Fabric Structures in Architecture...Their past and their future

by Horst Berger

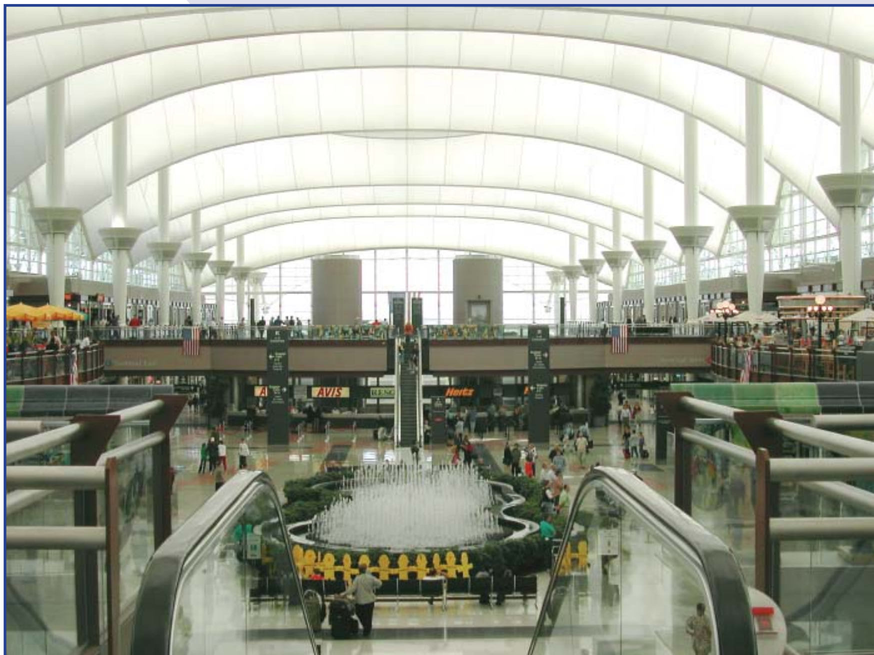

Figure 1: Denver International Airport. Photo by Horst Berger

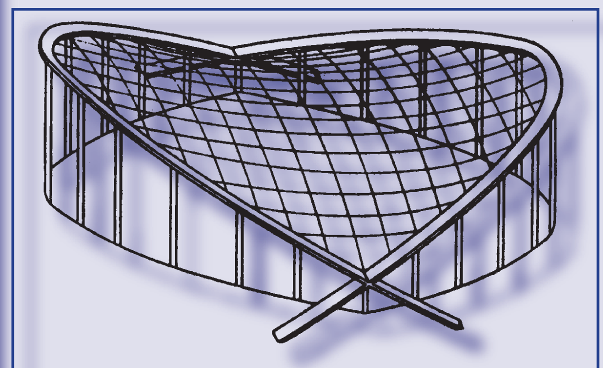

Figure 2: Schematic of Raleigh Arena

The Denver International Airport terminal is one of the great spaces of recent public architecture. (*Figure*.1). Daylight from the transparent fabric roof and the cable supported glass walls floods the almost 300-meter long hall. The delicately curved folds of the fabric structure, supported by two rows of slender columns, echo the great basilicas of the Middle Ages. Yet the visible lightness of the space - both calming and exhilarating - is totally contemporary. And from the outside, the giant tents are a dramatic structure to look at.

This building, now ten years old, demonstrates the successful use of fabric architecture in a major public building. It was one of the quickest to build and it is one of the simplest to maintain. It cost less than any other building with the same daylight level and free span. And it is one of the "greenest" buildings around.

What led to this remarkable application of tensile fabric architecture and technology, and why was its success not repeated in the last decade?

"...the roof structure is a saddle shaped orthogonal cable net covered with metal deck."

Tensile structures in architecture had two origins, both in the United States. One of these was the development of a cable net roof structure for the Raleigh Arena in North Carolina, completed in 1953. As designed by architect Matthew Nowicki and engineer Fred Severud, the roof structure is a saddle shaped orthogonal cable net covered with metal deck. The cables span between intersecting perimeter arches which rest on mullions. (*Figure 2*, schematic sketch). Saddle shaped roof systems quickly spread to many parts of the world, both as cable nets and concrete shells. Over the next decade, Severud designed many cable roof structures, most prominently the roof of the Madison Square Garden arena in New York City, (1962). The other origin was Walter Bird's pneumatic Radome enclosure design of the late 1940s. These were the first structures using a fabric membrane (PVC coated fiberglass) as a structural material. (*Figure 3 shows Walter Bird standing on top of one of his early domes*). His firm, Birdair Structures; soon began to produce pneumatic covers for tennis courts, warehouses, and many other purposes.

For the 1963/64 New York World's Fair, the architect Victor Lundy designed multiple sphere pneumatic trees for Brass Rail restaurants, ten of which were built by Birdair Structures. The engineering firm was Severud Associates, and I was the associate-in-charge. Having previously designed a tensile roof for Victor Lundy's Uniterian Church in Hartford, CT, my contribution here was the design of the tensile canopies under the pneumatic structures and the supports of both systems.

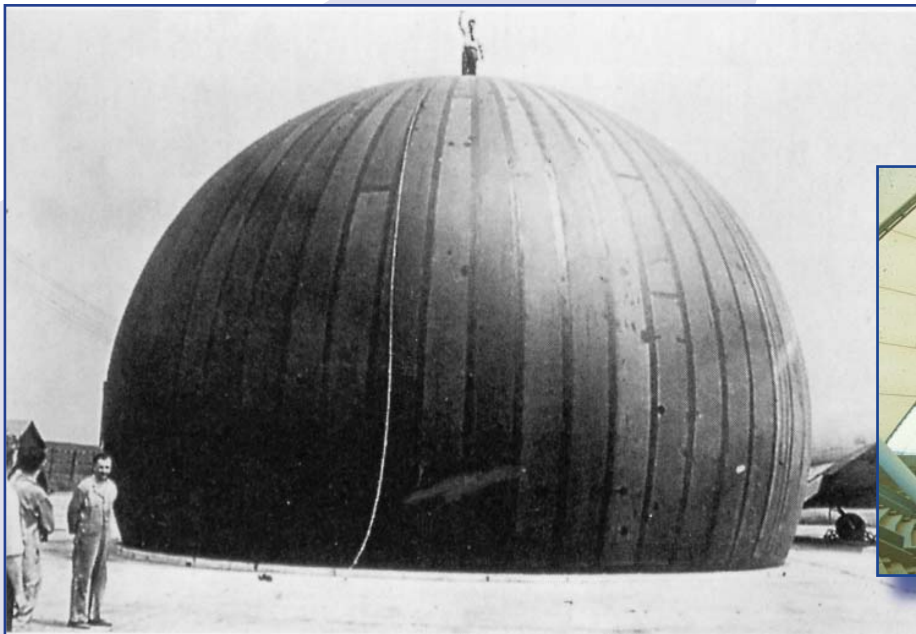

Figure 3: Radome. Photo courtesy of Birdair Corp.

Figure 4: Riyadh Stadium. Photo by Horst Berger

Figure 5: Haj Terminal. Photo by Horst Berger

Figure 6: Independance Mall. Photo by Horst Berger

Figure 7: Pontiac Silverdome. Photo courtesy of Birdair Corp.

The serious entry of fabric structures into architecture in the US began with the low profile air-supported fabric roof of the US Pavilion at the 1970 World Fair's in Osaka. Geiger Berger Associates was formed in 1968 to handle this project. For the next 22 years, Geiger Berger Associates and Horst Berger Partners pioneered the evolution of fabric structures in architecture in the US and elsewhere, using fabric structures in permanent buildings of increasing size and importance.

> ***"This roof structure produced an impressive free span space at an amazingly low cost..."***

The Osaka Pavilion was a cable reinforced, low profile air supported fabric structure, based on a concept David Geiger had developed. This roof structure produced an impressive free span space at an amazingly low cost in a very short time.

The Osaka success led to eight major stadium roofs including the record breaking

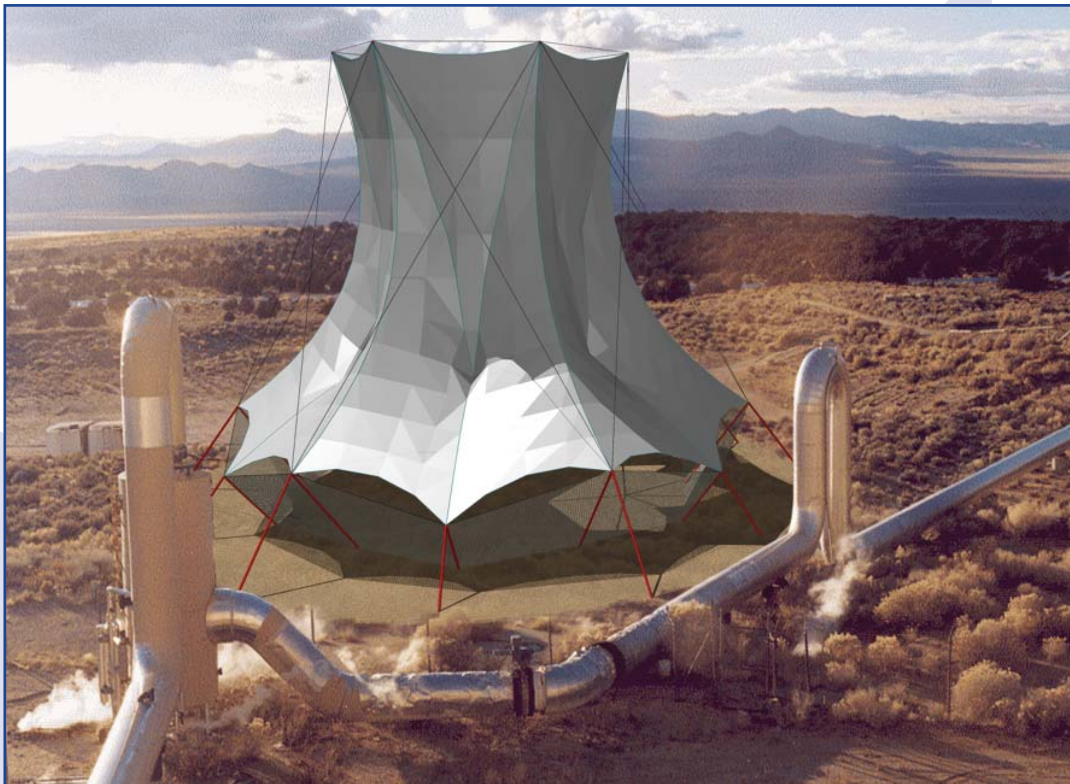

Figure 8: GEO Thermal Power Plant. Photo by Horst Berger

Pontiac Silverdome, seating 78,000 people with a translucent Teflon coated Fiberglass roof spanning 220 x 177 meters. The structure was a very American undertaking, as the developer for the stadium had the courage to trust that the enormous novel structure would work. And, indeed, these structures proved to be highly economical and fast to erect, making enclosed stadiums affordable and attractive. Though, in the long run, air-supported roofs for very large spans proved to be problematic, four full size stadiums covered with these structures still function in the US today, and one in Tokyo, built under license from Geiger-Berger.

In the wake of and parallel to the success of the air-supported structures, I pursued my primary interest: to develop, design, engineer and promote fabric tensile structures for use in permanent buildings. The first chance for a highly visible application, however, was temporary: the Bicentennial Celebration of 1976 in Philadelphia. Two large structures and a series of small stage and food pavilions enlivened the downtown with fabric structures. The city loved the Independence Mall pavilion (*Figure 6*) to the degree that they did not dismantle it after the celebration. In spite of the fact that it was not designed for snow loads, it was kept through two winters.

The Philadelphia structures led to many fabric tensile projects. But by far the most fascinating direct consequence was the Haj Terminal at the Jeddah airport. It was, and still is, the world's largest roof structure, covering a total of 427,000 square meters. Any one of its 210 units is as big as the entire Independence Mall Pavilion. Its purpose is to provide shelter against the desert heat for the hadjis on the way to Mecca. And it does that very successfully. I call it the "forest in the desert" (*Figure 5 shows about 10 % of the covered area*). The Jeddah project demonstrated that fabric structures have a place in the world of serious large-scale architecture. SOM were the architects. This was the toughest design and engineering job of my career, because of the enormous size and complexity of the structure and the speed with which this entirely novel project had to be constructed. It was built in two years. Now, after almost 25, years it is in excellent condition.

"...the world's largest roof structure, covering a total of 427,000 square meters."

In Saudi Arabia it led to the largest span stadium roof over the Riyadh Stadium (*Figure 4*). In spite of the large central opening, it covers more area than any other covered stadium. This structure became the realization of a concept long evolving in my mind and first shown in sketches which made the cover of Architectural Record in 1975. The roof was completed in 1985, and demonstrated the unique characteristic of fabric structures design: the structure is totally visible and totally invisible, because structure and enclosure are the same. The form, however, is never arbitrary but follows a subtle law, determined by the stress pattern, that is simple and potent... to produce structures of a lively variety almost as rich as nature itself. Daylight, shining through these delicately shaped surfaces, gives additional life to these structures. Only a real forest of trees - grown naturally - is more alive.

Of the many buildings that followed, I can count over 40 as my own designs. The most important among them were a series of structures which became architectural landmarks. These include Canada Place in Vancouver, B.C.; the San Diego Convention Center; the Mitchell Performing Arts Center at the Woodlands, near Houston, Texas; and the terminal Building at the Denver International Airport.

Canada Place in Vancouver covers a pier with a convention hall and an Imax movie theater. It also serves the docking facilities for ocean liners. The sail-like roof design derived from the end-supported structure of the Folk Life Pavilion in Philadelphia; but, I turned the parallel tents by 45 degrees to satisfy architect Eb Zeidler's desire to follow the city street pattern. This gave it the strong sculptural image. The building was completed in 1984.

When the Vancouver-based architect Arthur Erickson was selected to design the San Diego Convention Center, he crowned his building with a large fabric roof covering the outdoor exhibition space. The roof spans 91.5-meters x 91.5-meters with no interior columns. Its main supports are cable supported flying struts with cables spanning between triangular concrete edge buttresses. These give the building its almost gothic characteristic. A horizontal suspended spine with forked ends allows for keeping the open ends totally support-free. In this building, structure is architecture… the graceful spanning elements, and the gently curved surface form they take on, are clearly readable; lightness of structure is visible, lifting technology to an art form.

The design of the Woodlands (*Figure 9*) pavilion ended up completely in the hands of Horst Berger Partners and mine. This amphitheater had 3000 seats under the roof and 7000 seats on a grass covered berm. (The seating has meanwhile been expanded). I designed the seating and berm to form a double curved bowl, not unlike the Roman amphitheaters, but with much gentler curvatures. The roof consists of a tent-shaped fabric membrane suspended from three A-frames. The extension of the horizontal strut concept allows broad canopies to form the edges providing an intimate cover for those under it, and a lively proscenium arch for those on the berm outside.

Figure 9: Woodlands. Photo courtesy of Birdair Corp.

The most welcome aspect of the design was the successful acoustics, which work both for the Houston Symphony, for which this is the summer home, and for rock concerts at the other end of the sound spectrum. This is due entirely to the strong anti-clastic forms of the tensile units acting as black holes for the sound, thereby avoiding disturbing echoes.

So why did the success of these major buildings not lead to a whole new generation of fabric structure architecture? Architectural fashion is at least part of the answer. There is also a perception that fabric structures are temporary, despite the long life of the many existing examples. But there are two actual obstacles.

One is the status of fabric materials which seem expensive and difficult to handle. The fact is that today's fabric materials have come a long way. Materials have arrived on the market which are much more cost effective and easier to handle. Other materials - with some development - could attain much longer life spans and much higher translucencies.

The second obstacle is the apparent difficulty of designing tensile surface structures. The existing "formfinding" programs were written by specialists for specialists. They are generally expensive and often take months to learn; and they are often not design oriented. But here also, change is on the way. With my architecture students at City College, I am presently testing a new, design-friendly formfinding program, which will become available in the next few months.

I want to conclude with an example of a vertical fabric structure from a different field. Over the years I have designed a number of fabric cooling towers for power plants. My most recent design is a tower for a geothermal power plant in Utah. (*Figure 8*). It was for an NREL project. It is just 60-meters high. But that makes it equivalent to a 20 story apartment building. Of course, there is no direct translation into architectural buildings. But as the human body has a flexible skin for its outermost enclosure, a tensile skin might not be a bad idea for the enclosure of buildings.▪

Horst Berger is currently a Distinguished Professor of Architecture at City College of New York, and a Principal of Light Structures Design/Horst Berger at DeNardis Associates. He is a former partner of Geiger Berger Associates and Horst Berger Partners.