# Dorton Arena

## On the occasion of its 50th anniversary and its dedication as a National Historic Civil Engineering Landmark

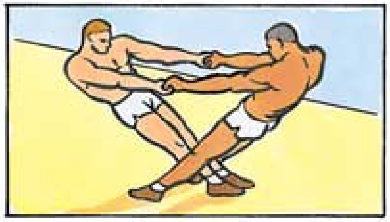
Henry Petroski

Not very long ago, I picked up at the Raleigh-Durham International Airport a prominent and very busy structural engineer who had flown in from Chicago to give a talk at Duke. As we were driving toward Durham, I asked him if there were any structures in the area that he would like to see during his brief visit. He did not hesitate before naming just one: the Dorton Arena. Since we were driving in the opposite direction from Raleigh and the North Carolina State Fairgrounds on which the arena sits, and since we did not have much time to spare before his talk, I told him that we would risk getting caught in traffic if we went there first. Perhaps we could go by after his talk.

### Exploiting Tension

The Dorton Arena, completed in 1952, was the first stadium-like structure designed to enclose a large, covered, column-free space. It is thus the predecessor of such covered stadiums as the Houston Astrodome, completed in 1965, and the superdomes that so dominate sports-stadium design today. Yet for all of its influence on subsequent design and construction, the significance of the unique Dorton Arena remains relatively unknown outside the structural engineering and architectural communities. Instead of relying strictly on the primitive principle of compression, in which loads are carried by bearing down on what supports them, as do pyramidal piles, planar walls or circular arches and domes of stone, the Dorton Arena is a structure whose roof is supported in tension.

Tension structures carry their loads by resisting being pulled apart. Suspension bridges, with their graceful cables, are very prominent tension structures. Tents are also tension structures, with their fabric stretched over poles the way the bridge cables are slung over towers. Indeed, although not often visualized in this way, a large circus or event tent can appear in profile or silhouette to resemble a suspension bridge or series of suspension bridges in tandem. Because tensile structures work by resisting being pulled apart, they also have to pull against something; thus, suspension bridges require anchorages, as tents require stakes, to maintain their configuration. Among the Dorton Arena's unique features is the elimination of any anchorage or stake-like components, thus making it a more economical and elegant structure. So, how does it resist the essential tension?



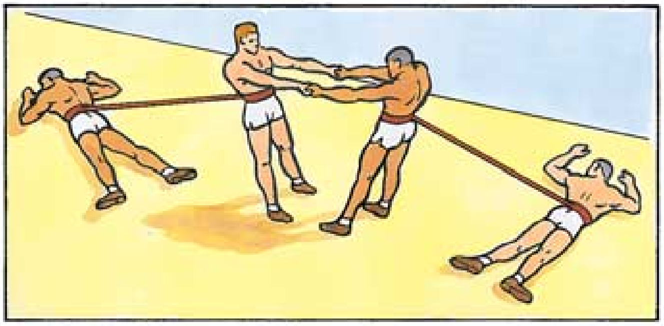


Figure 1. Structural action of Dorton Arena relies on tension and compression (upper), eliminating the need for anchors (lower). (Adapted from Severud 1954.)

The roof cables pull against a pair of crossed and inclined concrete parabolic arches that are perhaps the arena's most dominant feature. Like all arches, these work in compression, and the pull of the cables in the plane of each arch is transformed into a compressive force that flows down the legs of the arch into the ground. The structural action of the building has been given the anthropomorphic interpretation of being like two men who lock arms and pull against each other. If they were standing

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upright, their mutual pulling action would tend to make them fall toward each other. To keep this from happening, each of the men can place his feet behind those of the other as he leans backwards and pulls with his arms. In this cross-tied stance, each of the men would only fall backwards if he let go of the other. However, the men might also slide on the ground if they did not have their heels dug in or their legs tied together in some way. An analogous action is going on beneath the surface in the Dorton Arena, where the feet of the arches bear against massive abutments and the crossed legs are tied together with steel cables.

The structural action of the arena as embodied in the human model is considered a brilliant, original and extremely elegant solution to the ever-present engineering problem of equilibrium. By making the structure's arms out of steel cables, which are very efficient in tension, and making the leaning body out of concrete, which is very efficient in compression, the best properties of both materials are exploited. If the arches were not inclined—if the men were not leaning backward—the structure would not work. For two men to pull against each other while standing upright, an additional structural element would be required. This could take the form of another man standing behind each and holding him back with a rope. Then the structure would be analogous to a suspension bridge, with the backup men acting like anchorages. As beautiful a structure as a suspension bridge can be, its need for anchorages (and the extra cost they entail) puts a blemish on it as a less efficient structure than the Dorton Arena. But how did this elegant structure come to be, and why is it on the State Fairgrounds in Raleigh, North Carolina?

## A First for Cables

The principle of using cables to support a roof, albeit not a permanent one, is said to have been employed in the Roman Colosseum 2,000 years ago. Some suspended roofs were evidently used in Russia at the end of the 19th century, but steel strips rather than cables were used as the support elements. Suspension-bridge development, especially in the later 19th and early 20th centuries, provided a testing ground for using steel cables in large-scale tension structures, but the Dorton Arena's permanent cable-supported roof system was the first in the world on such a large-scale structure, one measuring the length of a football field in each direction.

The origins of the Dorton Arena lay in the postwar years, when J. Sibley Dorton, a veterinarian turned fair manager, promoted long-range plans "for future expansion of the North Carolina State Fair into a permanent State Exposition on a year-round basis" in the temperate climate of the Piedmont. He envisioned a "modern, well-planned Exhibit Arena and Assembly Building, adequate to accommodate and seat 15,000 people." The building, which was the centerpiece of his vision, would "provide adequate facilities in the amphitheatre for the proper showing and sale of all forms of livestock, as well as shows for automobiles, textile machinery, and every other conceivable type of industrial shows and sales, as well as all forms of sports and athletic events."

The architect chosen to flesh out Dorton's vision was William Henry Deitrick, who was born in 1895 in Virginia. He developed ties to North Carolina by attending Wake Forest College and marrying Elizabeth Hunter of Raleigh, the city in which he set up his architectural practice in the mid-1920s. He thus had more than two decades of experience designing buildings and planning land use in the state before he received the North Carolina fairgrounds commission.

Since the late 1930s, Deitrick's firm had practiced out of a structure dubbed the "ivy tower office" owing to its location in the renovated Raleigh Water Works, with its distinctive octagonal vine-covered granite tower. The Tower—as the building inevitably came to be known—has been described as "a professional training Mecca for young architects" of the time. Among the young architects that Deitrick engaged periodically as consultants were Matthew Nowicki and his wife Stanislava. Matthew Nowicki was born in 1910 in Russia but received his architectural training in Poland, where he began to practice. Among his commissions were a sports center in Warsaw. He also had ties to the U.S., having studied as a boy at the Art Institute in Chicago, having later served as Cultural Attache to the Polish Consulate in that city, and having served as the Polish representative to the Committee for the United Nations Building in New York, a building for which he also served as a consulting architect.

In 1948, Nowicki joined the School of Design at what was then North Carolina State College in Raleigh, serving as acting head of the Department of Architecture. He spent a summer at Cranbrook Academy in Michigan as a consultant to Eero Saarinen on a planning study for Brandeis University. Back in Raleigh, he served as a consultant on several Deitrick projects, working on the interior of the Carolina Country Club, a State Art and History Museum and preliminary designs for the State Fairgrounds—including an arena, which, during its development, came to be referred to as the livestock-judging pavilion. Nowicki also collaborated with and consulted for architects in California and New York on both domestic and international projects. Shortly after the arena was commissioned, Nowicki, who was returning from India where he had consulted on the design of the layout for a new capital city in Punjab Province, was killed in a plane crash in Egypt. One critic called the untimely death of the 40-year-old "a catastrophe to architecture."

The sketches for the arena that Nowicki left behind show clearly the structural concept for the building that was eventually realized as Dorton Arena. One sketch for an early scheme shows an uncovered bowl-like structure, while another sketch shows the bowl covered with a sagging

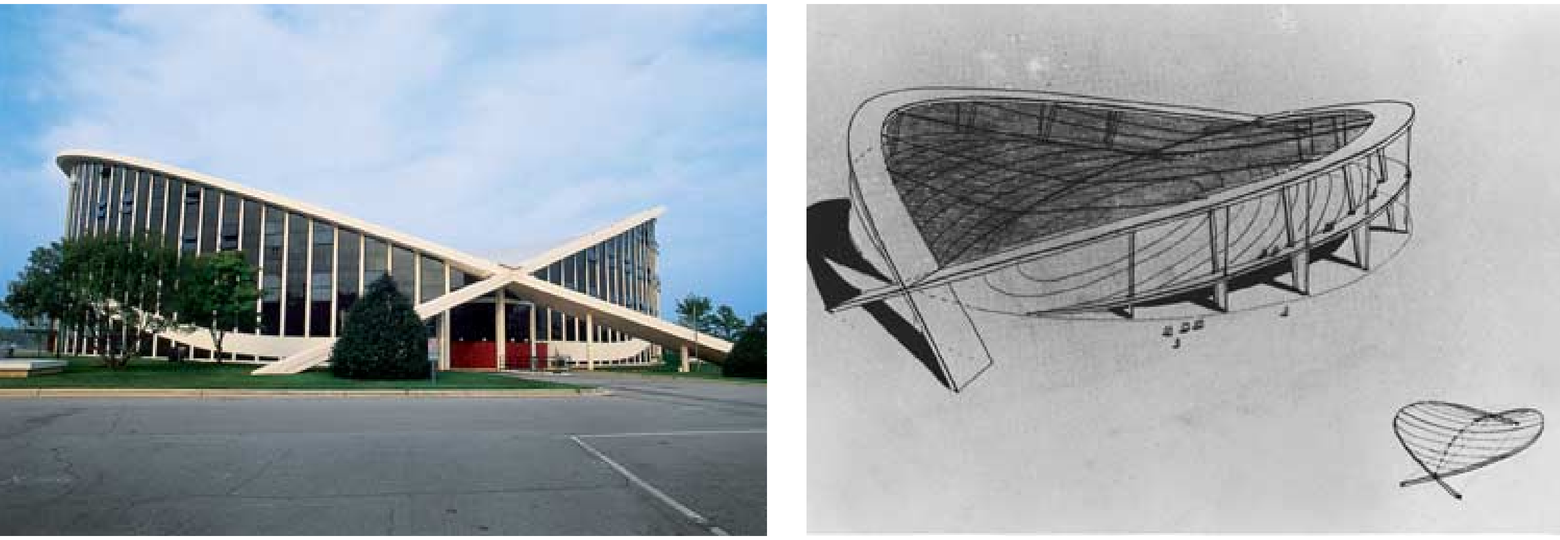

Figure 2. Dorton Arena today is remarkably true to Andrew Nowicki's original sketches. (Image at right courtesy of the North Carolina State University Archives.)

roof supported by inclined arches resting on battered columns. Other sketches show the peripheral columns upright, the way in which the structure was eventually built. However, sketches of the kind Nowicki left are not sufficient for constructing a building, especially one so innovative. There remained considerable work to fill in the details of the scheme and choose the exact materials and sizes for the structural bones and protective skin.

The office of William Deitrick took over the supervision of the detailed work of design and construction, with Stanislava Nowicki apparently providing considerable insight into the creative intentions that her late husband had shared with her. It was essential to involve a consulting structural engineer in the development of such a novel design, and Deitrick chose to work with the New York firm of Severud-Elstad-Kreuger. Fred N. Severud, who was described as a "creative engineer" and a close friend of Deitrick, served as structural consultant. Severud developed the structural system that made the pavilion stand, and he would later extend the principles of the building's long-span cable-net roof to structures such as the Yale Ice Hockey Rink in New Haven, the Reception Building at Washington Dulles Airport and the circular-roofed Madison Square Garden in New York. Severud Associates, as the firm is now known, was also the engineering firm for such projects as the Gateway Arch in St. Louis, the Denver International Airport and the Guggenheim Museum in New York.

Whatever changes mechanical principles would force in the details of Nowicki's conceptual design for the structure, Deitrick was insistent that they be held to a minimum, so that the completed building would look as much as possible "as Matthew would have wanted it." That is not to say that there was no room for creative engineering and construction, for Matthew Nowicki did not leave much beyond his sketches. Among the practical details that remained to be worked out were how the building, once designed in detail, would be constructed. This task fell to William Muirhead, a contractor from the neighboring city of Durham.

Most structures are built from the ground up, of course, and so the livestock-judging pavilion began with foundation work: footings for the columns, walls for the basement and the arena floor. Like the men in the anthropomorphic model, the two leaning parabolas, which the weight of the roof would tend to make slide past each other, had to be able to push against something. Thus, underground concrete abutments were constructed to take the thrust, and these abutments were connected by tunnels through which steel cables could pass to connect the bases of the parabolas to each other. The cables further check any tendency for the bases to slide apart, which would bring the parabolas closer together and let the roof sag below its desired profile. The steel columns that support the concrete parabolas were erected next, thus providing perches onto which a wooden form could be constructed to hold the concrete until it set. (A special mix of concrete was used so that it would stay put until set and not run down the 22-degree incline of the parabolic legs.) Among the many elegant details of the design is the use of the outside columns also as mullions to hold the window frames and glazing in place. The columns, spaced six feet apart, thus serve an efficient, dual purpose.

The roof was put in place by first installing steel cables to span the space between the backward-leaning parabolic arches. To ensure that connecting hardware was located in the right places to receive the ends of the cables, careful surveying work had to be done to transfer precise locations into the concrete formwork. The surveyor responsible for overseeing that everything was where it should be was John R. Gove, of Chapel Hill, the third of the three North Carolina cities that establish the vertices of the state's Research Triangle. In an early use of a digital computer, the locations for the cable sockets were precisely calculated from equations describing the arch. Each cable had to be accurately sized beforehand, so that it hung with the proper sag. (The finished roof would have a maximum sag of about 31 feet over the 300-foot span.) There are actually two sets of cables in the roof, at right angles to each other, forming the so-called cable-net.

It was originally thought that the roof would be covered in some kind of fabric, but as often happens in building, what was available when construction bids were submitted was considerably more expensive than an alternative. To save money, the cable-net was thus covered with corrugated steel panels, on top of which was placed insulation, and on top of that conventional waterproof roofing materials. Among the concerns about the roof, no matter its composition, was that it would flutter in the wind. (The upward suction of the wind was calculated to be as high as 16 pounds per square foot, whereas the weight of the roof that resisted uplift was only 6 pounds per square foot.) To prevent the roof from moving upward in the wind, guy cables were installed between cable-intersection points on the interior of the roof and the structural columns around the periphery. The soundness of the roof design was tested when Hurricane Hazel passed almost directly overhead in 1954. The roof weathered the storm, whose winds were estimated to have gusted to around 100 miles per hour.

When completed in 1952, the livestock-judging pavilion was hailed as a unique structure enclosing a unique space. Indeed, it was the latter that Nowicki had set out to achieve, and in the course of developing his scheme for it he had come up with the former. Nowicki wished to give every spectator not only an unobstructed view of the arena floor, which was large enough to host a standard horse show, but also a sense of openness. Whereas those sitting in the topmost seats in most covered stadiums of the time had to watch their head, lest they bump it on the roof, Nowicki's saddle-shaped roof gave even the uppermost spectator a sense of openness not significantly different from that experienced by someone sitting near the arena floor. The cable-net roof was described as "the exact reverse of a dome," with the roof's upward curving ends allowing a maximum amount of light to come in through the windows. According to one critic, the interior was lit in a way that "marked a new epoch in architecture." The pavilion, which was built at a cost of $1.5 million, was designed to hold almost 5,000 spectators in permanent seats. Another 4,000 could be accommodated in chairs set up on the arena floor.

Among the honors that the structure soon received were the Engineering Gold Medal of the Architectural League of New York and the First Honor Award of the American Institute of Architects (AIA) for 1953. In 1957, it made the AIA's list of 10 buildings expected to exert the most influence on design in the next century. The Museum of Modern Art in New York was among the museums in which the model of the building was exhibited. The immediate, enthusiastic and unqualified architectural success of the livestock-judging pavilion led one contemporary critic to ask, "Why, in this land of the engineer, are there so few frank expressions of integrated engineering that create dramatic architecture?" It was certainly a valid question then, and it remains a valid one now.

Dramatic architecture, like dramatic engineering, begins with a creative idea for solving an old problem in a new way. There were plenty of unimaginative livestock judging arenas located in state fairgrounds around the country, and there were numerous covered riding arenas and sports stadiums that could have served as models for what was needed in Raleigh. Duke University's Cameron Indoor Stadium, less than 20 miles away in Durham, was just one example right in the area. Indeed, many architectural and engineering problems are solved by adapting existing solutions with minor modifications, often without regard to the unique needs or opportunities of a new site. Matthew Nowicki, by thinking about the problem anew, perhaps using his European experience and training to reach beyond examples to principles, was able to rise to the occasion and propose a truly imaginative scheme. And his inspiration was well served by Stanislava Nowicki, his widow and collaborator, his friend William Deitrick, the architect, and his friend Fred Severud, the engineer. With the blessing of J. S. Dorton, representing the client, and the sympathetic construction skills of William Muirhead, the contractor, Nowicki's dream was realized. The formula for dramatic engineering and architectural achievement is simple, then: Just recognize a brilliant idea when it occurs, and preserve it through the long and arduous process of its becoming a reality.

When it opened, the fairgrounds pavilion that was built "to serve agriculture, industry, and commerce" was officially and unpretentiously named the State Fair Arena. Unofficially and unappreciatively, it was referred to as the Cow Palace. While under construction, it had been referred to as "a flying saucer anchored to a glass platform," and shortly after its opening it was called the "parabolic pavilion." But from the start it was also recognized among professional architects and engineers as "the most important building in America today."

In 1961, at the opening ceremonies of that year's fair, the building was renamed the J. S. Dorton Arena, in recognition of the long-time manager of the North Carolina State Fair, who had recently died. The building was placed on the National Register of Historic Places in 1976, a considerable honor for a structure barely a quarter-century old. This year, as it reached the half-century mark, it was named by the American Society of Civil Engineers as a National Historic Civil Engineering Landmark, a distinction that cannot be applied to anything less than 50 years old. On October 18, a plaque declaring its landmark status was unveiled at the opening day of the 2002 fair.

No matter how much recognition the Dorton Arena has received, it continues to function as a State Fairgrounds building. The fair can only occupy the arena a couple of weeks a year, however, and so the building is available to rent the rest of the time—at a cost of $1,400 per day or 10 percent of the gross ticket sales, whichever is greater. Among the high-profile events that the arena has hosted have been comedy shows and rock concerts. It has also been the site of farm shows, home shows, ice hockey games, basketball games, high-school proms, wrestling matches and circuses.

In spite of its humble beginnings and unpretentious uses, the Dorton Arena remains "a familiar architectural landmark, studied and hailed as a masterfully unique design, nationally and internationally." Unfortunately, getting my visitor to the airport to catch his return flight did not allow us to go to Raleigh to view the structure. He went back to Chicago not having seen one of the most significant engineering and architectural structures in the Research Triangle area and in the world. I look forward to the day when he can return for a more leisurely visit and we can admire the Dorton Arena together.

## Acknowledgment

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