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Building a Sprung Arch

Steel Support Framework

All arches except a stacked corbelled arch exert an outwards thrust that must be supported in order for the arch to remain standing. The catenary arch's graceful parabolic curve transfers all outward thrust to the ground at the base of the arch and is the only type of brick arch that does not require external buttressing support. This is the reason for the popularity of catenary-arch kilns in low-tech or low-resource situations. For most studio applications the catenary arch creates an internal space that is less useable, and without a steel frame it cannot be equipped with a hinged door. For these reasons, most studio kilns built today are of the sprung-arch or flat-top design.

In pre-industrial times the outward thrust of the arch on sprung-arch kilns was supported by substantial earthen or stone buttressing, and this is still used in some situations, such as traditional Southeastern groundhog kiln. In all other situations today a welded steel framework provides the buttressing support. If this frame serves only to absorb the outward thrust of the arch, then a very simple welded design will work. However, if you plan to hang a hinged door, then a very stout welded frame is necessary.

Before building the frame, complete the kiln walls up to the level of the arch. Generally 3" x 3" x 3/16" angle-iron is adequate for the kiln frame, except where a hinged door is planned, in which case you should use at least ¼" x 3" x 3" angle iron for kiln 24 cubic feet or less and 1/4" by 4" by 4" angle for a larger one. Before constructing the kiln frame, improvise a temporary wood spreader-frame in the door opening to maintain even spacing from top to bottom - ***do not overlook this step***. To accomplish this, place vertical 2x4 boards up either inside edge of the door opening, with carefully cut horizontal 2x4 spreaders fastened between them to maintain the space.

Once that spreader framework is in place, stand appropriate lengths of angle iron at each corner and hold them snugly in place with a strap clamp (extended with a rope if necessary). If the cinderblock base is exactly the size of the kiln, then the verticals will rest on the concrete slab. If the base is larger than the kiln, then the verticals will rest on the ledge provided by the block base. These corner verticals must be tall enough so that the front and rear horizontal crossmembers will clear the peak of the arch.

When the corner verticals are in place, install the front-to-rear horizontal members that will provide the buttressing support for the arch. The most common arrangement is a length of heavy angle iron resting atop walls and welded between the corner verticals, with the vertical leg of the angle on the outside of the kiln. This is adequate for a softbrick arch or a small hardbrick arch, but for a larger hardbrick arch it is far better to use a length of 2" by 6" channel iron welded in the same location, with the legs of the channel facing outwards and the inside surface flush with the inside face of corner angle irons. This arrangement tends to remain

cooler with less chance of warpage over time. In either case, the purpose is to support the outward thrust of the arch and transfer it to the corner verticals.

Once the buttressing angles or channels are installed, crossmembers are welded horizontally at the top and bottom of the frame on all four sides (totaling eight crossmembers in addition to the buttressing angle iron or channel) to tie the corner verticals together to create an integral frame around the entire kiln structure. As mentioned above, the front and rear top crossmembers must be high enough to clear the maximum height of the arch. If you are going to have a stacked or roll-away door, then the top and bottom crossmembers can all be flatbar. If you are going to have a hinged door the kiln frame requires more rigidity and the top crossmembers should be angle iron.

Welding is the only practical way to assemble the frame. A well-built welded frame is permanent, and will usually outlast the brick lining. A frame does not have to expand and contract any more than the metal itself does, and the idea of a bolted frame with spring-loaded expansion joints at the corners is misdirected and will actually hasten deterioration of the arch. With a sturdy all-welded frame, when the refractory eventually deteriorates, the kiln can be rebuilt within the existing welded frame, drastically simplifying the job. Once the cross members are welded in place, remove the strap clamp and the spreader frame in the door opening.

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Once the kiln frame including buttressing support crossmembers is completely welded in place, you are ready to proceed with the arch. There is some leeway in choosing the curvature of a sprung arch, with no hard and fast rule for what height of arch is best. Very low arches are extremely risky in home-built studio kilns and must be avoided. When you are preparing to build an arch consult the tables in the back of Olsen's *The Kiln Book* or the pocket handbooks provided by refractory suppliers.

Find the appropriate tables for a 4 1/2"-thick arch using standard arch brick and standard 45-degree skew bricks. For stability, I prefer an arch with at least 2" of rise per foot of span, and such an arch will always start at either edge on a 45-degree angle provided by the skew bricks, which look like a standard firebrick with a 45-degree face along one long edge. Once you find the correct table, select the appropriate arch to span the inside width of your kiln. When building kilns with hardbrick, purchase enough skew brick to support your arch. When building with IFB, it is a simple matter to build a wood jig to guide your masonry saw or hand-saw and cut skews from standard straight brick.

Depending on the desired curvature and span, an arch for a studio kiln will be composed of some combination of #2 arch bricks, #1 arch bricks and straight bricks. #3 arch bricks are the most radically tapered and are never used on studio kilns except for very tight arches spanning firebox opening and other such applications. A very small kiln with considerable rise in the arch might use a combination of #1 and #2 arch bricks, but almost all average-sized studio kilns use some combination of #1 arch bricks and straight bricks in the arch. Such an arch is composed of

front-to-back parallel rows of either arch bricks or straight bricks, every other course starting with a half brick so that the seams are staggered in each adjacent row, creating what is called a ***locked arch***.

No matter what combination of arch and straight bricks your arch calls for, the front-to-back rows of straight and arch bricks should be equally dispersed across the arch from side-to-side, and the sequence of types should be the same on either side of the center point of the arch in order to get a symmetrical arch. For example, an arch that spans a 3' 9" opening (45" – five straight-brick across the inside back wall of the kiln) with 2.3" of rise per foot of span using standard 45-degree skew-bricks would require 18 rows of #1 arch bricks and 5 rows of straight bricks, totaling 23 front-to-back rows of bricks from one side of the arch to the other. For this configuration, starting from both edges of the arch simultaneously and working towards the center, you would lay three rows of #1 arch bricks, a row of straight bricks, three rows of arch bricks, a row of straights, and three more rows of arch bricks. In an IFB arch, the last remaining row of straights would be cut/trimmed to fit in order to provide the row of ***key*** bricks down the center at the top of the arch. If the arch is hardbrick, the key row is normally cast with a high-duty castable refractory like ANH Refractories Mizzou Castable.

The length of the arch from front to back depends on whether the arch spans only the interior space of the kiln, fitting inside the front and back walls, or spans the whole depth of the kiln including the front and back walls. I prefer the latter, because it gives a better looking kiln, and if you wish to have a hinged door, that design is essential to provide a continuous flat surface on the face of the kiln for the door to close against. On the other hand, for a kiln with a stacked door, if you build the arch only the depth of the inside dimensions, then the stacked door simply overlaps the front of the arch at the top, and there will be no reason to cut and fit door-bricks to conform to the inside curvature of the arch.

The Arch-Form

When constructing a sprung arch kiln, once the vertical wall of the kiln is completed up to the level of the arch and the steel framework is in place, construct a temporary arch-form to provide support while you lay the arch. The width of the arch form is the exact interior width of your kiln, minus ¼" clearance to allow easy removal from the kiln once you ***spring the arch***. That term refers to the moment when you lower the arch form and the brick arch stands on its own.

The arch-form generally incorporates a series of plywood ribs cut to conform to the curvature of the arch. In Olson's *The Kiln Book* or in pocket refractory handbooks you will find tables giving exact measurements of all standard variations of sprung arches. For example, the arch mentioned above, which spans a 45" opening has an overall interior rise of 8 5/8" and a radius of 2' 9 5/8". To create a smooth curved surface to support the underside of the arch, the ribs are usually covered with a flat, flexible material, such as sheet metal, Formica, or Masonite, but as another option can be covered with thin slats of wood. Decide which of these materials you are going to use, and subtract that thickness from the radius given for your arch. For this description, we will assume that we are using 1/8" Masonite, and subtract 1/8" from the 2' 9

5/8" radius, giving 2' 9 ½". To create the first rib for this arch-form, you need to lay out the appropriate arc. To make a simple but effective compass for this purpose, drill a hole and affix a pencil at one end of a strip of wood, and exactly 2' 9 ½" from the center of the pencil drive a nail or screw through the strip to serve as a pivot. Draw an arc on a piece of plywood, and with a straight-edge draw a line 44 ¾" long (having subtracted 1/4" for clearance when removing the arch form) where the endpoints exactly intersect the arc. This will give you the layout for the first rib, and once you cut it out you can use it as a pattern for the remaining ones.

Depending on the depth of the arch you will generally need at least three or four ribs. Along the lower edge of these ribs, cut notches to accommodate two 2x4s running front to rear, spaced a foot or so from either edge, tying all the ribs together. Once you have fastened the ribs to the 2x4s, the curved upper surface of the arch-form is faced as mentioned above with hard flexible sheeting material such as sheet metal, 1/8" Masonite, Formica, very thin plywood, or thin strips of wood laid edge to edge. Whichever material you use, make sure to affix it very well so that it follows the curve smoothly right down to the bottom edges of the arch form. When using sheet metal, Formica, or Masonite, it will be necessary to notch the ribs at the outer edge to accommodate a strip of wood which is flush with the surface of the ribs, so that the sheet metal or Masonite can be fastened directly to this strip all along the outer edges. Otherwise it will want to curve upwards except where it is fastened to the ribs. This is an extra step but well worth it.

If the arch is to be constructed so that it fits inside the front and back walls of the kiln, build up a temporary structure of cinderblocks or lumber within the kiln to support the arch-form directly under the outer 2x4s. Leave some space on top of the support structure, and at the front and back of the outer 2x4s use wood shims and tapered wood wedges (an inch thick at the thick end) to achieve the correct height to support the arch. ***The wedges are critical.*** A laid arch, even if IFB, is very heavy, and without the wedges, the arch form and supports would be firmly stuck in place. After the arch is completely laid, the wedges are driven out, and at that point the arch is ***sprung***, and the arch-form and its supporting framework may be removed.

More often, the arch extends the entire outside depth of the kiln front to back. In this event, when building the walls, temporarily leave the rear wall and door-jambs one brick shorter than the side walls. They can easily be built up to the proper height after you spring the arch. This will allow space to temporarily support the arch form on top of the rear wall and the door-jambs, using a combination of wooden blocks and tapered wedges. If you do not have front door jambs in your design (if the opening is the full width of your arch-span), you will need to build up temporary cinderblock supports in the front. If building a cross-draft kiln, you'll have a door-jamb on only one side of the door, and on the other side you will need to build a temporary structure to support that corner of the arch form.

Once the arch is sprung, the arch form may easily be removed to the front or rear. Take good care of the arch form, because you will need it again when you dismantle the kiln or rebuild the arch.

Laying a Sprung Arch

When the arch form is exactly in place atop the tapered wedges, install the skew bricks and backup bricks before beginning the arch. Place the skew bricks so that the tapered edge aligns with the inside edge of the side walls. If the arch buttressing member is channel iron installed as described above, then a row of unaltered straight bricks will fit snuggly in the space between the channel iron and the skew bricks. If the buttressing member is angle iron placed inside the corner vertical angle irons, then IFB will have to be cut and fit to accommodate the shape and thickness of the angle iron and effectively fill the space in order to support the skew bricks.

Once the skews and backup bricks are in place the arch bricks are laid one row at a time from front to rear. As mentioned above, in order to have a proper ***locked arch***, each successive front-to-back row must be offset one-half brick. If the rows of skews start with a full brick, then the first row of the arch would start with a half brick, the next with a full brick, the next with a half brick, etc. When this is done properly there will be no adjacent seams throughout the entire arch. As mentioned above, any rows of straight bricks in the arch should be spaced evenly across the arch, interspersed among the courses of arch bricks.

Always lay the bricks evenly from either side simultaneously. If everything worked perfectly, which it never does, when you got to the center the final row of ***key*** bricks at the top would fit exactly. Instead, on an IFB arch we normally cut the brick to create a custom-fit key row. Make sure they are all exactly the same along the whole row from front to back, and after cutting them to shape, blow off the cut surfaces with compressed air to remove any loose grit that otherwise might sift down on the wares during firing.

With a hardbrick arch it would be very difficult to cut custom key bricks, even with a proper diamond masonry saw. The simple solution is to attach a board against the front and back ends of the gap and pour it full of a high-duty hard castable refractory such as ANH Refractories Mizzou castable. Before filling the gap with castable, cut a series of wood wedges of the appropriate thickness and the exact right angle, and gently drive them into the opening at 5” intervals along the opening in order to spread the arch bricks and assure that there are no gaps between rows that could result in a loose arch. Once you have mixed your castable and filled the rest of the gap, remove all the wedges and fill the spaces left by the wedges.

If the kiln is an updraft, leave an appropriate flue port in the arch. When an updraft kiln is especially deep front to back, as in a production car kiln, it is usually necessary to have several flue ports, with separate kiln-shelf dampers above each one.

Insulating and Reinforcing the Arch

A single 4 1/2"-thickness of arch bricks provides good strength and insulation, but not much rigidity, and in every firing it will flex with expansion and contraction, adding to the breakdown of the bricks, and worse, the amount of material sifting onto the wares below. It is always a good idea to cover the arch with at least 4" of rigid castable insulation. Before doing so, cover the arch with a layer of aluminum foil. This will prevent the arch bricks from bonding to the insulation layer, which allows the arch to move in a more natural way during expansion and

contraction. If the kiln is an updraft, build up a collar of brick around each flue before applying the insulating layer.

You can easily make your own insulating castable with a mixture of 40% sand, (builders sand, cheap playground sand, or river/beach sand), 40% sawdust or vermiculite (use vermiculite for an indoor kiln where the smoke from the sawdust would be a problem), and 20% fireclay. For an arch exposed to the weather, reduce the sand to 30% and add 10% Portland cement. If it is available, use roughly crushed IFB scraps in place of the sand. Any of these mixtures without Portland cement will shrink considerably in drying. Just go back with the same mixture and fill the cracks until no more form.

If you have access to a significant quantity of scrap IFB, simply pave the arch (cover with foil first) with a 4 1/2"-thick layer of scrap brick generously mortared together with the above sand/fire clay/vermiculite mixture. With any of these systems, the added layer will drastically strengthen the arch and give better insulation.