

Repairing a Carbon Fiber Bicycle Frame

by [art medlar](#) on February 23, 2013

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Intro: Repairing a Carbon Fiber Bicycle Frame

One fine morning I was riding up the mountain and I guess I was pedaling too hard or something.

Somehow — and we're not precisely sure of the precise sequence of events — it seems that I managed to break the bike chain. The broken chain then got itself entangle in the rear derailleur. Since I was still pedaling, fairly hard, this caused the rear derailleur to be ripped from the frame.

All of this happened within the space of about a second. The next second would be even more exciting.

Since I was still pedaling, and the chain was still on the front chainring, the derailleur was then dragged through the narrow space between the rear wheel and the right-side seatstay. Since this part of the frame is a crispy brittle carbon fiber tube, the derailleur managed to take a nice chunk of tube with it as it went sailing past.

This is an interesting bit of damage. I'd never seen it before and although the bike, after a bit of chain tool activity, was still seemingly rideable, it was difficult to know exactly how dire a problem it was. Unlike steel which will bend considerably, carbon fiber tends to fail all at once and catastrophically. So it's a safe conclusion that this is a big problem.

The internet wasn't terribly helpful. Apparently, this is not an uncommon thing. There's a company outside of Santa Cruz called Calfee Design which seems to do almost all the repair work for everybody and everybody seems to recommend their work. Sadly, their work starts at a \$300 minimum, requires the entire frame to be stripped down and shipped, and they don't make any particular guarantees.

The first bikeshop people I talked to were anxious to sell me a new bike. A friend who knows a thing or two about frames said to chuck it and buy a new frame. Trek, the company who made the frame with the brittle part right there in the derailleur flight path, would happily sell me a new frame through their "crash replacement" program which borders on a complete scam and briefly made me hate them.

Things weren't looking good.

Then I ran into James at the Missing Link bike shop in Berkeley. While everyone else had been pessimistic and dour, James was brim full of gung ho. And while he had no actual personal experience in this department, he knew someone who had heard of someone who had done it himself.

Good enough! This was precisely the encouragement I needed. So I rolled the bike home and set about figuring out what I'd need.

The entire project took three days, almost all of that spent waiting for stuff to dry. Materials mostly came from TAP Plastics, a local chain selling all kinds of fascinating and deadly polymers. There are a bunch of cheaper alternatives on the internet but I wanted to get this done in a hurry. You probably have a similar place in your nearest large urbanization.

What follows is a set of photos and notes on the process. I hope this is helpful. As far as whether this is a safe or effective way to repair a frame, you're on your own. Seek the advice of a qualified professional. I am neither.



Step 1:

Note the hipster single-speed setup. After the violent detachment of the derailleur, this got me back home. Also note: hole about six inches up the right seatstay.



Step 2:

Perhaps the only advantage to having 24 spokes on the rear wheel is that there's all that space where the derailleur was able to slip through, preventing even more damage. And no spokes broken.



Step 3:

A better look at the hole. At this point, it's hard to tell how extensive the damage is.



Step 4:

OK, looks bad. Why on earth you'd design a bike frame with a crispy, nominally irreparable component right here in the line of fire is beyond me.



Step 5:

Here's the damaged derailleur hanger. Intentionally made of softer material than the frame or the derailleur itself. When the chain broke and got wrapped around the (now missing) derailleur, it pulled very hard. This broken piece is designed to break off before a chunk of the frame or the derailleur break. You can see the little allen bolt where the broken piece can be removed and a new one put on. They're not terribly cheap (about \$20) but far less expensive than a frame.



Step 6:

There appears to be some damage to the inside, wheelside surface, though it seems mostly superficial.



Step 7:

So let's get started. The plan is to sand off the clearcoat around the damage, fill the hole, and then wrap a few more layers of carbon fiber and epoxy around the tube in order to, hopefully, return it to serviceable strength.

First, I taped off about a six-inch segment of the seatstay around the damage, and began sanding.



Step 8:

Tools at this point are sandpaper and fingers. I started with some 220 grit paper, being a little gunshy at first, but that was working real slowly so pretty soon I went at it with some coarser 110.

Here it is sanded down to the fiber level. You know when you get to this point because the sanding dust turns dark grey rather than white.



Step 9:

Once all the loose crap is sanded away, the hole is smaller than I thought. And there doesn't appear to be any obvious cracking of the tube beyond the perimeter of the hole.



Step 10:

Now to start patching the hole. The idea is to fill it with epoxy, let that cure, and then sand down to a smooth surface which will then be wrapped in fiber.

The epoxy and filler come from a local epoxy and filler shop. There is infinitely more of each than I'm ever going to possibly use but these are the minimum quantities available. Total cost was a little under \$50.

What we're looking at is a large round bottle of marine-grade epoxy resin, a small round jar of "cab-o-sil" filler, and a smaller rectangularish bottle of epoxy hardener. Epoxy resin is a magic liquid that stays liquid indefinitely. Until you pour some of that hardener liquid into it. Which starts a crazy exothermic (ie, gives off a lot of heat) reaction that quickly results in a hard, solidified resinous mass. The speed of the reaction is determined by the types and amounts of epoxy resin and hardener used. Generally, the slower the hardening, the stronger the eventual bonds.

There are trade-offs to be made in the choice of epoxy resin. Some are stronger than others. Some dry clearer (as opposed to browner/yellower). For this job, I wanted the strongest I could find. But I also wanted as colorless an end-product as possible (because I was attempting not just a mechanical repair, but an aesthetic one as well). I ended up looking through the catalog (where these qualities are listed) and picking a resin that seemed to be good enough in each department.

And this "cab-o-sil", what is it? The label says "fumed silica". A white fibery powderous substance that is probably hell on a lung. Make sure you're wearing a dust mask. It's here to give the epoxy some body so that it can be stuffed into the hole and stay there. The other option would have been microspheres. Which are these tiny, bigger than dust but not much, hollow glass bubbles that do roughly the same thing. The difference seems to be that the bubbles produce a much lighter solid while the silica produces something a little stronger. Proper tradeoff? I don't know. The internet sez microspheres, the plastic shop guy sez cab-o-sil, and the price is the same. Since we're talking milligrams here, I go for the silica.



Step 11:

At this point the plan is to goop a healthy amount of goop into the hole and past the hole into the tube. Let it harden and then sand it down smooth. In theory, this should give the new fiber a smooth surface to bind to. And should stabilize the ragged edge of the damage.

Is this the right approach? It seems like it but often these things have a way of being completely counterintuitive. It could be that by loading the tube at this point with a stiff epoxy will concentrate stresses at some other point, simply moving the failure to a different part of the tube. Or maybe not.

Plus it's hard or impossible to tell what stresses and strains this particular tube sees in action. I'll bet there's a mechanical engineer with a masters degree in exactly this but that mechanical engineer is not me.

Working out the physics of a static load on a bike frame isn't too difficult. But where's the fun in a static load? Once it get moving everything gets awfully complicated. And all of the obvious simplifying assumptions (the chain pulls the center of the rear axle, the rider's weight is always on the pedals, the bottom bracket isn't flexing in three axes, the road is smooth, etcetcetera) all of them seem likely to also be wrongifying assumptions.

So I tape off everything around the hole.



Step 12:

The closer the tape, the easier this is going to be to sand down after it cures.



Step 13:

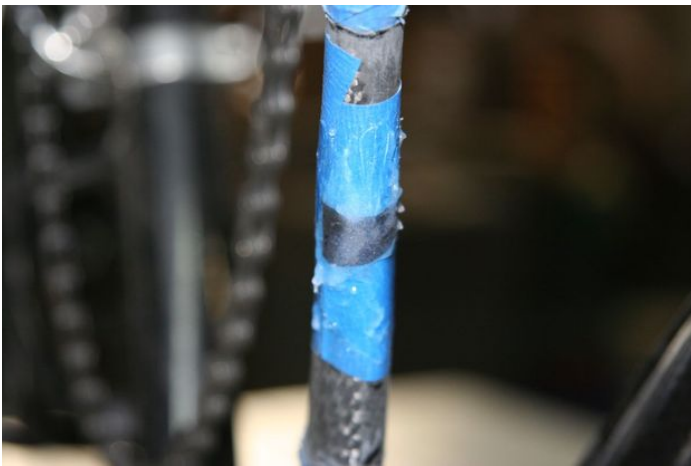
The epoxy is mixed 4:1 with the hardener and then I added the filler. Enough to get it to about a peanutbutter consistency. Once mixed, there's oh maybe 15 minutes before it heats up and solidifies. Which seems like it should be plenty of time but almost never is.

This is hundreds of times more glop than I'm going to need. But it's fairly difficult to mix up small amounts of epoxy with any accuracy. And if you get the proportions wrong you end up with a sticky, non-hardening mess that's a huge bother to wipe off and start over.



Step 14:

I glopped on enough to fill the hole and maybe about 1/4 of the tube inside. Again, is this the right thing? Maybe I should attempt to fill the tube around the hole. It seems like that would make it stronger. But then, there are lots of ways that I could imagine that also weakening the tube. So I compromised.



Step 15:

The next day it's solid. Now to peel off the blue tape and sand it down.

It turns out that peeling off epoxied blue tape is not particularly easy and I've got to sand off a lot of the epoxy from the tape first. So the order of operations becomes sand, peel, sand.

Lesson: next time, be even less sloppy with the epoxy.



Step 16:

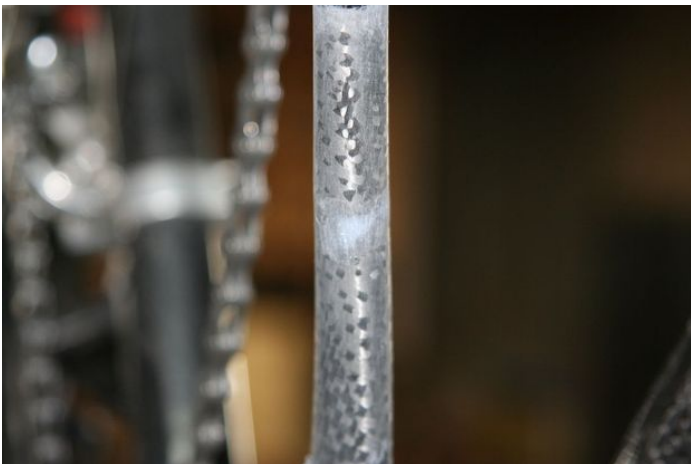
Once sanded, it looks pretty nice. There's a strong temptation to stop right here.

**Step 17:**

Another couple of views of the filled hole.

**Step 18:**

I could shine things up and craigslist the bike right now and who would be the wiser? But that would be cheating.



Step 19:

Here's the carbon fiber. It's about \$45 per yard but the epoxy shop guy was willing to sell me one foot for \$15. Which is still about 20 times more than I need.

This stuff frays like mad at the edges and that's a bit worrying. I have no real idea how to cut it but scissors seem to work.



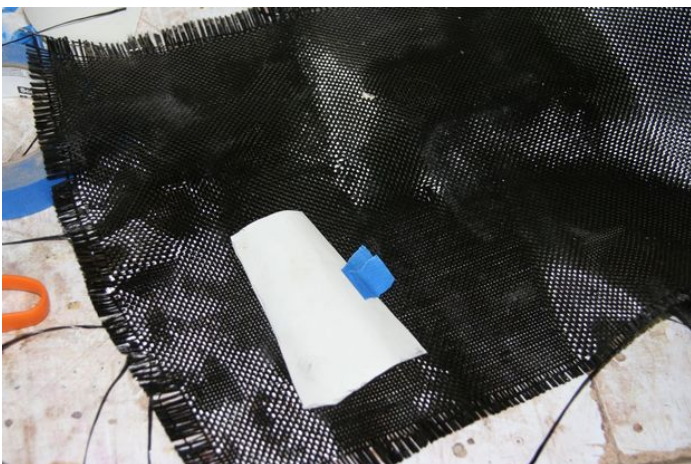
Step 20:

The shape of the tube that I'm repairing is pretty space-age. So a simple rectangle isn't going to work. I made a little template out of paper.



Step 21:

How many layers of fiber should I use for the repair? No clue. Numbers like four and five seem to get tossed around on the internet when people talk about making airfoils and things.



Step 22:

So I replicate the template four times.

What's happening here is I'm going to cut out a piece of fabric that's the same complex shape as that white cardboard template. The fabric is going to be soaked in epoxy and then wrapped four times around the frame tube, covering the hole.



Step 23:

Masking off everything on the bike you don't want to get epoxy on is crucial. In retrospect, this is far too little masking. The epoxy is going to go everywhere.

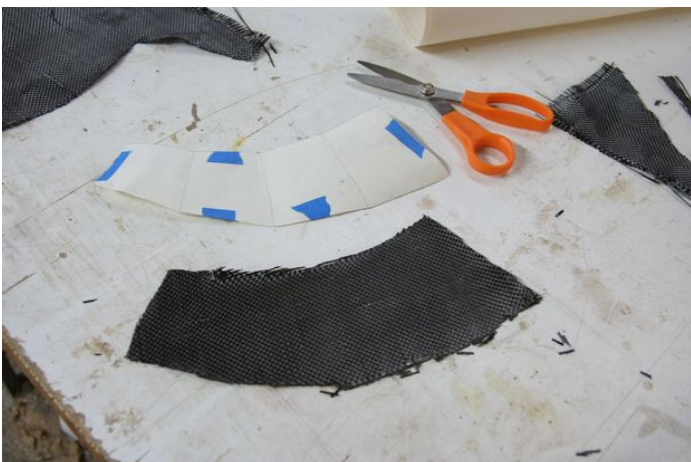
Time spent with plastic and tape at this point will pay off handsomely tomorrow. This paragraph has been brought to you by the voice of experience.



Step 24:

I'm going to wrap a single piece around the tube and I have this theory that each successive wrap should be a little narrower than the one below it. The idea is that then there won't be an abrupt change in thickness at the edge of the repair. So note how I've modified the shape of the fabric from the original template: it tapers a bit to the left. The right edge is going to be attached to the frame tube first and then wrap around four times, ending with that narrower edge on the left.

This will turn out to not be strictly necessary — it sands down pretty nicely — but I'd do it this way next time too.



Step 25:

Bike upsidedown is not the best position in which to be doing this. Lay the bike on its side, broken side up. The problem is that the epoxy-soaked fabric will want to follow gravity downward. At least until it starts to set up and gets a bit tacky. But then that only leaves you a couple of minutes where it's still workable.

At the time this didn't occur to me, so watch as I do it wrong.

(This is the point in the process where you go visit the bathroom, have a little snack, relax for a bit. When you come back the epoxy's going be prepared and the next hour is time- and attention- critical.)



Step 26:

I again mixed up far more epoxy than I needed. The paint brush was used to wet the entire sanded portion of the tube. The fabric was laid out on a disposable surface and a healthy amount of epoxy poured over it.

To spread the epoxy over the fabric I needed a roller of some kind. The local horrible Michael's Craft Store seemed like a place to find this roller of some kind. I've been fooled that way before. What a disastrous place, it's 60% dried flower arranging, 35% scrapbooking (!) supplies, and then an assortment of random art supplies and other garbage. But today I was in luck. One of those random other things was a toy rolling pin for fifty cents.

The epoxy is glopped on and then spread out with the roller. You don't need to use a silly toy; a dowel or an empty beer bottle would also work. However, anything you use will never be able to be used for anything else ever again. So use something disposable.

This is also a good time to talk about ventilation. At this point in the process, the epoxy is giving off clouds of god-knows-what kind of volatile poisonous gasses. You should endeavour as much as possible to avoid breathing these vapours. Open windows, a gentle breeze, and a respirator rated for organic solvents are all good friends to have while working.



Step 27:

There are no photographs of the fabric wrapping maneuver because I was pretty busy and covered with epoxy while that was going on. However, it went about exactly as expected after the initial scare where the fabric kept sliding off. You start with one edge of the fabric attached to the frame tube and begin wrapping it, as carefully and neatly as possible. Keep the tension snug, avoid folds and creases, don't let your mind wander.

Once the fabric is in place, the next thing is to cover it with another tight wrapping while it cures. The material of choice for this seems to be black electrical tape wrapped so that the sticky side is out.

Something to be careful of here, which I was not, is to wrap the tape in the same direction as the fabric was wrapped. What you're seeing here, though you can't see it, is the tape being wrapped in the opposite direction. This has the misfeature of causing the fabric wrapping to loosen if you're not excessively careful. It eventually came out alright, so maybe not a major issue, but save yourself some worry and do everything in the same direction.



Step 28:

Lots and lots of epoxy will ooze out while the tape is being wrapped. A giant mess! Wear gloves and remember to have already masked off everything you don't want epoxy on. Because once it is on, it's not coming off.

Once complete, I took a pin and poked a few dozen holes in the tape so that more could leak out. Lots did.



Step 29:

There are some stray fibers left hanging out. At this point I'm not sure what sort of problem that's going to be, if at all.

The loop of blue tape on the non-damaged tube is there at the corresponding location of the hole. This way, once it's all sealed up I'll have some idea where the damage was.



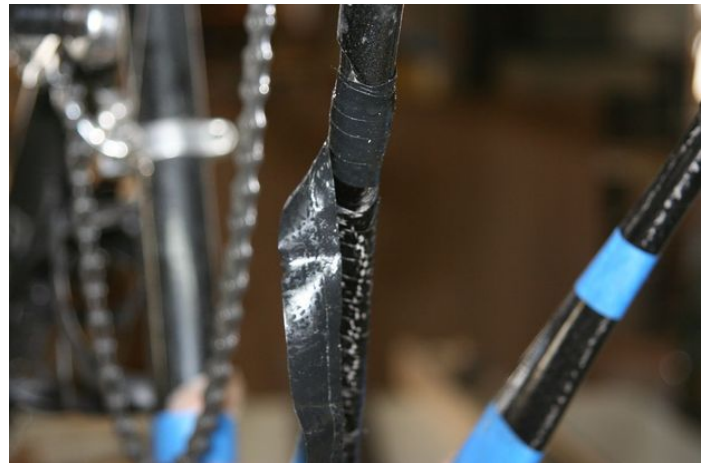
Step 30:

Next day, everything's nice and hard again.



Step 31:

The tape peels off nice and easy. There's a bit of a spiral but that should sand off easily. I hope.



Step 32:

Yep, just a light sanding with some 220 grit and it's starting to look interesting.



Step 33:

Inside done, now for the outside.



Step 34:

When I said I mixed up too much epoxy, this is what I meant. But it cures to a really nice amber color. Next time I'll find some dead bees first and stick them in the extra before it hardens.



Step 35:

Once it's sanded, it's looking good. But the fabric pattern is all wonky. It probably would look ok left like this but I decided to go for one more, this time carefully wrapped, layer.

Still, there's now no longer any sign of the original injury.



Step 36:

Out comes the template again.



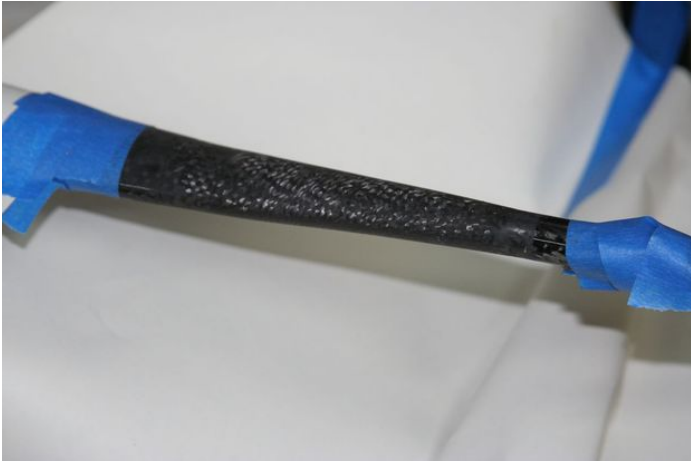
Step 37:

This is all happening the day after the initial fabric wrap, so I need to mix up even more excess epoxy. This time I tried hard to keep it under control.



Step 38:

Also, I laid the bike on it's side this time.



Step 39:

The epoxy soaked fabric is wrapped around the tube, very very carefully and trying to match the pattern in the new fabric as closely as possible to the pattern on the original frame tube.

The seam is on the inside, wheelside, where it will be less visible. Then it's all wrapped with tape as before.



Step 40:

Pinholes again. Gloves are important. You will be very happy if you do this with gloves on.



Step 41:

More oozy everywhere.



Step 42:

Hey, next day it's looking very nice!



Step 43:

More light sanding. Followed by some heavier sanding to get the shape right.

Five layers definitely adds some bulk. Though not as much as I was expecting. Five layers of dry carbon fiber is pretty thick but once it's soaked in epoxy and compressed, it's thinner than I thought it would be.



Step 44:

Painting time. The spray booth and turntable are probably overkill but I happen to have them around. You could do this in any clean, well-ventilated space.



Step 45:

Again, mask off EVERYTHING. You will have learned your lesson by now.



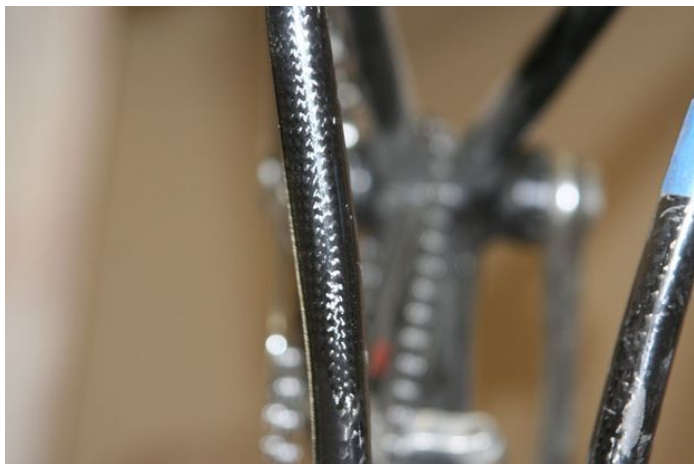
Step 46:

Time to put a glossy coat over the repair to match the original frame topcoat. I'm not sure what's the right thing to use here. Probably the original clearcoat is some sort of catalyzed unobtainium from a country with very different air quality regulations. Next best thing's probably a rattle can from the hardware store. I don't think I'll be needing the rust stopping action. And again, about 20 times more stuff than I need.



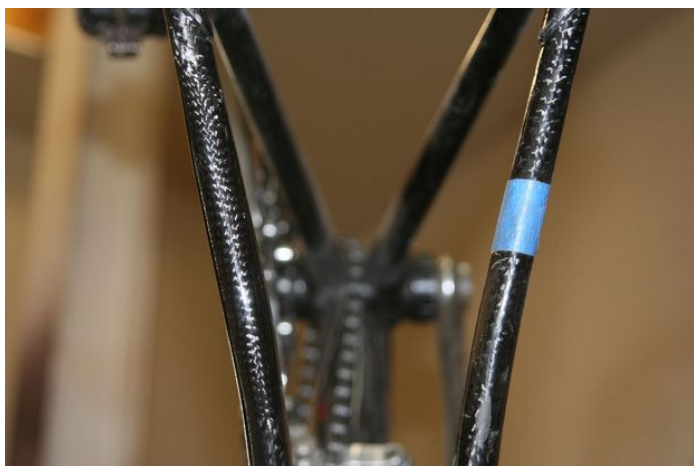
Step 47:

Ten very thin coats or so, applied as per label directions, and an overnight to dry. And it's looking nice.



Step 48:

The weave pattern isn't the same as the original. Which is a bit of a drag. But otherwise, it's hard to tell there was ever anything wrong. From this angle, the slight bulge of the five new layers is visible. (the repair is on the left side of this photograph, directly opposite the blue tape.)



Step 49:

Back outside to the brick wall where we started. Smooth and shiny. Now it's just a matter of screwing on some new parts and I should be back on the road.

As an epilogue: I have ridden this bicycle almost 3000 miles since the frame repair. I haven't noticed any issues at all. I've left that little blue loop of tape on the left seatstay, directly opposite where the original hole was, so I can locate and carefully inspect the site of the repair. So far, it's holding up well.



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