Building Barrel Vaults

Two ways to ease construction with modern materials

Editor's note: Presented on the following pages are two very different approaches to building a residential barrel vault with modern materials. A vault is an arched ceiling or roof, and its precedent as an architectural form was probably set by the cave dwellings of prehistoric man. The Egyptians used bricks to build the first manmade vaults about 4,000 years ago. Engineering the vaulted form has been a recurring theme in architectural history ever since.

Masonry vaults exert significant outward thrust on their supporting walls, and for centuries the efforts to resist that thrust led to innovative construction techniques—groin vaults, pointed arches, flying buttreses. But toward the end of the 19th century, with the advent of lightweight steel frames for construction, outward thrust was becoming less of an issue in vaulted buildings. In the 20th century, the steel reinforced-concrete shell was developed. This allowed the construction of a vault that exerts no lateral thrust and can be supported just on the ends as if it were a beam. Today the engineering and construction of vaults continues to evolve in response to new building materials.

The barrel vault (also called tunnel or wagon vault) is semicircular in section and is the simplest form of vault. —Kevin Ireton

Trusses and Plywood Gussets

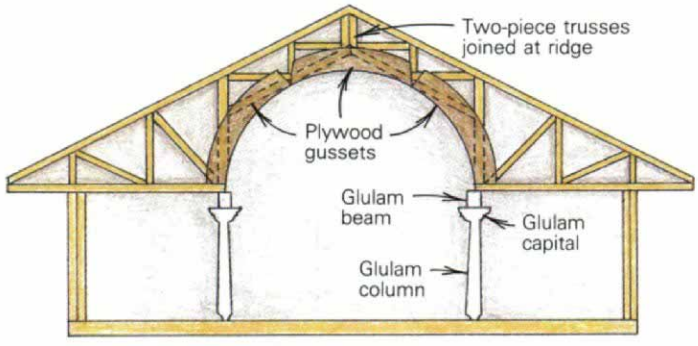
by Gerry Copeland

When I design a house I don't usually start with a dramatic geometric shape already in mind. Most of my designs evolve from site determinants, function, client preferences and budget. However, recently I built a house on speculation, and I wanted it to stand out from its conservative competition in suburban Spokane.

I had recently visited a small Episcopal church in Charleston, S. C. The nave of the church was dominated by a spacious great room with a voluptuous barrel-vault ceiling. This experience, along with a hankering to do some curved detail work, set me in a determined direction. Hopping on the post-modernist bandwagon, I designed a traditional gable-roofed house around a great room, with a vaulted ceiling front to back, a large Palladian window and some whimsical columns and capitals.

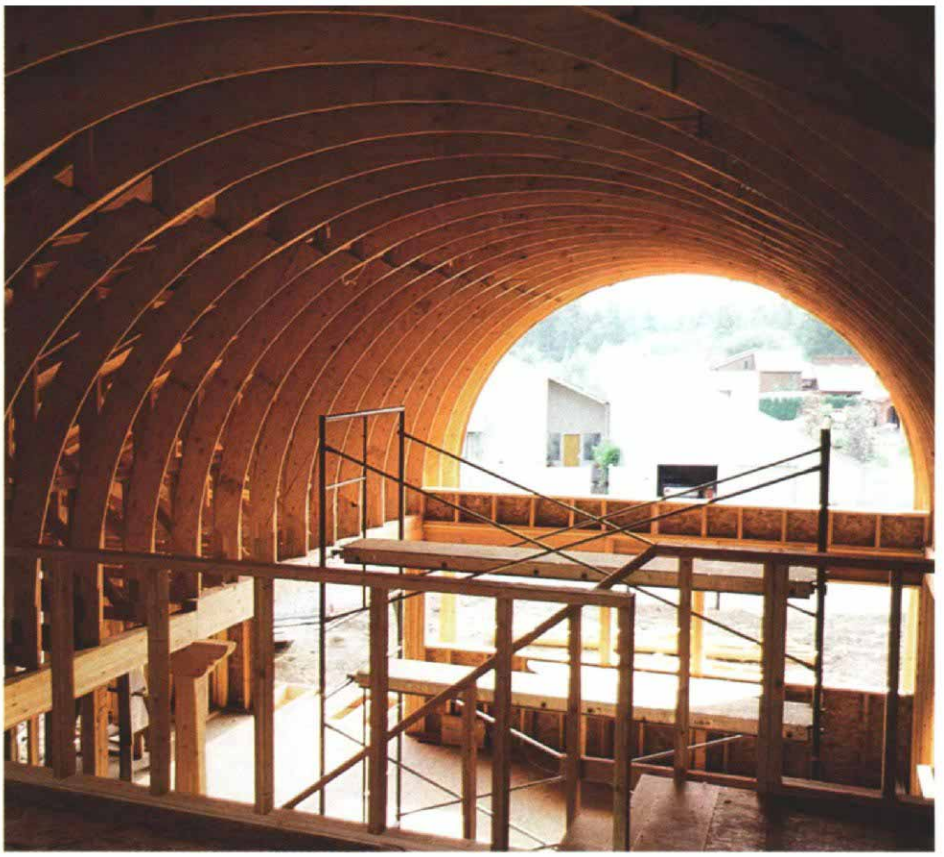
Design—I made the vault 16 ft. wide because that seemed to be the smallest semicircular shape that was still a functional space. Because the rear of the great room was to have a balconied loft, the curved ceiling needed to be an average usable height. I considered an 8-ft. radius to be the minimum for this.

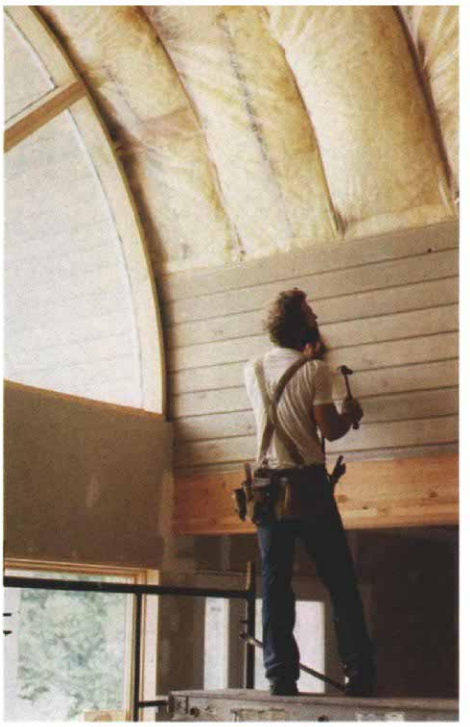
For visual impact I wanted the space to be open from the front of the house to the back. A 16-ft. wide Palladian window at the front of the house and a 5-ft. square window at the back (selected because of cost restraints) provide dramatic lighting.



The basic structure of the house seemed obvious once I laid out the central vaulted space, drew the roof pitch I wanted (6½ on 12) and added supporting columns at the bearing points. By providing a minimum of 18 in. for insulation and ventilation at the narrowest point betweeen the vaulted ceiling and the roof, the roof-truss configuration emerged. A 44-ft. long house-width truss with a bite out of the middle would have been too flimsy to transport and erect. The truss fabricator suggested dividing the truss into two at the ridge line, with two parallel-chord sections cantilevered over the vaulted space to meet in the middle (drawing left).

The design of the rest of the house fell into place quite easily, though with some compromises to the plan in order to keep the central vaulted space as a strong visual element. It was, for example, important to keep the vaulted space uncluttered by inter-





To create the barrel-vault shape, curved plywood gussets were stapled to the roof trusses. The ceiling was finished with 1x6 T&G pine nailed to the plywood gussets. The boards had to be hand-nailed because pneumatic tools wouldn't draw them up tightly against the framing.

secting wall planes. Being a builder as well as an architect, I was eager to work out the details and start framing.

Building the barrel—After all the support columns, beams and walls were in place, the trusses were set by crane onto the structure, one bundle stacked flat on top of the framing at each end of the house. Then my crew and I rolled each truss into its upright position, first one half of the pair, then the other. The cantilevered top sections straightened up nicely once they were pushed together, aligned and nailed. We stapled ½-in. plywood gussets across the adjoining webs at the ridge to tie the two trusses together. After all the trusses were erected, double-checked for alignment and nailed down, we cross-braced them according to the truss manufacturer's instructions, ran solid blocking between them over the exterior walls, and then sheathed the roof with ⅝-in. CDX plywood.

Following the wall sheathing and shingling, we cut the curved gussets that would be attached to the inside surfaces of the trusses to form the vault. After much deliberation over which material to use, we decided on ⅝-in. CDX plywood. In retrospect, a higher-quality ¾-in. plywood would have been a better choice for greater stiffness and a thicker nail base. In order to find the most cost-effective way of cutting the plywood, I spent an evening laying out the curves to scale on paper. I ended up with a cutting solution that yielded four curved gussets, 8 in. high and 8 ft. wide, per sheet.

To scribe curves on the plywood, we used an 8-ft. long wire, wrapped around a pencil on one end and around one of five nails on the other. The five nails were driven into the floor 8 in. apart and represented the centers of each arc. This allowed us to draw them quickly. Then we cut the gussets with an orbital-action jigsaw. Altogether we cut 17 sheets of plywood for a total of 66 gussets.

I'm not sure whether it was by luck or by intuition, but any three of these gussets together, point to point, made a half-circle that was exactly 16 ft. wide. So by lining up the ends of the gussets with the opening in the trusses, we could assure perfect alignment. The gussets were stapled to the trusses with 2-in. sheathing staples. When all the gussets were in place, we sighted down the 42-ft. length of the barrel and saw that the alignment was perfect. At this point in the framing, someone looked up at the exposed framing and said, "This is what the ribs of the whale must have looked like to Jonah" (photo above left).

Siding the ceiling—We used 1x6 T&G pine, prestained with two coats of semi-transparent stain, to finish the ceiling (photo above right). Keeping a straight line for 42 ft. with only a slender ⅝-in. plywood edge to nail to would not be easy, so we eliminated all the crooked pieces, as well as those pieces with loose knots. Because of the barrel-vault shape and the T&G connection, board-to-board nailing into the edge of ⅝-in. plywood seemed strong enough. But if I were to do it again, I'd use ¾-in. plywood and construction adhesive at each rib. In order to get a straight start, we chalked a line at the base of the vault, along the trusses. The first two or three courses could be nailed directly into the bottom of each truss. We decided to use 6d finish nails driven with hammers because our pneumatic nailers wouldn't draw the boards up tight.

We quickly wished that some benefactor had donated perfectly straight and clear T&G cedar for the entire job. Every two or three rows, we sighted down the barrel and compensated for waviness by prying away from a gusset the boards that were bowed inward. All butt joints were beveled at a 45° angle. These joints looked good a year later but would have been better still had the lumber been perfectly dry.

The 16-ft. Palladian window was made for us by a local cabinetmaker and custom window fabricator. Most window manufacturers limit the size of their efforts to windows 8 ft. or less in diameter. Because of this window's size, extra thick muntins, 3-in. by 6-in., were used to withstand lateral wind load. It was built and shipped to the site in one piece, and installing it was a struggle for three of us. The double-insulated glazing was installed by window-glass fabricators after the frame was in place.

Glulam columns—Along the front half of the barrel vault, the roof trusses bear on 6-in. by 16-in. glulam beams, supported by whimsical columns cut in a classical profile (photo facing page). The columns were cut from 5⅛-in. by 12-in. standard architectural-quality glulams made up of laminated 2x6s. Because they were to be painted, minor blemishes and construction bruises could be filled, sanded and finished upon completion. We made the 8-ft. long taper cuts on each side of the columns by run-

The front half of the barrel vault is supported by a pair of 6-in. by 16-in. glulam beams, which in turn are held up by tapered glulam columns.

Photo: Joe Nuess

ning the pieces through a large handsaw. Even with a new 1-in. wide blade we could barely cut straight enough to enable a 6-in. hand-held power plane to smooth out the irregularities. All four edges along the column's length were finished with a router and a ¾-in. beading bit, starting 6 in. down from the top and stopping 10 in. up from the bottom.

The column capitals with the tight radius cuts were done easily on the same large bandsaw using a ⅜-in. blade. These short pieces of glulam were easy to handle. We made the curving cuts so cleanly that only a minimum of sanding was necessary to finish. The edges were dressed with a ⅜-in. roundover bit. Then we attached the capitals to the columns by drilling down from the top and fastening them together with two ⅜-in. by 12-in. lag screws. The bottoms of the capitals were notched 1 in. to sit over the tops of the columns.

My barrel-vaulted spec house definitely stood out from its conservative competition, but was on the market for an agonizing two years before it eventually sold. □

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Drawings: Michael Mandarano