HE HOUSTON Astrodome, the Georgia Dome, and many other large, covered sports venues trace their ancestry to a relatively little-known structure that was built not for athletic events but for judging livestock. Known as Dorton Arena, this revolutionary building was the first modern stadium to employ a permanent cable-supported roof.

The concept for the arena, which was erected in 1952 on the North Carolina State Fair Grounds, in Raleigh, was the brainchild of Matthew Nowicki, an architect who was born in Russia and received his training in Warsaw, Poland. Nowicki went on to become an architectural ambassador of sorts, serving as a cultural attaché to the Polish consulate in Chicago and as a consultant on the design of the United Nations headquarters building, in New York City. In 1948 he joined the architecture faculty at North Carolina State College (now North Carolina State University). When J. Sibley Dorton, the manager of the state fair, commissioned the Raleigh architect William Henley Deitrick to design the arena, Deitrick engaged Nowicki as a consultant on the project.

Dorton wanted a building that would serve as the centerpiece of his plan to expand the fair into a year-round exposition. The new pavilion was to be used for judging livestock as well as for horse shows, circuses, and other events. Architects of less imagination might simply have mimicked the design of existing arenas with conventional roofs, but Nowicki saw the project as an opportunity to try something new.

In a remarkable set of freehand sketches, Nowicki turned conventional long-span roof design on its head. In a typical covered stadium of the day, spectators in the uppermost seats often found themselves bending over lest they bump into the ceiling. Nowicki solved that problem by creating a saddle-shaped roof that curved upward at the sides of the building. This shape gave every spectator plenty of headroom as well as a clear view of the exhibition floor. At the same time, it allowed an unusual amount of sunlight into the building.

Even more novel than the shape of the roof was the means of its support. Instead of bearing directly on columns or
walls, the roof would be held up by a network of steel cables. The cables, in turn, would stretch between two inclined parabolic arches of reinforced concrete rising from common abutments on two sides of the building. These parabolic structures would slope in opposite directions, each at an angle of approximately 25 degrees.

The entire structural system could be expressed in terms of the interplay between two basic engineering principles: tension and compression. The arches would function in compression, while the roof would be in tension. As Henry Petroski, Ph.D., P.E., Dist.M.ASCE, explains in *Pushing the Limits: New Adventures in Engineering* (New York City: Knopf, 2004), which includes a chapter on Dorton Arena, tension structures carry their loads by resisting being pulled apart. This resistance typically depends on being anchored to some other structure, as seen in the anchorages of a suspension bridge or the stakes of a tent. In Dorton Arena, the roof cables are anchored in the inclined arches. The genius of Nowicki’s design was to cross the ends of the arches at the centerline of the building, where they bear against massive abutments. As a result, the tension of the roof is transformed into a compressive force that the arch legs transfer to the abutments, making the building as a whole surprisingly economical and efficient.

Tragically, Nowicki did not live to see his ideas realized. On his way home from a project in India in 1950, he died in a plane crash at the age of 40. Deitrick assumed oversight of the project but remained faithful to Nowicki’s vision. The design should be changed as little as possible, he insisted, “as Matthew would have wanted it.”

Because Nowicki’s drawings were conceptual in nature, much detailed design work remained to be done. Fred Severud, F.ASCE, of New York City–based Severud-Elstad-Krueger Associates, performed the structural engineering. William Muirhead Construction Company, of Durham, North Carolina, was engaged as the general contractor. The Bethlehem Steel Company, of Bethlehem, Pennsylvania, was the cable subcontractor, and John R. Gove, of Chapel Hill, North Carolina, was the surveyor.

From Severud’s point of view, the most noteworthy aspect of the building was its use of materials. The cables supporting the roof were made of steel, which is efficient in tension, while the inclined arches were made of concrete, which is efficient in compression. In this way, the designers used the properties of both materials to good effect, making the $1.5-million structure extremely economical.

The network of cables actually consisted of two sets of cables at right angles to each other, forming a grid that stretched 300 ft at its widest point. Each cable had to be sized accurately in advance so that it would sag in just the right way to create the desired saddle shape. The roof itself was originally intended to be fabric, but corrugated

The architect William Deitrick’s faithfulness to Matthew Nowicki’s original design, which featured a cable-supported roof stretched between a pair of inclined arches, is reflected in this rendering. Below the point at which the arches intersect, their lower extensions and a central vertical column combine to form a “tripod,” below, that supports the arches.
steel panels were substituted to reduce costs. The contractor then topped the panels with insulation and conventional roofing materials.

Among the challenges associated with the construction of the roof was the possibility that wind might cause it to flutter. To prevent uplift, the contractor installed guy cables that extended from the vertical columns on the perimeter of the building to many of the points at which the cables intersected one another. This system was put to the test in 1954, when Hurricane Hazel swept through the area with winds gusting to 100 mph. The roof successfully weathered the storm.

J. Sibley Dorton, the manager of the North Carolina State Fair Grounds, wanted a building that would serve as the centerpiece of his plan to expand the fair into a year-round exposition. Since its completion, in 1952, the arena that bears his name has been used not only for judging livestock—its original purpose—but also for horse shows, circuses, and other events.

Tragically, Matthew Nowicki did not live to see his building erected. William Deitrick, above, saw the project through to completion.
as Severud notes in his own article on the project (“Materials Combined to Advantage—Concrete in Compression, Steel in Tension,” *Civil Engineering*, March 1954, pages 52–55). “The continuations of the arches are not structurally part of the arches but are members of a ‘tripod’ supporting the arches,” he explains. “This tripod has three legs, two of which are the extensions of the arches and the third is the center column directly under the intersection.... For varying conditions of wind and snow load, [the center column] may be either in tension or in compression.” The column keeps the tripod from tipping inward or outward, making it “a vitally essential element of the structure.”

Belowground, the foundation design was complicated by the fact that no rock foundation was available, only firm clay. The legs of the arches bore on concrete abutments, but the thrust was so great and would act at such a small angle with respect to the ground that the engineers had to devise some means of preventing the footings from slipping in the horizontal direction. The solution was to use prestressed steel cables to tie the abutments together underground.

**Dorton Arena**, a little-known building in Raleigh, North Carolina, influenced the design and construction of such celebrated structures as the Houston Astrodome and the Georgia Dome. The cable-supported roof was originally intended to be fabric, but corrugated steel panels were substituted to reduce costs.

On the sides of the arena were vertical concrete columns approximately 8 ft apart that not only supported the dead load of the arches but also acted as mullions framing the glass exterior of the building. The columns enclosed a space designed to accommodate some 5,000 people in permanent seats and another 4,000 in chairs on the arena floor. The elliptical performance space in the middle of the building measured 221 ft long and 127 ft wide.

Known at first as the State Fair Arena or simply the Livestock Judging Pavilion, the structure attracted a great deal of attention from the architecture and engineering community when it opened, in 1952. It was renamed in Dorton’s honor in 1961 and listed in the National Register of Historic Places in 1973. In 2002 ASCE accorded landmark status to the building as part of its Historic Civil Engineering Landmark Program.

—JEFF L. BROWN

Jeff Brown is a contributing editor to *Civil Engineering*.