The Catenary Arch

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Flying into Lambert International Airport in St. Louis, Missouri, the passenger is treated to one of the most awe-inspiring monuments in the United States of America – the St. Louis Gateway Arch.

Designed and built by Eero Saarinen, a Finnish architect, in the early 1960's, this towering structure was an engineering feat of no small order. Standing on the grounds of the **Jefferson National Expansion Memorial**, located on the riverfront of downtown St. Louis, this elegant steel glissade dominates the skyline of the oldest European city in the U.S. Midwest. Visitors from around the world marvel at the grandeur of this mega-structure of steel. The Gateway Arch stands out as a giant; its design is timeless in its simplicity, regal in its play on light, and modern in its form.

Debate on the location of the Gateway Arch began in 1947. Initially designated for an area near the banks of the Mississippi River; over time this area was deemed to be too dangerous for a historic monument. The current location of the Gateway Arch was finally agreed upon in the mid 1950's and the St. Louis Arch was built on higher ground. Construction of the Gateway Arch began in 1963 and was completed in October of 1965.

The Arch has 60-foot deep foundations. The Arch is very stable and was built to withstand high winds and earthquakes. The structure sways about one inch in a 20-mph wind; it is designed

to sway up to 18 inches in 150 miles per hour winds. The two bases are equilateral triangles (triangles with three 54-foot-long sides). At the top of the Arch, the triangle is only 17 feet long on each side. It is 630 feet in height, 630 feet wide at the base, with a 60 feet depth foundation. The inner shell of the Arch is carbon steel, while the outer skin is stainless steel. The exterior is of stainless steel and has a 50 percent greater coefficient of thermal expansion than the carbon steel. When heated by the sun, the massive panels of stainless steel which were perfectly flat on the ground, buckle predictably, high on the Arch. The effect is cosmetic only and does not affect the structural integrity of the 630-foot-tall catenary arch. It takes a tram to move from the observation deck to the top of the arch four minutes (it travels at a rate of 240 feet per minute). There are 1,076 steps in each leg of the Arch (the stairs are only used for maintenance and emergencies).

Facts:

- The structure is known as a catenary curve – the shape a free-hanging chain takes when held at both ends, and considered the most structurally-sound arch shape.
- The Arch weighs 17,246 tons.
- Nine hundred tons of stainless steel was used to build the Gateway Arch, more than any other project in history.
- To ensure that the constructed legs would meet, the margin of error for failure was 1/64th of an inch.
- All survey work was done at night to eliminate distortion caused by the sun's rays. Since the Gateway Arch was constructed before the advent of computer technology, relatively crude instruments were used for these measurements.
- The Arch sways a maximum 18 inches (9" each way) in a 150-mph wind. The usual sway is 1/2 inch.

Beyond this technological and architectural triumph, the Gateway Arch lays a monument tied to a much deeper symbolic setting that connects Thomas Jefferson, U.S. westward expansion, and the Louisiana Purchase into a wider historic reality that is Masonic in both spirit and measure. Great monuments of this stature tell us more than what is visible on the surface; they also represent "where" and "when" we are -- both physically on the face of the Earth as well as in our cultural evolution -- and thus are testaments to the values of our society's political craftsmen. The Gateway Arch is a marker of both time and space, anchored into the ground by visionaries that have kept a sacred geometric and geophysical astrology alive for centuries in hopes of freeing mankind of tyranny and oppression.

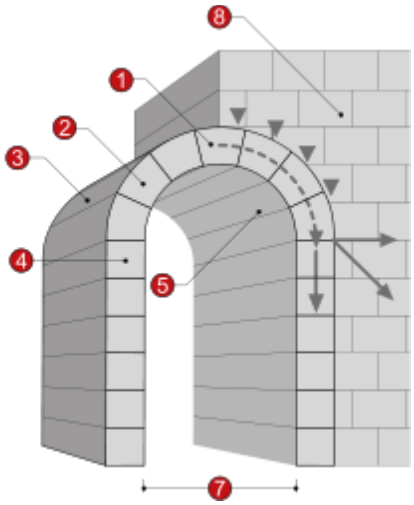
Every time I see the Gateway Arch, I recall in Freemasonry's Fellowcraft Staircase Lecture, the candidate is made to take three, and five, and seven steps, which compose the staircase. When he reaches the seven steps, the candidate is told they represent the *Seven Literal Sciences*. In the Scottish Rite, the 30th Degree, that of the Knight Kadosh or Knight of the White and Black Eagle, the Master Mason again meets the *Seven Literal Sciences* on the double seven-ringed ladder. An elaboration and use of the Masonic sciences is one of the pathways the Master Mason must follow for Enlightenment.

While the form of a Symbolic Lodge and Scottish Rite Lodge are that of an oblong square representing a Jewish Encampment, that of a Royal Arch Chapter approaches that of a catenary

arch, symbolical the entrance to the *Holy of Holies*. To make Masonic meaning and significance of the Gateway Arch, it is necessary to review the definition, construction, history, and technical aspects of arches.

The Masonic Arch

There are two ways to span an opening: one is to put a beam across it, the other is to build an arch into it. Almost any curved structural member which is used to span an opening is commonly, and very loosely, called an "arch."



A Masonry Arch: (1) Keystone (2) Voussoir (3) Extrados (4) Impost (5) Intrados (6) Rise (7) Clear

In precise usage the term "arch" is restricted to spanning members which are constructed of wedged-shaped blocks called "voussoirs," which hold each other firmly in place and prevent each other from slipping because they are smaller at the bottom than the top.

After the foundation for the arcade is prepared, a "plinth" (base block) is usually laid for each pier. When each pier is finished, it is frequently capped with an "impost," upon which the lowest voussoirs, called the "springers," will be laid. The top of the impost, from which the arch will rise, or "spring," is called the "springing." Before the voussoirs can be set in place a supporting frame, the "centering," must be built. If the span to be arced is not to wide, the centering can be placed on the impost and no additional support will be required. The voussoirs are then laid up with mortar and, after the topmost voussior (the "keystone") has been slipped into place, work must stop until the mortar has set. When the mortar is dry, the centering can be taken down and used elsewhere to constructing another arch. The outside curve of the arch is called the "extrados" and the inside curve is called the "intrados." The surface between any two arches of an arch called a "spandrel."

The Catenary Arch

The word catenary is derived from the Latin word *catena*, which means "chain". The curve is also called the "alysoid", "funicular", and "chainette." The catenary is the ideal curve for an arch of uniform density and thickness which supports only its own weight. When the centerline of an arch is made to follow the curve of an up-side-down (i.e. inverted) catenary. If the arch is made of individual elements (e.g., stones) whose contacting surfaces are perpendicular to the curve of the arch, no significant shear forces are present at these contacting surfaces. (Shear stress is still present inside each stone, as it resists the compressive force along the shear sliding plane.) The thrust (including the weight) of the arch at its two ends is tangent to its centerline.

However, the conditions for a catenary to be the ideal arch are almost never fulfilled: arches usually support more than their own weight, and on the rare occasions when they are freestanding they are sometimes not of uniform thickness. The ideal shape for an arch supporting

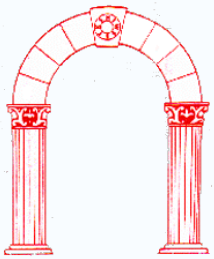
a heavy weight is more like a parabola than a catenary. As a result, there are very few arches that have been deliberately built as catenaries, though there quite a few incorrect claims that various arches are catenaries.

In Royal Arch Chapters, the centenarian arch is horizontal, not perpendicular as most arches are made. We are taught the catenary arch is created by hanging chains, or heavy ropes, supported horizontally between two points assuming a natural curve which, inverted as shown by a broken line, gives the shape of a true centenarian arch. Thus, by binding the Companions together, the Chapter is a symbol of orderly and organized body. It is the arch memorial of the vaulted shine in which the sacred writings were deposited. It is not only a symbol of strength but a symbol of the heaven.

Conclusion

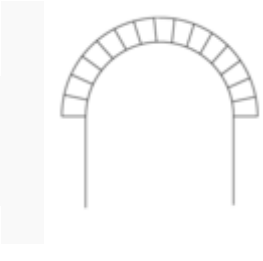
In your travels I hope your faculties will be awakened to the vistas of sight, sound and ideas and look at bridges, overpasses, even the power lines extended between poles and visualize architectural arches from a new perspective. Remember the Staircase Lecture of the Second Degree and think about the Three-Five-Seven steps the Fellowcraft candidate follows as he raises the staircase. Remember the Mystic Ladder of the Thirtieth Degree as the Knight Kadosh wars against ignorance. The lesson of the Second and Thirtieth Degree is education and expands the intellect and leads man toward an understanding of what is true.

An arch is strong and permanent not only because of its form, but every stone performs its function and contributes its strength, stability, and permanence to the arch. Like the stones in arches, the Chapter's strength, stability, and permanence is based on every individual Companion faithfully performing his allotted duty to the ultimate good of the Chapter and mankind.



Gallery Showing Arch Forms Displaying in Roughly the Order in Which They Were Developed

Triangular arch

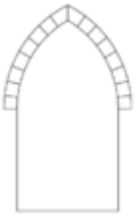


Round arch or Semi-circular arch

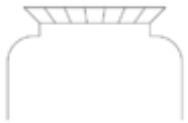
Segmental arch

Unequal round arch or Rampant round arch

Lancet arch

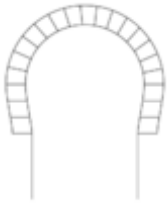


Equilateral pointed arch

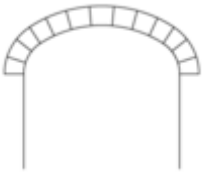


Shouldered flat arch -see also jack arch

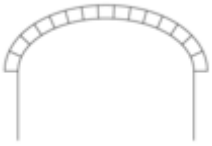
Three-foiled cusped arch



Horseshoe arch



Three-centered arch

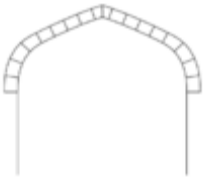


Elliptical arch

Inflexed arch

Ogee arch

Reverse ogee arch



Tudor arch

Catenary or Parabolic arch

Appendix A

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