Laying Up Brick Bovedas

Inwardly leaning arches defy gravity

by E. Logan Wagner

It's not often that an architect gets a chance to incorporate traditional- masonry domes, called *bovedas,* into a house, but that opportunity came to me. My clients owned a site on the north slope of a 5,000-ft. mountain in hot, semi-arid southwestern Texas, 80 miles north of Big Bend National Park. They wanted a house incorporating traditional elements of Spanish architecture, so the final design centered around an open courtyard. Square in plan, each corner of the house was topped by a boveda (photo right).

A boveda is a dome built without the aid of formwork. Made of brick or other masonry material, bovedas originated in Egypt and the Middle East, where ingenuity made up for a lack of trees to provide lumber for roof supports. During the Renaissance, masonry domes took on an unprecedented popularity and were standard fare for most religious buildings in Italy and Spain. And when the Spanish conquered the Americas, missionaries converted the natives first to Catholicism and then to Spanish masonry techniques.

Many churches were built with bovedas, as were granaries, kiosks and water cisterns. Far from dying out when the Spanish left, however, the rich tradition of masonry bovedas survives to this day, primarily via a handful of skilled masons from the eastern part of the state of Jalisco, Mexico. The house built for my clients called for considerable skill on the part of the builders, but the star of the show was the *bovedero,* Sr. Don Alfredo Avila Almaguer, son of Don Mateo Avila (see "O'Neil Ford's Boveda House," *FHB* #23, pp. 26-31).

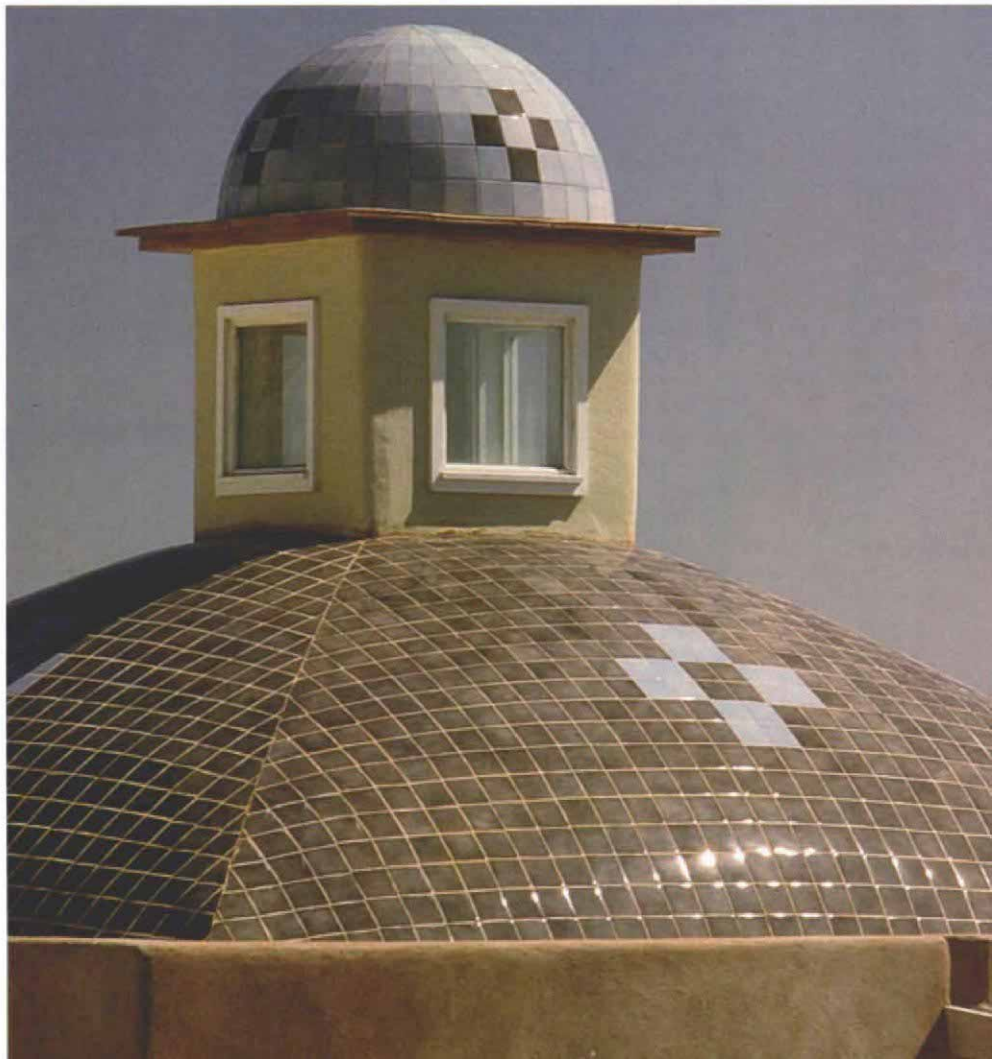
A bovedero is a mason who specializes in the making of bovedas. The traditional techniques of making bovedas were rediscovered in Lagos de Moreno, Jalisco, Mexico, by Don Alfredo's grandfather many years ago. As Don Alfredo recounts the story, his grandfather and a few other masons in Lagos were hired to remodel an old residence. While doing the work, they stumbled upon an abandoned cistern built in the boveda tradition. Intrigued, Don Alfredo's grandfather and his companions set out to try and recreate the boveda process. Two generations later, the building of bovedas has been returned to the level of virtuosity prevalent during colonial Mexico, and Lagos de Moreno has also become the boveda capital of the country.

The basic brick—The materials and tools needed for boveda-making are few. The brick, known in Jalisco as *ladrillo de cuna* or wedge brick, is a lightweight and relatively soft brick made from the clay soils around Lagos de Moreno. Mixed with water, the soil turns to mud and is poured into wooden molds, each containing four bricks. When released from the molds, the partially dry bricks are left to dry completely in the sun. Two good sunny days are sufficient for drying the bricks to a whitish appearance, whereupon they are fired in a wood-fueled oven for one day and one night.

The final size of each brick is roughly 2 in. by 4 in. by 8 in., and each one is slightly cupped due to the drying process. This cupping creates suction in the mortar that helps the brick, as it is being layed, to adhere to the course below.

The basic mortar—For mortar, Don Alfredo makes up a 4:1:¾ mix of sand, lime and portland cement, and adds just enough water to give it a thick, but manageable consistency. It hardens in a relatively short period of time, and combined with the suction created by the curvature of the brick, the mortar is able to hold bricks in place at steep angles without support. The porosity of the brick encourages an even faster bond by absorbing the moisture of the mortar.

Mixing the mortar is labor-intensive because Don Alfredo prefers not to use a mechanical mixer. First, he creates a volcano-like cone of sand, then adds the lime and finally the cement. A crater is formed in the "volcano" and then filled with water. Using a hoe and shovel, Don Alfredo skillfully cuts in



portions of the dry material so that the water does not spill out over the edge of the crater. As the mixing continues, more water is added as needed. Cement dye is sometimes mixed with the dry ingredients in order to lend color to the mortar.

The basic tools—The steel trowel is one of the bovedero's most important tools. With it, he is able to transport the mortar skillfully from a shallow wooden tray to wherever the next brick is to be layed. While this technique is perhaps familiar to masons the world over, a bovedero will also follow the unconventional technique of using his trowel to cut and shape the brick.

Bricks with one rounded end are used to form a cornice around the interior base of the boveda (see drawing below). Called the *pecho de paloma,* or pigeon's breast, the cornice thrusts 2 in. to 3 in. into the center of the room as decorative trim. To shape each brick, Don Alfredo holds it in one hand while chipping away at the edge on one end with his trowel. He works to no layout lines, and yet shapes each brick to a uniform, graceful curve. Then, with a coarse stone, the brick edge is smoothed out into its final form. In the hands of an expert, the procedure takes somewhere between 10 to 15 minutes per brick. For one with little experience, however, it is advisable to sketch out the finished shape of the pecho de paloma on the slender side of the brick, so that the curvature of all bricks is nearly identical.

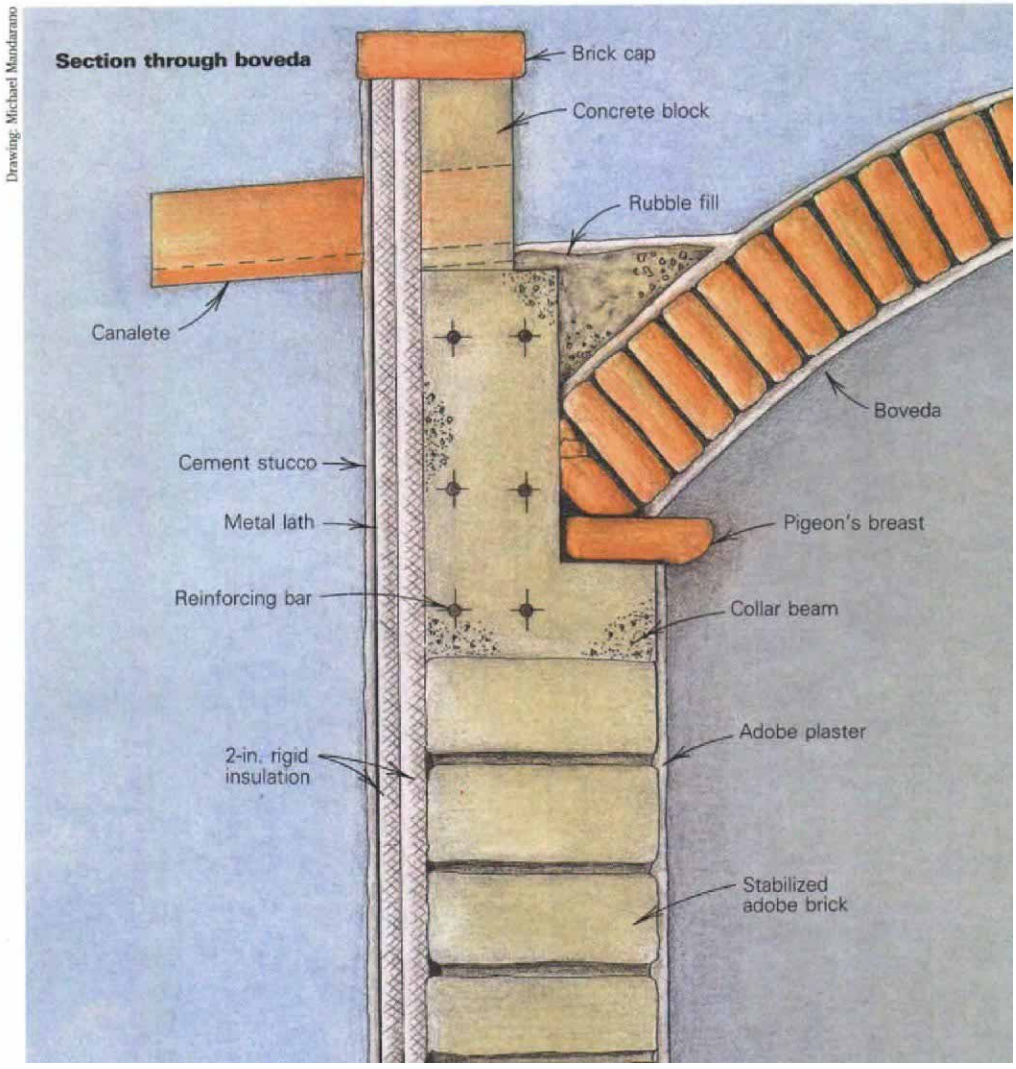
There aren't many other implements in the bovedero's tool repertoire. He needs a steel brush to clean off excess mortar after several courses of brick have been set. A small wood wedge, made from scrap wood found at the construction site, is used to rake the mortar at each course. The mortar box is made from wood, and is elevated to a comfortable height so that the bovedero exerts the least energy in his delivery of mortar from the box to the boveda.

By definition, a boveda is layed up without benefit of formwork. Don Alfredo does, however, use scaffolding in order to reach the interior of the boveda. After carefully leveling the scaffolding on adobe piers, he planks it at a level just shy of the pecho de paloma. From this level the boveda will take shape, and its height will be determined by Don Alfredo's reach.

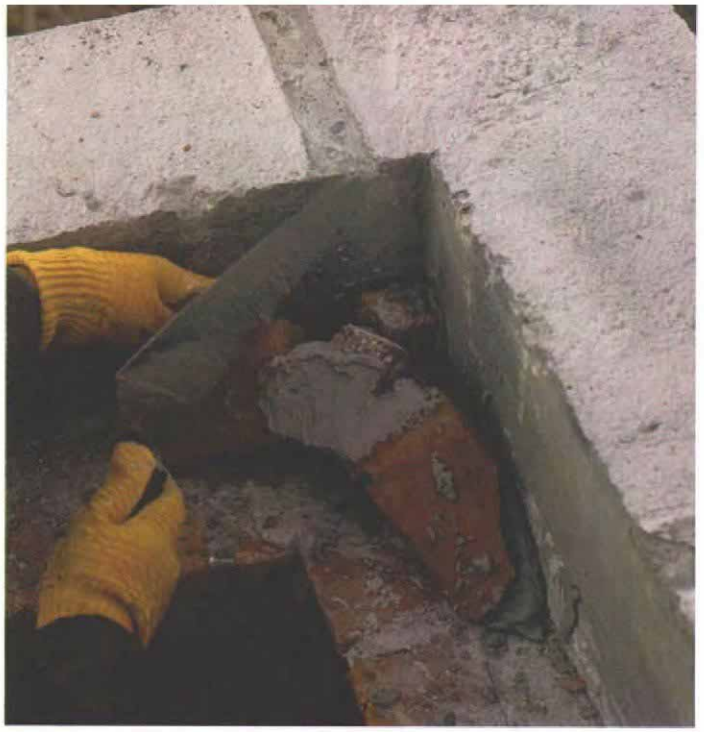
The structural support—The bovedas on this house each span approximately 18 ft., although Don Alfredo has built bovedas with spans of up to 40 ft. In any case, the weight of the dome is considerable, and proper support for the boveda is crucial. Exterior walls for this house are load-bearing adobe. Asphalt emulsion was added to the dirt mixture to make the adobe weather-resistant (this is called "stabilized" adobe). To reinforce the tops of the walls, a crew from Rainbow Adobe, builders and adobe brick makers in Alpine, Texas, formed and poured a continuous, reinforced-concrete collar beam (see drawing below). On the inside of this collar beam, a lip provides a platform from which the boveda will spring. The boveda can cover a rectangular, square or circular space, and the collar beam must be shaped accordingly.

After the collar beam has cured, one course of brick can be layed flat on the inner lip; this is the pecho de paloma, which trims the base of the boveda. Although the cornice is not structurally necessary, it gives the interior of the boveda a pleasing, elegant base. And as a practical matter for contemporary homes, it provides a recessed space for indirect lighting. Later on we installed low-voltage string lighting (similar to Christmas-tree lights) along the lip.

Starting the boveda—A boveda begins simply, but this beginning is one of the most crucial steps in the process of construction. Once the desired shape of the boveda is determined, the bovedero adjusts the angle of repose of the brick to form the curvature desired. The rounder and taller the dome, the greater the angle of the brick from the horizontal. Bovedas are a series of arches that "lean" on the arch layed previously. At each corner, progressively larger arches are layed



Drawing: Michael Mandarano



The boveda begins on a ledge formed in a reinforced-concrete collar beam. The curve of the boveda shell starts rather simply with small fragments of brick embedded in thick mortar (photo above left). Additional, slightly larger, brick fragments are added to form an arch over the first few brick fragments (photo above right), and larger bricks are carved away where they meet the vertical face of the collar beam. Soon the bovedero is able to use full-sized bricks, and a segment of the boveda begins to take shape (photo left). Note the lack of formwork to support the dome. Due to suction created by a shallow depression in the underside of each brick and to the thick mortar, bricks will stay in place on the angled dome without any aid. The size of each segment of the boveda is determined in part by how far apart corners are. Adjoining segments meet halfway between two corners (photo below), and later on, the space between them will be filled with more bricks. At the apex of the dome, a small area is left open to provide space for the lantern. At this point, the dome is strong enough to stand on, and the bovedero seals the dome with layers of cement stucco and fiberglass-reinforced cement (photo facing page).

until adjoining arches meet halfway between their respective starting points.

Don Alfredo begins the boveda at one corner of the collar beam, and with his trowel, chops the brick into small pieces 1 ½ in. thick and the width of a brick. Three such pieces form a tripod that is embedded in a thick slop of mortar (top left photo, facing page). With slightly larger pieces, he forms a tiny arch supported by the tripod. The next arch is larger, but the span is not yet long enough to require the full length of a brick (top right photo, facing page). Each successive arch calls for longer and longer brick pieces, until full bricks are being layed (middle photo, facing page).

At the peak of each arch, a piece of brick must be fit exactly to fill the gap remaining between the two opposing rows and is, in effect, a keystone. So many odd and irregular brick pieces are used over the course of building a boveda that brick scraps are routinely collected for later use.

After each two or three courses, Don Alfredo stops to clean and screed the excess mortar from the coursing. While he has been working, his indispensable assistant has been very busy supplying him with a constant supply of mortar and bricks. The assistant also helps Don Alfredo to rake out the excess mortar between the brick courses, and cleans successive courses with a steel brush.

The partial vault at one corner is complete when the largest arch reaches halfway along adjacent sides of the collar beam. Don Alfredo then starts the process again in the next corner. Again he begins with small pieces of brick, the seedlings of the next vault, and patiently forms ever-longer arches. With two corners complete (bottom photo, facing page), Don Alfredo builds the remaining two corners, and finally, the four dome-segments stand ready for the next phase. Outlined against the sky, the corners are strikingly beautiful, as if the rounded corners of the brick shell were flower petals yielding to the budding of a flower.

Completing the boveda—With all four segments of the dome complete, Don Alfredo begins to fill the spaces between them. He sets two courses of brick between each segment in the V-shaped intersection of two vaults, then repeats the process two courses at a time around the dome, gradually working upwards. Soon he has almost completed the full curvature of the boveda—only a small, squarish opening remains at the very apex of the dome, and it is from this point that the *linternilla* will rise (photo below).

The owners wanted to surmount the shell with a linternilla, or lantern. Windows in a lantern allow hot air rising from the rooms below to escape, and this encourages convective currents indoors. The lantern also plays a soft, natural light on the interior surface of the boveda and serves as an ornamental crown for the exterior.

By this time the dome, though unfinished, is strong enough to stand on, and Don Alfredo hikes to the top. Here he builds four brick stub walls to surround the small opening in the top of the boveda, and frames a window into each. Building the lantern walls requires modest skills, at least compared to the work preceding it.

Echoing the shape of the boveda, a domed cupola, made of adobe brick, is built atop the lantern. A cornice of 12-in. by 12-in. clay tile, called a *ceja* (eyebrow), provides the base from which to build the cupola. The first course of clay tile is guided by a string compass centered in a temporary wood frame spanning the interior of the lantern. Each circular course of the cupola becomes progressively smaller until the half-sphere is completed. To this point, Don Alfredo and his assistant have taken ten working days to build the boveda.

A hard shell and a parapet wall—Although the raw brick boveda has a most beautiful appearance, it requires a cohesive membrane that will consolidate the bricks in the shell and protect them from the weather. For these bovedas, two coats of cement stucco and a top coat of fiberglass-reinforced cement were applied to the larger dome of the boveda.

The cupolas called for a different approach. After three coats of cement stucco were applied to the cupola, it was painted with a coat of moisture-sealant paint. Then ceramic tile was laid in thinset exterior tile mortar (Custom Building Products, 6511 Salt Lake Ave., Bell, Calif. 90201). This mortar resists the large temperature changes typical of the high-country climate of southwest Texas.

A parapet wall 2-ft. high surrounds each boveda. Fill consisting of masonry rubble, covered by cement, creates slopes to conduct the water toward cut-stone water spouts called *canaletes*. The parapet wall keeps water from washing over the walls of the house.

The *boveda de aristas*—The basic construction techniques involved in making a brick boveda can also be put to other uses. A boveda that Don Alfredo is particularly proud of is his ***boveda de aristas,*** or groined vault. Located at the main entrance of the house, this boveda is supported by four brick arches, one for each side of its base. The columns (groins) of the vault form the arches and become wider as they rise, until eventually, the brick coursing fuses into the round boveda itself. This masterpiece is a fitting tribute to the exquisite virtuosity of brick and to the talented bovedero who builds with it. □

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