

Building a Helical Stair

Laying out a spiral stringer
with a little help from the trig tables

by Rick Barlow

A house I recently finished near Telluride, Colo., needed a spiral stairway to wrap half-way around its 4-ft. dia. stone chimney. I decided that a helical stringer supporting the treads by fabricated steel brackets would satisfy structural requirements and complement the house's contemporary design.

In theory, making a laminated wood helix isn't that difficult. Basically all you do is wrap successive layers of wood around a cylinder so that it spirals upward at a constant angle. But to glue up a helical bent lamination like the one I wanted for my stair stringer would require a cylindrical bending form larger than the chimney itself. I could have framed up such a form from curved plywood plates and 2x studding, but that would have eaten up a lot of time and materials.

I chose instead to make a bending form from five pieces of $\frac{3}{4}$ -in. plywood and a strip laminated from three layers of $\frac{1}{4}$ -in. plywood (drawing, below). The trick was to space the on-edge pieces of $\frac{3}{4}$ -in. plywood at equal intervals along the proposed rise of the stairway, and to locate on each of these supports—or bulkheads—a 10-in. wide plane that would lie precisely $\frac{3}{4}$ in. below the surface of

my theoretical half cylinder. To these five planes I could attach three layers of $\frac{1}{4}$ -in. plywood. Glued together, this rigid plywood curve would be the platen, or base, of the bending form. To it I'd clamp the mahogany plies that would make the helical stringer.

In section, I wanted the stringer to be 5 in. wide by 6 in. deep, with its corners radiused with a $\frac{3}{4}$ -in. roundover bit. Plies $\frac{1}{4}$ in. thick would easily make the required bend, and I used 20 of them 6 in. wide.

The centerline of the helical stringer would lie $42\frac{1}{2}$ in. out from the centerline of the chimney cylinder. This meant that a typical 36-in. wide tread would clear the stonework by about $\frac{1}{2}$ in. Subtracting half of the stringer thickness ($2\frac{1}{2}$ in.), gave me a 40-in. radius for the concave side of the stringer. This dimension then was the radius of the outside (convex side) of the bending form.

To create the helix, the first and fifth supports of the bending form needed to support the stringer against vertical edges. The second and fourth needed 45° edges, and the stringer would run over a horizontal edge at the middle support.

I nailed the five plywood bulkheads to the

floor with 2x4 blocks and braced them diagonally to handle the forces they'd have to withstand during gluing and clamping. Next, I bent the three layers of $\frac{1}{4}$ -in. plywood over these supports. The first layer was screwed and glued to the bulkheads, and the next two glued on top. I made sure that during this process the whole assembly stayed properly aligned throughout its length.

I built the form so that its centerline would be 5 in. off the floor. This way the stringer could run long at each end and be trimmed to fit the floor and rim joist later. I covered the plywood helix with a strip of visqueen so the mahogany wouldn't get glued to the form.

Laying out the stringer—The laminations for the stringer started out as 16-ft. long mahogany boards. I had them milled to a thickness of $\frac{1}{4}$ in. and ripped into 6-in. widths. To determine the length of these pieces, a little trigonometry was required.

First, I drew the stringer in elevation as if it were a straight piece of wood (drawing, facing page). The height of the triangle thus formed was the rise of the stringer. This is the total rise (distance from the first floor to the second) minus one riser height, as in a standard staircase. The total rise (110 in.) breaks down into 14 rises of 7.86 in. (about $7\frac{7}{8}$ in.). Therefore the total rise minus one rise ($7\frac{7}{8}$ in.) for the top step (landing) results in a stringer rise of $102\frac{1}{2}$ in.

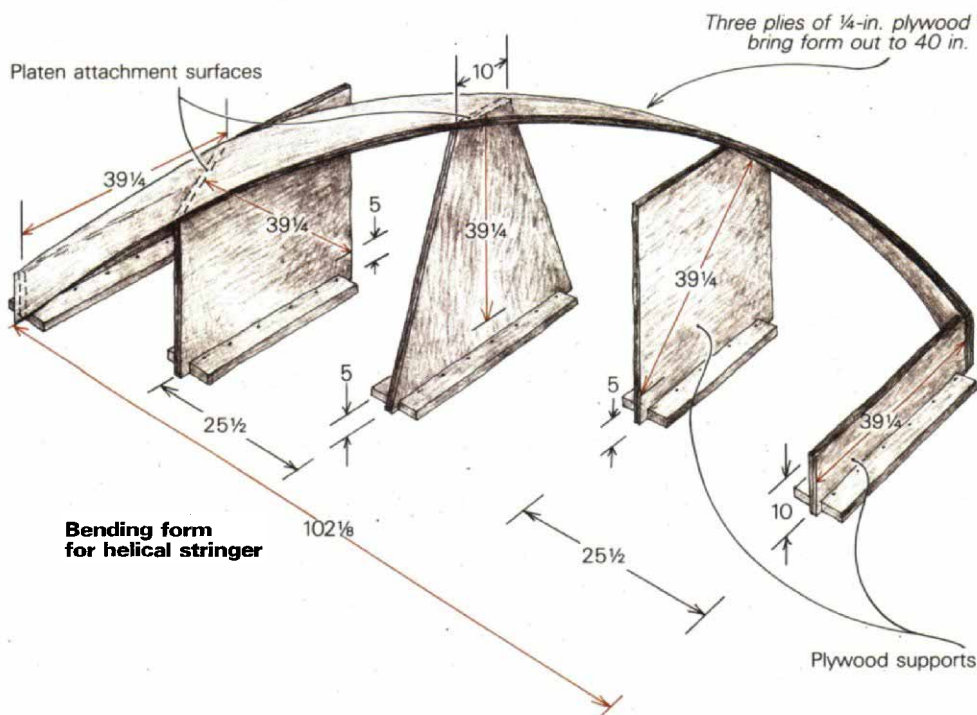
The base of the triangle represents the distance traveled by the stringer in its run around the chimney. In this stair, the stringer winds through a 180° arc around a $42\frac{1}{2}$ -in. radius at the center of the lamination. Its run, therefore, is $\pi \times 42\frac{1}{2}$ in., or $133\frac{1}{2}$ in.

The length of the stringer itself is the hypotenuse of this right triangle. The Pythagorean theorem ($a^2 + b^2 = c^2$) tells us it is 168 in. long, just over 14 ft.

Since the outer plies travel larger radii than those at the center, they required slightly longer pieces of wood. I ordered the 16-footers to be sure of sufficient length.

The drawing of the flattened helix also helped me determine various angles. By finding the cotangent of the triangle ($\cot A = \text{adjacent/opposite} = 133.5/102.125 = 1.3072$), I got the pitch angle of the stringer, $37^\circ 25'$.

The complement of this angle is $52^\circ 35'$. This is the angle that the stringer makes when intersected by a plumb line, an angle I needed



to know later when I counterbored the underside of the handrail to receive its posts.

I laid out the treads on the drawing of the straightened helix, and divided the 102½-in. rise of the stringer into 13 equal rises of about 7¾ in. each. I figured the distance along the stringer from one tread to the next by dividing 168 (the stringer's length) by 13. This distance is 12.96 in.

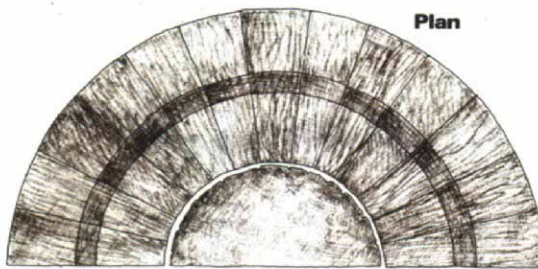
Gluing up—Now, with the mathematics out of the way, I started gluing up the stringer. Since I wanted the glue to stick to the steel tread-support plates as well as to the wood, I used a resorcinol-formaldehyde glue. It's a hassle to use, and almost impossible to remove from tools and hands when it sets up, but it's strong stuff.

After spreading the glue with a small roller, I laid three or four 16-ft. long mahogany plies on the upright center support, clamped them there and then bent each side down to the ends of the plywood helix. You need lots of clamps. I have eight bar clamps, four hand-screws, four smaller bar clamps and ten C-clamps. I borrowed about this many again from a friend and still had what I think is the minimum number of clamps for the length of this stringer, one clamp about every 3½ in.

Resorcinol glue has to cure at 70°F or above. It will set faster at temperatures higher than this, but it won't bond properly at temperatures below 70°F. Since I was doing this laminating in a house under construction in the wintertime at 9,000 ft. in the Colorado Rockies, I needed to camp out at the job site for seven days and nights to make sure the correct temperature was maintained while the laminating was going on. I glued up three or four layers at a time, letting them dry overnight before removing the clamps.

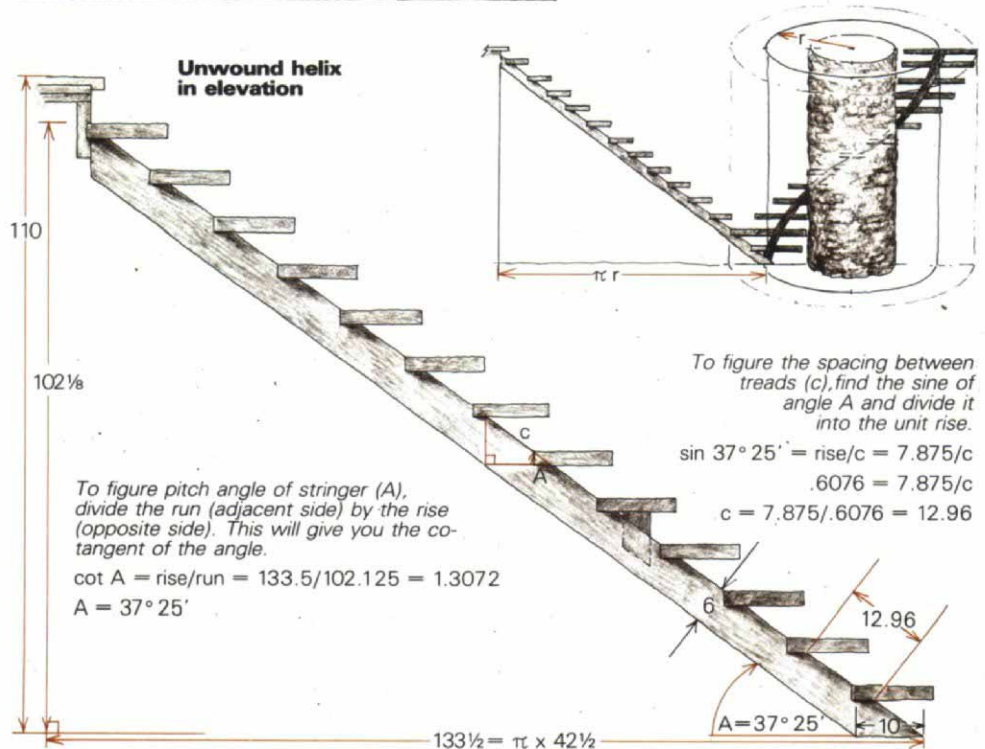
To rout the slots that would receive the steel tread-support plates, I laminated the stringer without glue between the third and fourth laminations and between the 17th and 18th laminations. This let me separate the first three and the last three plies from the center core of the stringer, rout out slots for the plates, insert and secure the plates, and then glue these inner and outer laminations onto the center one. The entire stringer was shaped and sanded before the plates were inserted so the steel would not get in the way.

I made two guide templates for my router to rout out the slots. One was for the thirteen slots on the convex curve of the stringer, and the other was for the thirteen slots on the concave curve of the stringer. Each jig was made to rout a 3-in. wide slot ¼ in. deep. To locate and orient each slot, I hoisted the center core lamination of the stringer into the position it would ultimately take, trimmed off the ends to fit, and temporarily secured it there



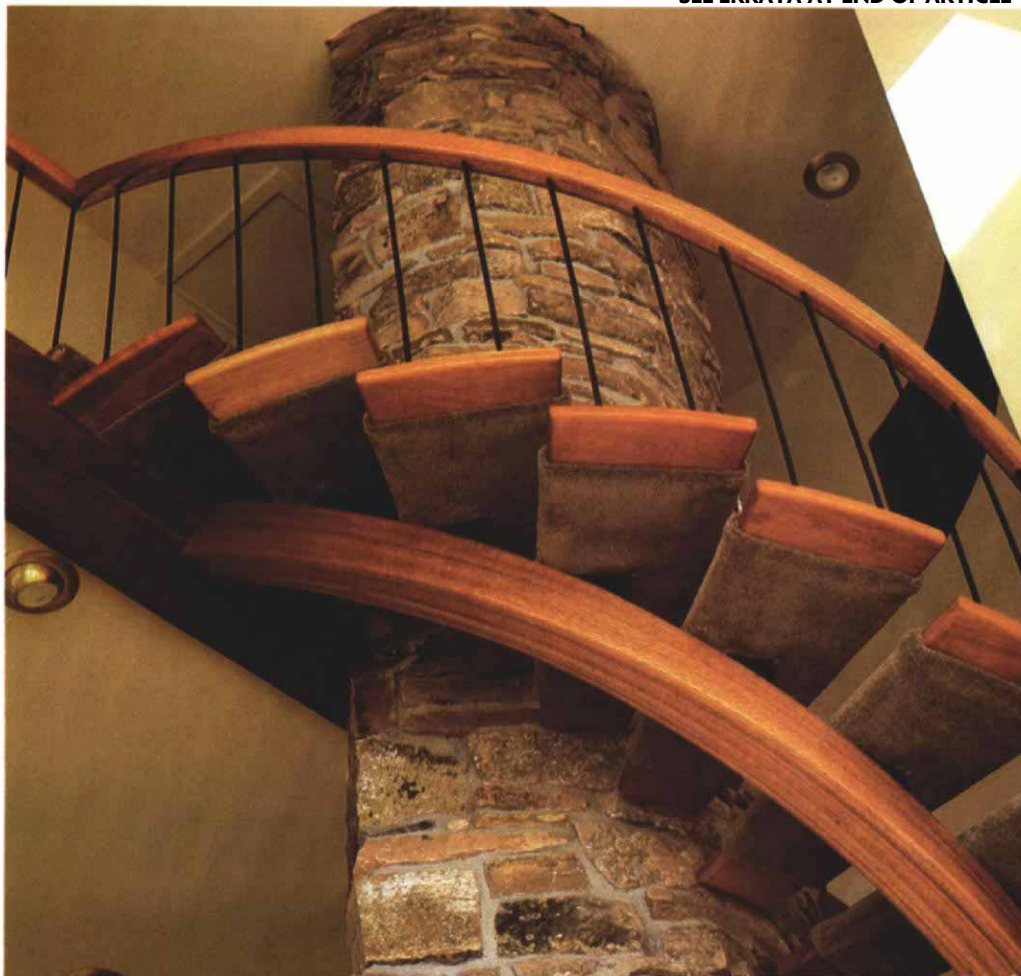
Plan

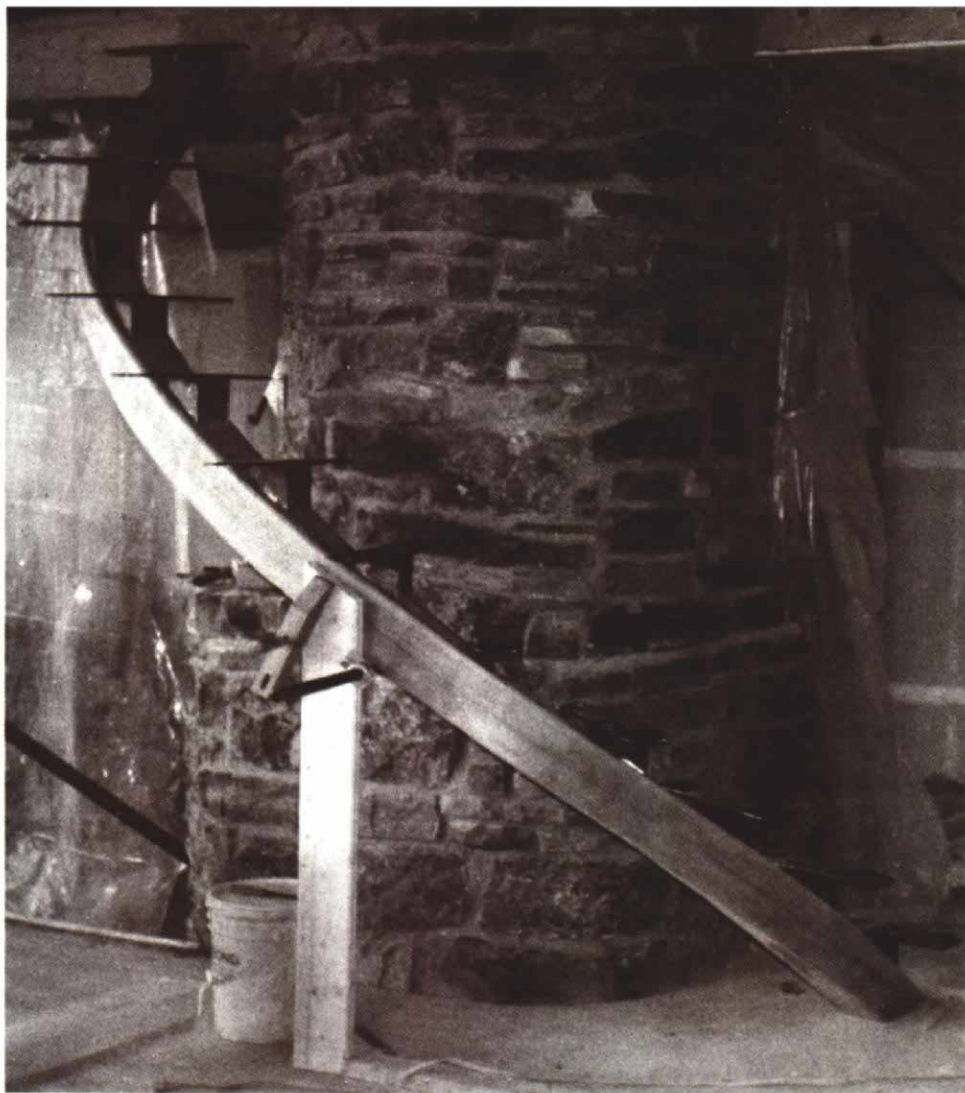
Trigonometry is used to figure pitch angle, stringer length, and tread spacing. The semicircular run is shown as the base of a triangle. The rise is its height, and the stair stringer its hypotenuse.



SEE ERRATA AT END OF ARTICLE

Barlow's helical stairway winds its way around a 4-ft. diameter stone chimney. The single stringer was laminated from 20 plies of ¼-in. mahogany. The treads, made of plywood and solid cherry end boards, are supported by brackets fabricated from ¼-in. steel plate.





Before its treads are attached to the steel-plate brackets, the stairway is installed. The temporary midway support will be replaced by a steel pipe that will be grouted into a masonry planter below.

with clamps and a 2x4 leg at its midpoint. Then using a level, I drew plumb lines on each side of the 26 slots. This way I was sure they would be plumb in the finished staircase.

These slots were 3 in. wide, and their sides followed the curve of the stringer, so the legs of the plates also had to be slightly curved. I hit the middle of each leg with a sledge while it rested on two other plates along their edges. One or two whacks did the trick.

I drilled holes in these plates for four 8d nails to hold them onto the stringer. These and the resorcinol-formaldehyde glue made for a solid bond between metal and wood.

With the tread-support brackets installed, I put the stringer back onto the form and glued the inner and outer laminations onto the core. They were already shaped and sanded, so I had to align the pieces precisely, and use pine blocks to keep the soft mahogany from being crushed by the clamp jaws. I was also careful to spread the glue so not much would ooze out of the joints. What squeeze-out there was, I wiped off before it dried. This assembly was left to dry overnight (photo above).

Installing the stringer—After a little more finish sanding, I cut the outer plies to fit the floor and rim joist. A 180° helix like this one

needs support at its midpoint. I drilled a 2-in. hole underneath the stringer and inserted a galvanized pipe that sits discreetly in some rockwork below.

When the stringer assembly was firmly attached in place, the horizontal tread plates were welded to the vertical plates protruding from the stringer. Using a universal level, I held the horizontal plates level in both planes, while a welder attached the plates from underneath. After cleaning up the welds with a file and wire brush and before attaching the treads, I oiled the stringer and painted the plates and the support pipe flat black.

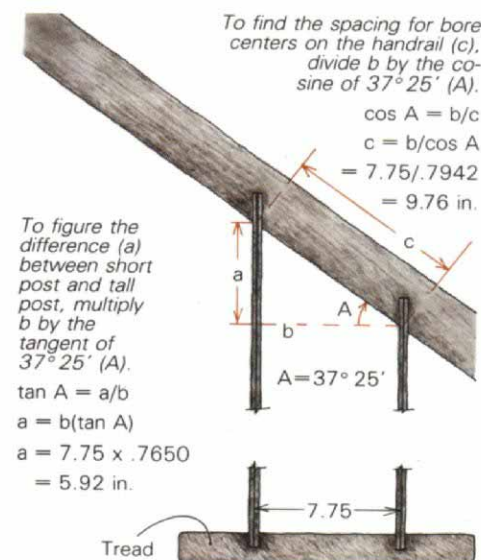
Making the treads—Working out the dimensions of the tapered treads required more figuring. The radius to the outside of the treads was 60½ in. Multiplying by π gives the length of a 180° arc, or 190 in. Dividing this by 13 treads gives 14.62, so the outside arc of each tread is 14½ in. Similarly, I found the length of the inside arc of each tread to be 5½ in. Nosing added an inch, so each tread is 36 in. long with a 15½-in. arc at its outer end and a 6½-in. arc at its narrow end.

I planned to carpet the centers of the treads, and leave solid cherry end boards on each end. I made a center of AC plywood by

laminating two ½-in. thick pieces onto a ¾-in. thick core, yielding a total thickness of 1¾ in.—the same as the cherry. The ¾-in. middle ply of plywood was cut 1 in. shorter on each end, to form a ¾-in. by 1-in. groove. I cut tongues on the cherry end boards and screwed and glued them to the center pieces.

I bandsawed the ends of the treads to conform to the semicircular plan view, and rounded over all the edges with a ½-in. piloted router bit. Finally, I fastened each tread to its mounting plate with four lag bolts.

Bending the railing—The form I built to laminate the handrail was like the one I used for the stringer, only with a larger radius. The handrail would be just under 16 ft. long, so I could use the same boards. I used eight laminations ¼ in. thick and 3 in. wide, making the handrail 2 in. by 3 in. in section. To accept the handrail posts, I counterbored two ½-in. dia. holes in each tread at the centerline radius of the handrail, and spaced them evenly 7¾ in. apart. I then counterbored the underside of the handrail. These holes had to be drilled at an angle of 52° 35' (the complement of the pitch angle). To find the proper spacing for



the bore centers here, I divided 7¾ (the horizontal spacing) by the cosine of the pitch angle, as explained in the drawing. Then ½-in. dia. steel rods, painted flat black, were inserted in the treads. Since each tread gets two rods, one must be longer than the other. By multiplying the tangent of the pitch angle by 7¾, I found the regular difference in length between the long and short rods.

With the help of friends, I worried the rods into their holes one at a time, starting at the bottom rod and working up to the top. By using a rubber mallet and some clamps, I brought the handrail down onto the 26 rods.

All that remained was to carpet the plywood center pieces and metal tread plates. Since the treads are visible from below, this was a difficult job, but it turned out fine. □

Kick Barlow is a contractor in Colorado.

ERRATA

Stair formula wrong

While reading the highly informative article "Building a Helical Stair" (*FHB* #16), I noticed an error on p. 71. The formula under the illustrations reads: "cot A = rise/run = 133.5/102.125." It should read: "cot A = run/rise = 133.5/102.125."

—Greg McCarty, Louisville, Ky.