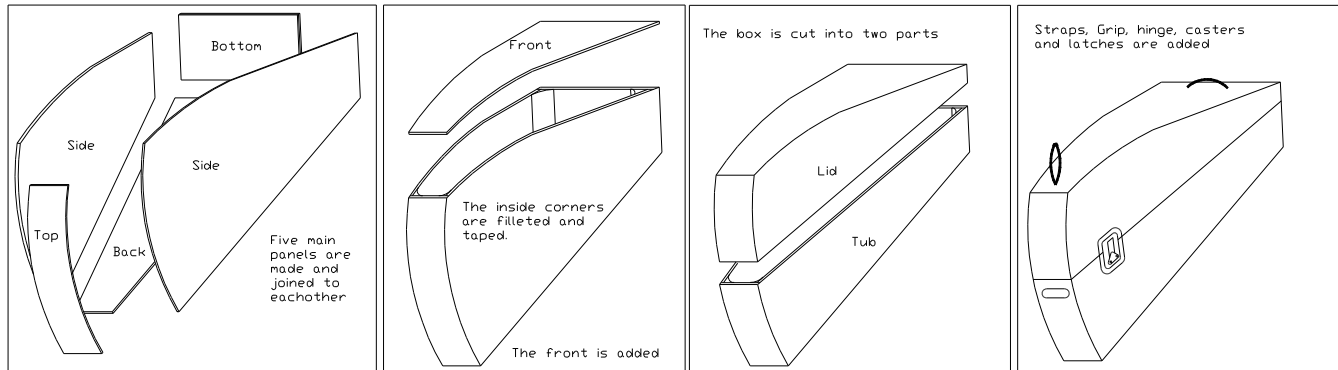
- It has to be tough enough to survive baggage handler abuse
- It has to protect delicate parts like the levers
- Ideally, the harp and case will be under 50 lbs so the airlines won't ding the harper with an overweight charge
- It has to be easy for a careless and rushed TSA agent to open the case, remove the instrument, inspect, replace the instrument and securely close it up again.



The case is made from 5-6mm plywood for the main panels, with 1.5" radiused corners and 6 oz. fiberglass taped seams (inside and out). The case is secured with two simple milspec "butterfly" catches. It has two built-in tilt casters on the base and an integral handle up near harmonic curve so a harpist can tow it behind her - wheeled luggage. Inside, the harp is cradled in two inches of closed cell foam at the corners. It is strong enough for hefty (250lb) man to stand on it.

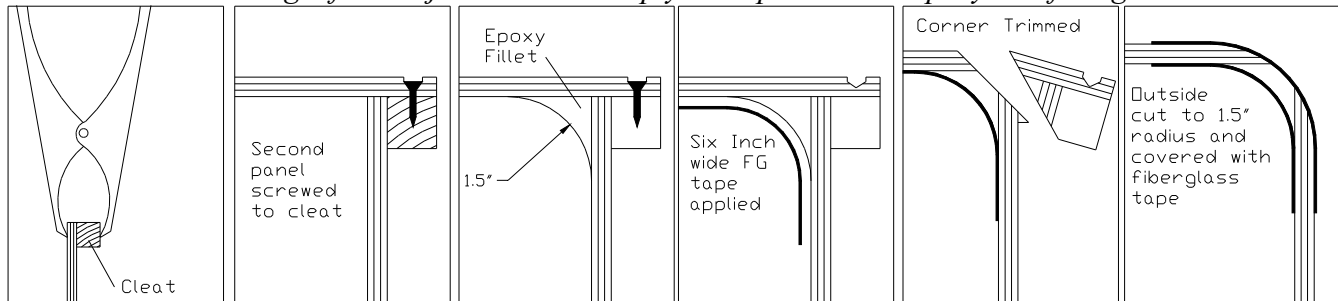
A list of suppliers and specialty materials needed for the case appear at the end of the instructions.

## **Construction process overview**

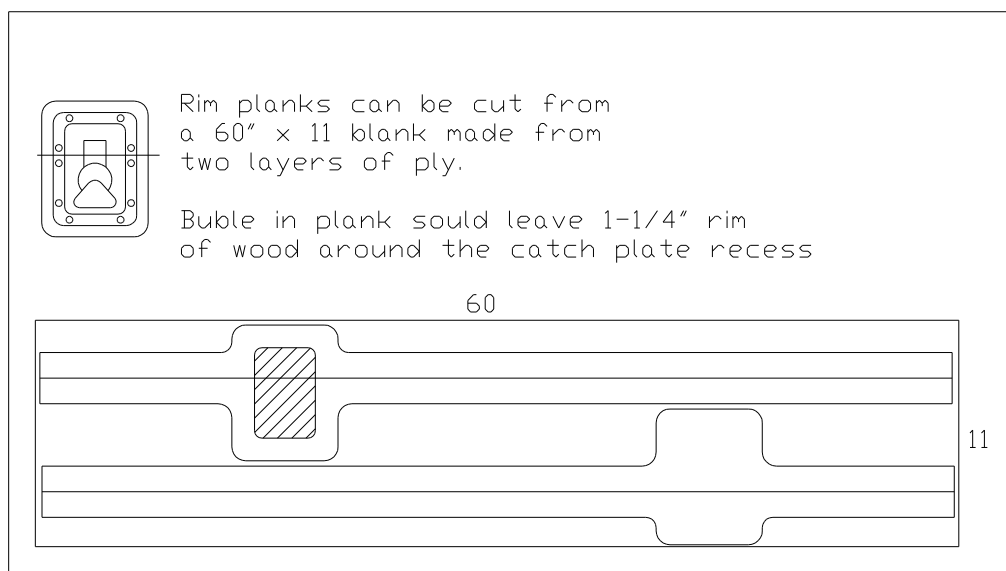
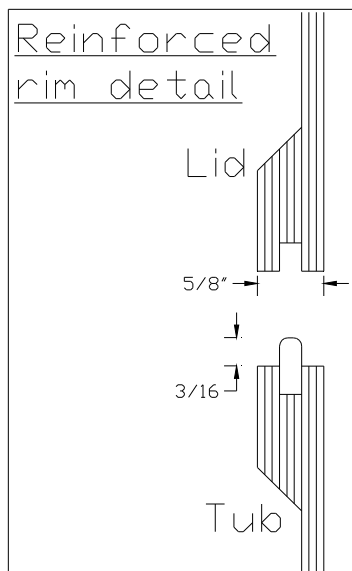


Much of the case strength and durability comes from the epoxy and fiberglass used to join the panels together. These joints are light and very, very tough. To hold the panels securely to each other while making the inside fillets, I use an external cleat that is trimmed off after the inside of the box has been fiberglassed..

### *Cross section – making a filleted joint between to plywood panels with epoxy and fiberglass*

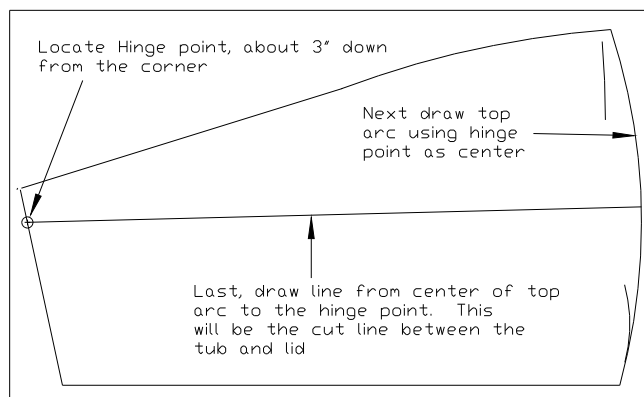
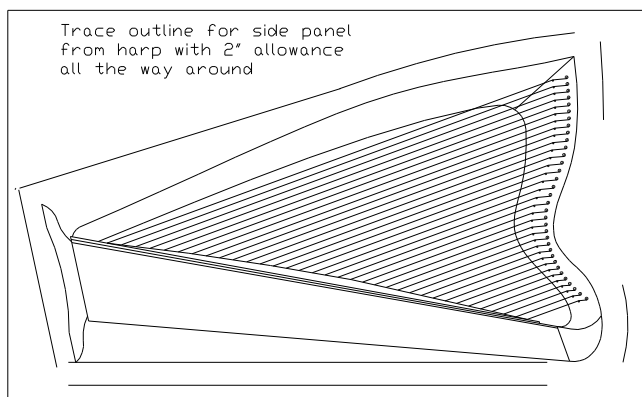


The 5-6mm plywood is too thin and flexible to hold up at the seam between the tub and lid. The rims of the tub and lid are reinforced with two layers of additional ply, making it about 5/8" thick. A tongue and groove arrangement will keep the tub and lid aligned when the case is closed. The catches also need to be placed along this seam and fastened robustly. The planks are made from double layer of ply. Each "rim plank" is glued on as a single piece on to each side panel. After the six big panels are glued together into a box, the case is cut into the tub and lid along the center of the plank.



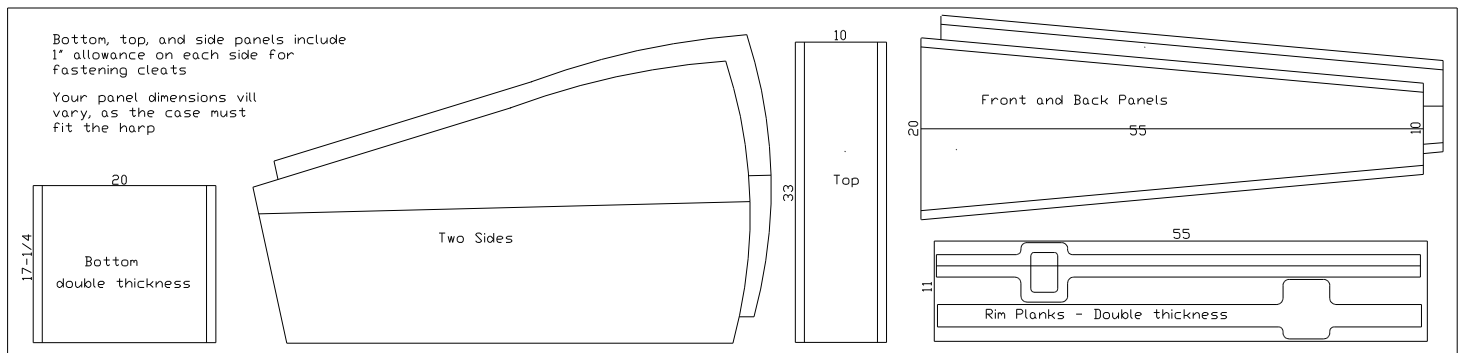
## Detailed construction process

I start by tracing an outline around the harp onto a sheet of 5-6mm plywood. I use a block of pine, 2" thick to draw a boundary that is 2" out from the sides of the harp. That makes it so the 2" foam that I use later on will cradle the harp firmly when the case is closed.



One the tracing, I mark the location for the hinge point. Next I trace an arc (using the hinge point as the center) that will become the top of the case. This arc needs to clear the knee block and tip of the neck by 2". I will also measure the width of the sound box (14" for the Luchair) and add four inches for padding and note the bottom width for the case directly on the side panel (18"). I make the top of the case 8" wide, which is just about right for my designs. If you have a harp that has a wide sound box at the treble end (brands like Dusty Strings, Thormahlen and Music Makers), you may need to make the top panel 2-3"wider.

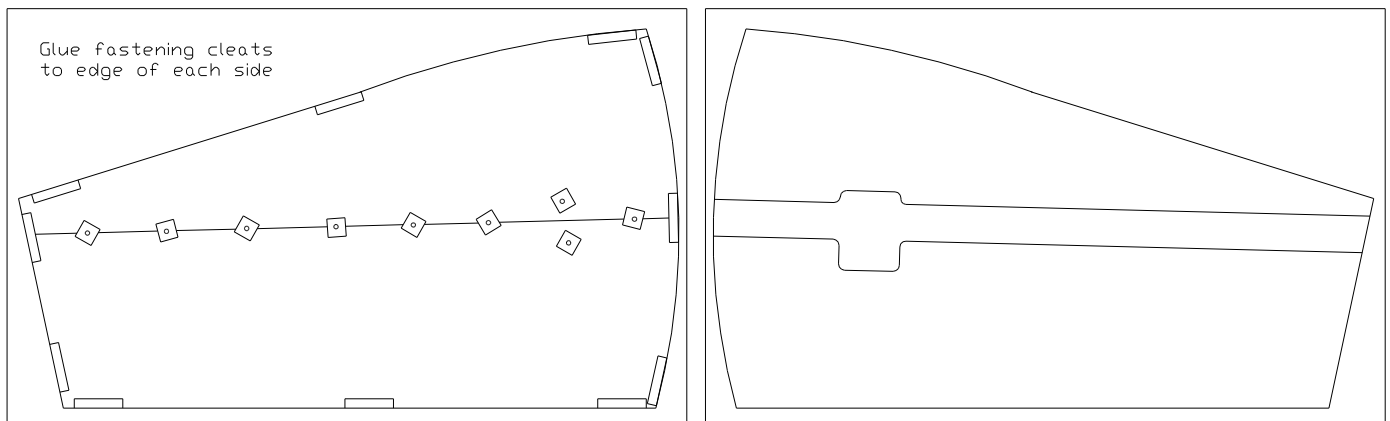
I cut out the first side and use it to trace out and cut a second side. I lay out two tall trapezoids that will become the front and back of the case, adding an extra inch of allowance for each side (18" + 2"). These are for the cleats that will be used to hold the case panels together temporarily while the case interior is fiberglassed.



While I am at it, I lay also measure and cut out the bottom and top panels. These panels should also have a one inch allowance on each side to allow me to screw these parts to the sides on the temporary assembly cleats.

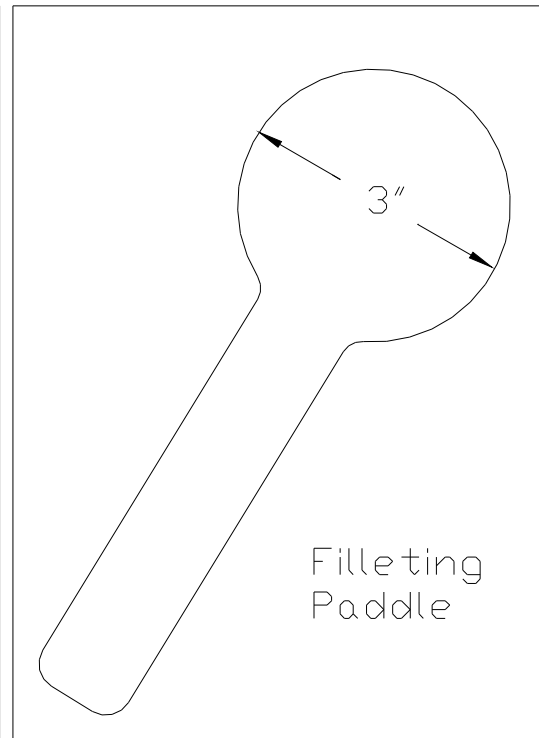
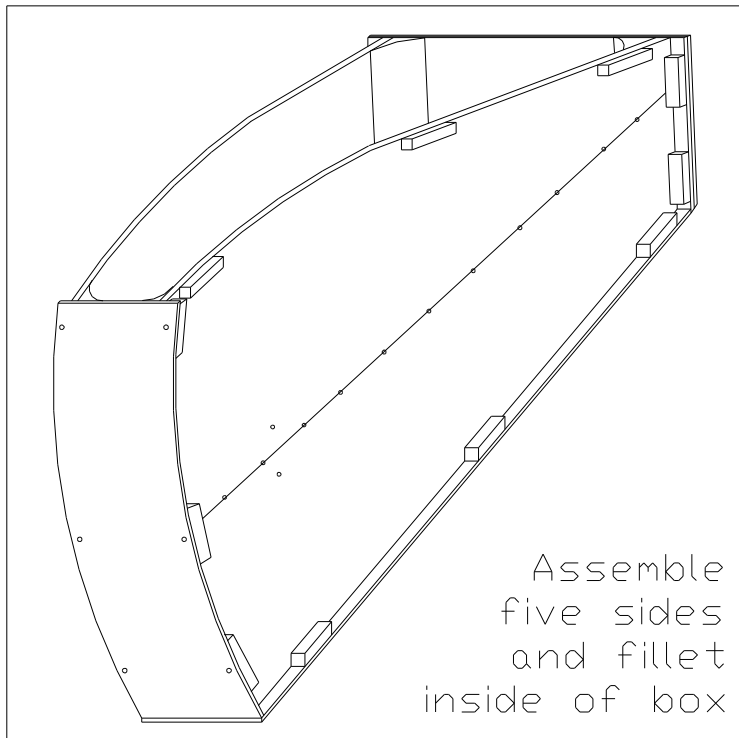
The hinge will be placed across the bottom panel. The wheels will be bonded along the edge of the bottom panel are also going to jar the case as whenever it is wheeled about. 6mm is just too thin, so I laminate the bottom panel from two pieces of plywood to make it thicker. I also laminate two long strips of plywood (11" x 55) to make the rim planks that will run along the edges of the tub and lid later on.

From a scrap pins I cut 22 fastening cleats, 4" long and  $\frac{3}{4}$ " x  $\frac{3}{4}$ ". I glue these assembly cleats to the perimeter of the side panels as shown with carpenters yellow glue. It may be tempting to use nails or screws to hold these cleats into place on the side panels, but the rounding that takes place later on at corners of the case will run smack into those metal fasteners, so don't do it!



On the opposite side of each side panel (the side that will become the inside of the case) I glue the side rails centered over the cut line. I use screws with plywood pads, through holes predrilled every 4-6 along the "cut line"

I screw the bottom, top and back panel to the sides to create an open, five sided box using 1" dry wall screws. The fastening cleats will allow you to bend the top panel to its final shape. I will sometimes take a block plane to cut a bevel on the cleats along the top of the side panels so the top will sit tightly against the sides. There may be some gaps, and some corners that are misaligned. You can fuss endlessly over these, but it helps to realize that the epoxy schmutz (fortified to the consistency of peanut butter) will effectively fill and bond  $\frac{1}{4}$ " or even  $\frac{1}{2}$ " gaps. The fiberglass and fillets are going to be much stronger than the panels themselves, and after 1-2 flights the case is going to be beat up and dirty, so cabinet grade fitting and refinement is probably a waste of time here.



I roll out the 6" wide tape cutting it to length for the 8 corner seams I will be filleting. It is a long reach down into the corner seam near the top, and I find it helps to prop the box 18" off the floor on a few 5 gallon paint buckets. From scrap plywood, I make a several paddles for spreading the epoxy. Make the head so it is about three inches in diameter.

There are some pretty decent videos on YouTube showing how to apply fiberglass tape over epoxy fillets on boat seams. If you are not familiar with this kind of construction, you may want to review them before starting the next steps.

I mix the epoxy in fairly small batches, 180 grams at a time, and add wood flour to thicken the epoxy to the consistency of peanut butter. I spread it over the inside corners, dragging the filleting paddle along the corners to spread it out. I start working on the vertical seams, leaving the easier flat seams for last. ... You may need to mix a thicker mix for the vertical corners. Check them after a half hour or so to see if there is any sagging. I use a 1" paint scraper to clean off the excess epoxy above and below each fillet, moving it to the next area to be filleted. There are some Michelangelo's of epoxy that can make beautiful, flawless fillets. I'm not one of them. This is going to be inside a case, and I have found I can eliminate a host of sins later on with some judicious sanding and grinding. Don't flip out over misplaced dollops, of epoxy schmutz.

You can wait a day for the fillets to cure, sand them smooth and then apply the fiberglass. I apply the fiberglass as soon as I have laid down the fillets while the schmutz is soft. It is a trickier do to because once the fiberglass touches and sticks it is impossible to move it without messing up the fillet. The fast method requires the builder to place the fiberglass accurately with minimal shifting. To fill the weave of the fiberglass tape, I mix batches of ~150 grams and use a cheap 2" disposable paint brush to fill the weave of the cloth. As the fiberglass is surrounded by epoxy, it will become nearly transparent. The goal is to get rid of any white spots, but it can take 2-3 minutes for the epoxy to soak in, so I will generally spread the epoxy over a 2-3 foot section before going back to work it in or to spread a little more to fill in the white spots.

After the epoxy and fiberglass have cured, I will screw the last panel onto the box (the front), using drywall screws. The front cannot be bonded until the case has been cut into the tub and lid, but the screws holding the lid will make the case rigid which increases the likelihood that the lid will fit accurately onto the tub.

Before I make those cuts, I trim the cleats and excess plywood from the seams that have been filleted. This allows me to extend the cut line around the top and bottom of the case. The cut is made with a circular saw, set to cut 3/4 inch deep. Working slowly and methodically will allow you to make a neat job of it.

The lid will now sit nicely on the workbench where I can epoxy the last four inside seams, using the same procedure I did for the other panels.

After the epoxy has cured, I remove all of the screws holding the panels to the cleats and I cut away the corners at a 45 degree angle. I find this easiest to do on my band saw (with the table tilted). I use a 1½” rounding bit in a router to neatly round over all the outer corners. The \$100 bit is not necessary; you as nearly as good a job using a grinder, belt sander or block plane, using a template to check your progress. After a while you will find the glue lines between the layers of ply along with the band of fillet can guide your efforts, helping produce a smooth radius for the fiberglass.

Once the corners are rounded over, I fiberglass the outside seams. Here again, it helps to roll out and cut the sixteen strips of 6” wide fiberglass tape to length. I fill any voids and air bubbles that have been exposed with a thickened epoxy schmutz (consistency of peanut butter). Working with in moderately sized batches of 150 grams or so and a new 2” paint brush, I paint a corner to be fiberglassed, and then drape the 6” wide tape onto the wet epoxy, brushing out any wrinkles as I go. I put another coat of epoxy onto the tape, taking care to saturate any white spots. I find it easiest to work the vertical corners and the horizontal seams last.

I will let the epoxy cure a full 24 hours before sanding the two shells down. I cut away excess fiberglass with a box cutter then go at the seams lumps and runs with a random orbital sander, a die grinder with a carbide whisker ball for spot treatments and coarse sandpaper (by hand) for the tight spots. Boat Builders may be tempted to make the entire surface smooth and hydrodynamic by sanding into the fiberglass or applying a skim coat of epoxy and lightweight filler to “fill the weave” of the epoxy. I think it is a waste of time. Sanding the fiberglass weave will weaken the corner. Applying a skim coat will add unnecessary weight. Remember, the case is going to get abrasions and grime on it, so excessive attention to cosmetics is going to be a moot point after the first two or three flights.

This is the worst part for me as the sanding produces lots of fine, itchy fiberglass whiskers. Wear a dust mask or respirator, long sleeves and pants. If you don’t have an air filtration system in your shop, consider doing the sanding outside on saw horses. I Brush all the dust off the case parts when I am done and shower directly after.

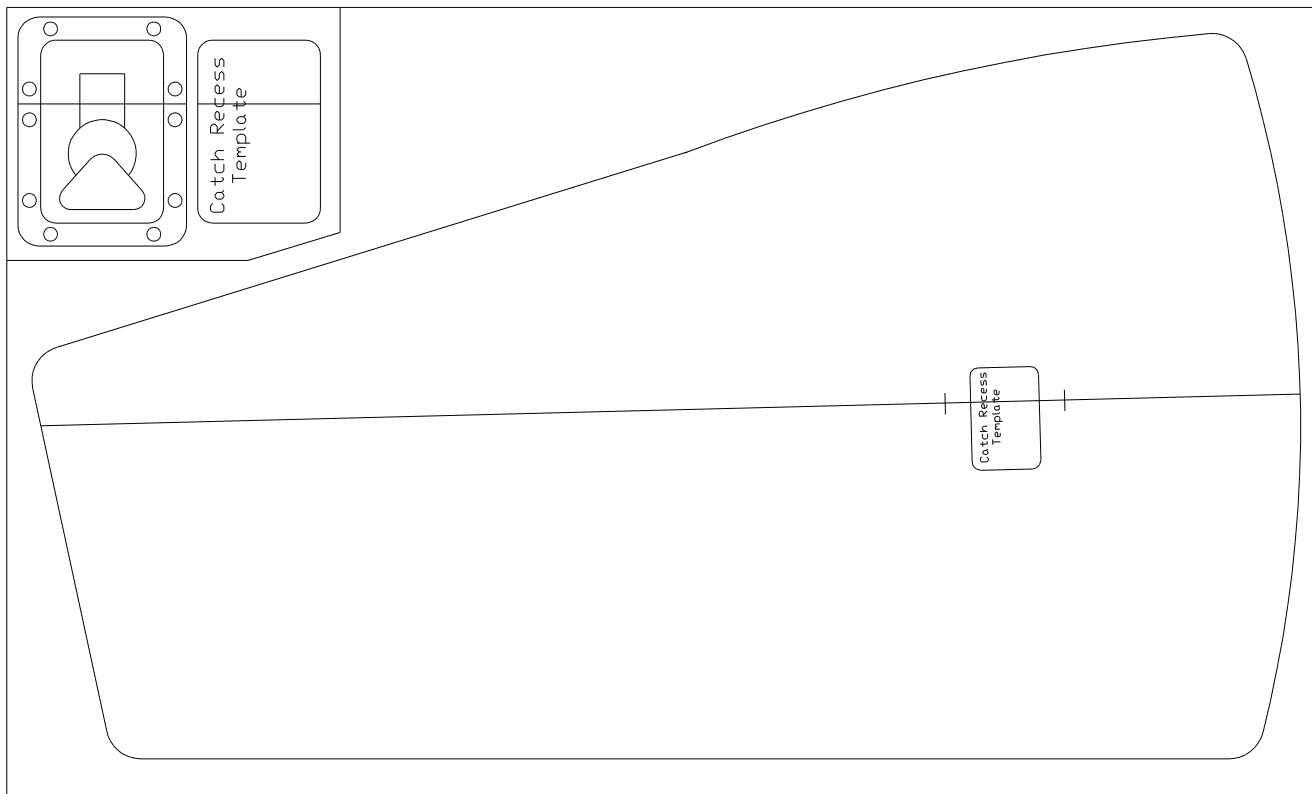
## **Mounting the Hardware**

The first task is to mount the case hinge. The bottom of the case should be two layers thick. I glue a strip of plywood, 1½ inches wide and 16 inches long to the inside of the case to give it the 5/8” thickness needed for the screws.

While I wait for the glue to dry, I will cut the piano hinge to length. These are usually sold in 2’, 3’ or 6’ lengths. The hinge can be cut to length by holding it in a metal workers vice and cutting it with a

hacksaw. A bit of grinding and filling will clean up the rough edges and round the corners of the hinge so they are less likely to catch on anything. Once the glue is dry, I will position the lid on the tub, and hold the hinge so the pin is centered right over the seam. I poke positioning holes for two of the screws with an awl and drive them into place. Then I check the position of the hinge one more time, mark starting holes for the other screws and drive the dozen or so screws into place.

The next task is to mount the catches. Cut a scrap of plywood to catch recess template. I also mark the position of the bump-outs on the internal reinforcing rim to the *outside* of the case. I center the template between those marks, trace around it and use a jig saw to cut it out.



As I did with the hinge, I hold the hardware in place and mark the screw holes with an awl. After catches have been installed, I test them to make sure they close. The screws holding the catches in place are very close to the edge plywood cut for the catch recess, and I worry about them pulling out. I fill the back of the recess (inside the case) with a thickened epoxy schmutz, bonding the catch into place. I can get a nice, flat surface inside the case by clamping a plywood square covered with a piece of wax paper behind the catch, and cleaning up the excess epoxy as it oozes up.

Next I route the slots for the tongue and groove that will keep the edges of the tub and lid aligned. I use a 3/16 slot cutting bit. While there are ball bearing sets that would allow me to set the cutter to a 3/16" depth, I have been always able to get by with carpet taping a temporary fence to the base of my. I stop the cuts an inch or two away from the bottom of the case, the catches and top. I fabricate the four "tongue" inserts from scrap plywood strip ripped to 3/8" wide and planed down to 3/16" thick on the thickness sander. I round the sharp edges on the tongue and groove with sandpaper, test fitting each strip, one at a time to ensure the case closes and catches will securely engage and lock before gluing these parts into place.

Mounting the casters and rubber bumpers

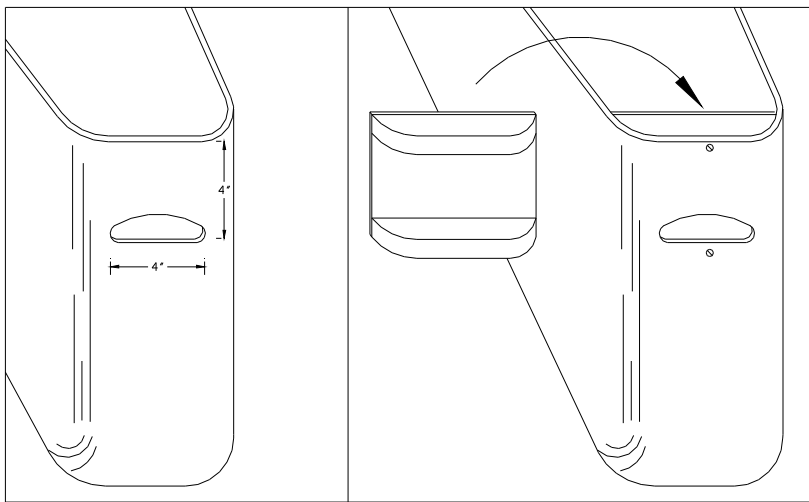


Mounting the casters is fairly straightforward. I cut slots into the along the edge of the tub between the back and bottom panels. If the slots are close to the side panels, the case will roll with more stability. I bond the casters into place with thickened epoxy, covering any holes in the caster housing with masking tape to make sure epoxy does not seep in and bond the wheel to the axle or housing. If you can hold the casters in place with one or two screws, you can mold thickened epoxy around the casters inside the case. After the epoxy is hard, I drill pilot holes and drive all 8 screws holding each caster into the plywood and thickened epoxy holding the casters to the case.



The casters stand about  $\frac{3}{4}$ " proud of the case, and to get it back to level, I mount two rubber bumpers with T-nuts on the bottom panel of the lid so when the case is standing upright it will not have the tendency to fall forward over.

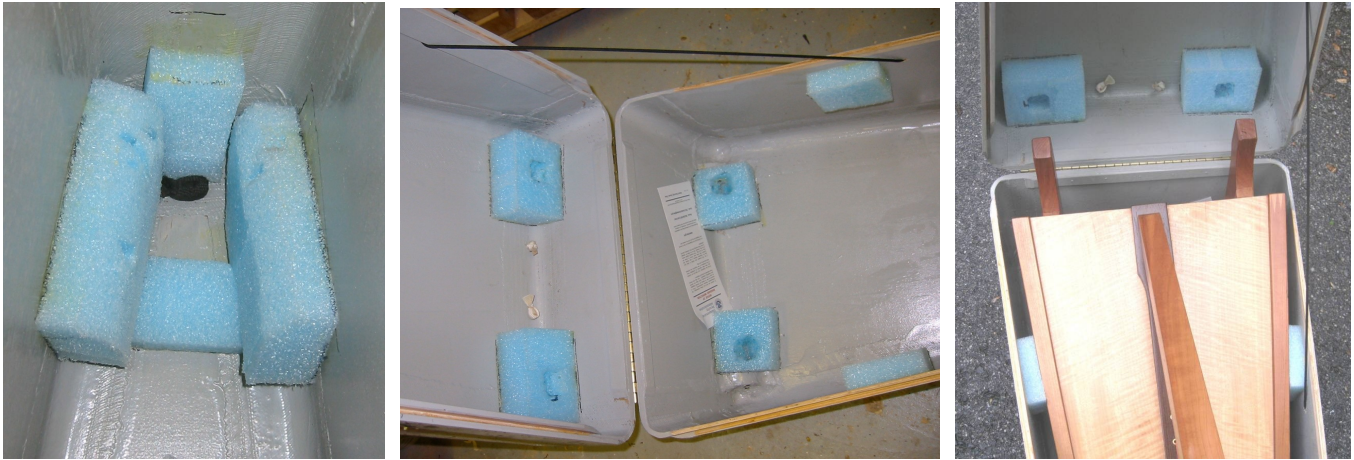
To fabricate a tow handle, I cut a hand-slot about four inches long and a little over an inch wide into the top of the case tub using a forstner bit and a jig saw. The slot should be about four inches below the rim of the case as shown in the illustration below. If you plan to pack your harp with its soft case would probably be enough.



The soft case weighs too much, so I like to enclose the hand-slot with back plate. First I scribe two scraps of 1x2 to the shape of the rim and then glue them onto a scrap of thin plywood approx 5 x 8 inches as shown in the illustration. I glue the back plate into place with thickened epoxy and the two screws shown in the illustration. Thoroughly sand to smooth the fiberglass and epoxy on the edge of the hand slot with sandpaper – you don't want the harpist getting any wood or glass fiber slivers. You can make it more hand friendly by gluing a patch of thick leather over upper edge of the hand hold to act as padding. I find CA glue works quite well for this.

The exact size and placement of these pads is going to depend on the geometry of your harp. I cut the  $\frac{1}{4}$  sheet of foam into strips that are 24 x 2 x 4 inches wide on the band saw. These are cut into blocks 4 x 4 x 2 and glued around the knee block, head and feet of the harp to cradle it within the case. I shape these blocks with a belt sander to conform to the fillets inside the case. 3M's adhesive spray Supper 88 will hold these in place, but I think the Cammie 373 works better.





Pockets for the tips of the feet have been melted into the foam with a soldering iron. I also added to small blocks of foam on each side of the sound box to keep the harp centered within the case. The black string is a lid restraining strap made from parachute cord that keeps the lid propped open for while the harper removes or places the harp into the case.

At the treble end of the neck, the levers will usually get adequate protection from the knee block which will contact the case side first. At the bass end, they are much more vulnerable. So, note in the picture on the right, that the pads on each side of the neck have are different thicknesses. If you have a choice, put an extra inch of padding on the lever side. The levers are more damage prone than the square ends of the tuning pins that are on the other side of the neck.

Ideally the foam should firmly cradle the harp. When you shake the case, you should not be able to hear the harp shifting around inside.

### Painting

I use Porch and floor paint because it is fairly tough and comes in covers that readily hide the scuffs and grime that inevitably come with travel. I use two coats applied with a little five inch roller for the flat areas and a brush for everywhere else. Splatter paint with an accent color will help hide scuffs too. The harp shown here has vinyl cut lettering that you can order from vendors like [www.greatlettering.com](http://www.greatlettering.com).



### Lifting straps, lid restraint

To make it easier to lift the case in and out of cars, I add two straps to the lid. Near the top corner of the lid, I drill a 5/16 inch hole. I cut a piece of nylon webbing about 18 inches long and feed both ends into that hole from the outside. I tie the ends together into a knot inside the case and pull the knot tight against the case wall, leaving a five inch loop to grab. At the bottom end of the lid I make another handle, this time using two 3/8" holes and tying each end of the strap inside the harp for each one.

Finally, I use the same technique to make a lid restraining strap from parachute cord. I cut a piece about 24" long and dill 3/16" holes near the rim strip. Parachute cord is a little stretchy, so I position those holes so they will stop the lid when it 4-6 inches beyond is vertical balance point. The restraining strap installed the opposite of the other straps, inside the harp with the knots outside. I glue the

knots to the side of the case with a dab of CA glue.

That's it!

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Materials needed:

From the Hardware Store

A little less than two sheets of 5-6mm plywood (Luan will work, but I find the \$20/sheet birch ply is more carefully made)

~20 feet of corner strips ripped from a 2x4 on the table saw

Four cheap disposable 2" paint brushes

From Epoxy Purveyor ( [www.raka.com](http://www.raka.com) )

1.5 Gallons of Epoxy

5 lb bag of wood Flour

25 yards of 6 oz fiberglass tape, 6" wide

Case Hardware ( [www.reliablehardware.com](http://www.reliablehardware.com) )

Qty	Part	Description	Price
2	A3020	Latches	\$6.25 ea
2	9024	Tilt caster,	\$8 ea
1	RH1221	piano hinge 3'	\$5
2	1606	Rubber bumper	70cents ea
5	RH1210	Nylon webbing	50cents/foot

Polyethylene Foam ( [www.closedcellfoams.com](http://www.closedcellfoams.com) )

Quarter sheet of their 2" thick 2.2 lb density foam (\$38 + s/h)

Cammie 373 Spray foam (\$10)

Short Pan head screws to attach hardware ( [www.mcfeelys.com](http://www.mcfeelys.com) )

100 count box of #8 x 5/8" Round washer Combo screw, item 0805-WCT

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After I posted this building guide on my website, Don Stackhouse wrote several suggestions for lightening the case. Don builds high model gliders, planes and parts for the same crowd, a trade that places a very high premium on making components that are extremely light, but strong and impact resistant too.

“. . .with regard to the epoxy fillers in the corner fillets. Yes, sawdust is cheap, but there are some other options. In general, for things like that I usually create a "syntactic" (i.e.: structural) foam by mixing milled glass fibers for strength:

[www.aircraftspruce.com/catalog/cmpages/milledfibers.php](http://www.aircraftspruce.com/catalog/cmpages/milledfibers.php)

plus microballoons for lightness and sandability:

[www.aircraftspruce.com/catalog/cmpages/bubbles.php](http://www.aircraftspruce.com/catalog/cmpages/bubbles.php)

plus some thixotropic silica to make it hold still after forming to shape, but still easy to spread and form into the initial fillet shape:

[www.aircraftspruce.com/catalog/cmpages/cabosil.php](http://www.aircraftspruce.com/catalog/cmpages/cabosil.php)

If you just want something essentially equivalent to the "wood flour", the microballoons by themselves will get the job done. Mix the resin first, then mix in microballoons to get a consistency a bit thicker than toothpaste, but not as thick as peanut butter. This will take about 2-3 parts microballoons to 1 part resin by volume.

The other structural alternative to milled glass fibers is flocked cotton:

[www.aircraftspruce.com/catalog/cmpages/flockedcotton.php](http://www.aircraftspruce.com/catalog/cmpages/flockedcotton.php)

As far as the structure goes, a way to save some weight might be to use Luan mahogany ply instead of birch ply, then lay up an outer and an inner skin of about 3 oz. fiberglass. For something exceptionally easy to form over the required shape, I recommend a satin weave, such as the 4-harness satin weave 3.1 oz,yd cloth from CST:

[www.cstsales.com/e\\_glass\\_cloth-ss2.html](http://www.cstsales.com/e_glass_cloth-ss2.html)

For something very similar but heavier, the Rutan 8.8 oz/yd bidirectional cloth (used on Burt Rutan's homebuilt aircraft such as the VariEze and LongEze) is outstanding:

[www.aircraftspruce.com/catalog/cmpages/rutan.php](http://www.aircraftspruce.com/catalog/cmpages/rutan.php)

Of course if cost is no object and weight is the major issue, there's always honeycomb core instead of plywood:

[www.aircraftspruce.com/catalog/cmpages/01-00488.php](http://www.aircraftspruce.com/catalog/cmpages/01-00488.php)

but at that point you will need some new techniques and equipment. The simplest approach might be to wax and mold release a couple sheets of Plexiglass, lay up the fiberglass skins on that and then (while still wet) sandwich the honeycomb in between, then peel off the Plexiglass after the epoxy cures. A vacuum bag system would be nice to squeeze everything together for a good bond over the entire surface, but simply laying the wet sandwich on a flat surface and then weighting it down with sand, or a partially-filled water bag (a water bed mattress?) would also work.

End-grain balsa sheet would be a good alternative to honeycomb:

[www.cstsales.com/end\\_grain\\_balsa.html](http://www.cstsales.com/end_grain_balsa.html)

It, in combination with glass skins, would be quite a bit lighter and stronger than ply, and might not be much different in cost. It could also be formed easily into curved shapes. For example, you could drape it over a form and lay up a glass skin on the outside to form a "tub" that combines the sides and back of your shell half, then add end caps, then lay up the inside skin after it comes off the form. Form your filleted corners along just the ends.

Lots of things possible with a fairly reasonable increase in the level of complexity.”