TEXTILE ARCHITECTURE IN AMERICA: a personal view of its past, present and future

Introduction

During the 1984 International Symposium on Architectural Fabric Structures in Orlando Florida, I was having dinner with three leaders of the industry at the time; on my left was Wally Bird, founder of Birdair Structures and across from me was Frei Otto my mentor who I had worked for in Germany for three years and next to him was Ian Liddell, an engineering partner of Buro Happold, who was another mentor of mine and designer of the Millennium Dome. Frei and Ian were arguing about the Diplomatic Club project which they were both working on in Riyadh, Saudi Arabia and Frei thought that the tensile structures were too high. Ian responded that they needed to have the height for the curvature and the two of them argued passionately about their point of view. After a half hour or so, both of them were at this point standing and Wally turns to me and says, " ...and both these guys like to work together?" Having worked both in the US and Europe, it highlighted to me the difference between the European and American approach to collaboration and architectural practice: the European one with its animated discussion versus an American one of a more quiet teamwork.

I have designed lightweight architecture for now forty years and I have seen its slow growth in the US and watched how it has developed from a unique building technology into an architectural language. To understand its development in the States, one needs to look at the two central figures in that restaurant, the American Engineer Walter Bird and the German Architect Frei Otto. Wally Bird was trained as an aeronautical engineer at MIT and in 1955 left to start Birdair, a manufacturing company which specialized in radar domes for military and inflatables for commercial applications such as swimming pool enclosures. Frei Otto wrote his doctoral thesis on the 'hanging roof' and then started his career designing event structures for his friend Peter Stromeyer who owned a classic circus tent company, Stromeyer AG. Frei went on to develop the first tensile structures in Europe and North America including iconic buildings such as the German Pavilion at the Montreal World's Fair, the Munich Olympic structures and the first gridshell in Manheim Germany.

Wally's big breakthrough came with the 1964 Pavilion at the NY World's Fair in Flushing NY and even more importantly the US Pavilion at Osaka in 1970 where he developed a low profile inflatable using a cable net restraint system. The engineers for the project were David Geiger and Horst Berger who had started an engineering firm in the States. Working with Birdair, they utilized the Birdair details as a design approach and from that project went on to develop as a world renowned engineering firm, Geiger Berger specializing in inflatable domes and tensile structures including the first cable dome in St. Petersburg, Florida and the iconic Georgia Dome in Atlanta. Horst left the firm in the 90's and worked with Severud Associates to develop the roof structures for the Denver International Terminal in Colorado.

After working at Frei Otto's studio in Germany, I came back to the States in 1978 and developed the firm FTL with two other partners. Our approach to tensile structures was based on my apprenticeship in Germany and both our use of physical modeling and lightweight detailing came out of the school of thought that these structures were as much a visual composition as a construction approach where every element should share embody the notion of lightness in both form and function. Our first projects were for the tent rental industry where we developed the first rental tent in the US that used tensile structures technology. Designed for Anchor Industries, we developed the Anchor Mod which was a modular laced tent system that had many fewer columns and webbing than traditional tents of the day. We developed the form using physical soap film models which created minimal surfaces and used an optimized form for analysis and patterning. From that design, came another rental tent system, the Anchor Century System which used a similar construction technology but looked more like a conventional tent and 30 years later, it still sells well as a tent product in the US.

With the advent of the 80's, new finite element software was developed which was applicable to these tensile structures. Having worked with the engineers of Buro Happold when I was in Germany, I continued the relationship and David Wakefield who was then at the Buro developed the 'tensylsuite' program which was a dynamic relaxation program that included digital form-finding, analysis and patterning services. By the end of the decade, we had the 'tensylsuite' software in-house in New York and used it for the next 15 years, but always in conjunction with physical modeling which we insisted on as an architectural tool to understand form and scale relationships that were difficult to visualize with computers, espeicially in those days.

Acoustic spaces: from NSO to Sun Valley

Working on a series of canopies for the White House in 1979, we were hired to design a performance pavilion on the West Lawn of the Capitol in Washington DC which was our first acoustic shell and it led to 30 years of designing music pavilions. We worked with Mstislav Rostropovich who was then the musical director and conductor of the US National Symphony Orchestra and the acoustician Chris Jaffe of Jaffe Holden where we were introduced to the acoustical qualities of membrane structures, its reflection of high and mid range frequencies and its sound blending capabilities. Chris liked the acoustic properties of saddle or hyperbolic paraboloids shaped surfaces because these surfaces provided for onstage hearing, with a blended projection towards the audience. When we set up the shell for a trial run on the West Lawn in 1979 (see fig. NSO 79), 'Misty' as he was called, told us that it was the best outdoor acoustics he had heard. So we thought this was a new way to control outdoor sound and went on to develop acoustic structures that used a series of membranes such as the Baltimore Pier 6 Pavilion in 1981 where we worked with the Chris again and the BSO (fig. Aldo's sketch). Here the idea was to create a "Tanglewood in a parking lot"[1] right on the Inner Harbor of Baltimore with seating for 2,000 spectators under roof. The pavilion was so successful that after ten years, we were rehired to design a larger one, this time one for 3,500 seats under cover which included a generous backstage, offices and a terraced lawn for outdoor viewing. Our interest here was the intersection of joining a large open air membrane structure to enclosed buildings. To do this we shaped curved roofs to the rigid framed pavilions which gave curvature to the membranes. From this project, our firm went on to develop over 15 music facilities over the years including projects in Jacksonville Florida and Charlottesville Virginia.

Our latest music pavilion which we completed in 2008 is the Sun Valley Pavilion which was designed as a seasonal facility and is a development of our interest in this musical architecture. The Sun Valley Pavilion is located on the south western end of the central campus at the Sun Valley Resort. The resort was founded in 1936 by the Union Pacific Railroad as a destination resort to increase ridership and is considered as one of America's preeminent ski resorts. Our facility was inspired by its natural setting and has become a community gathering place for performance events. The sky and mountain are captured by the free flowing roof, comprised of a seasonal luminous tensile membrane covering 1,500 seats and a permanent steel cable net with wood cladding which provides cover over the stage and support facilities (fig. SK3). Set into the surrounding landscape is an undulating park gently elevated like a natural amphitheatre, providing views of the surrounding mountains, for visitor to relax with a picnic basket and enjoy orchestral and popular music.

At the start of the project, we understood that the Symphony wanted a structure that combined the seasonal and ephemeral quality of a summer tent which they had previously rented with a more permanent facility that could accommodate the theatrical and acoustic requirements in keeping with such an accomplished symphony orchestra. In short, they wanted an outdoor feeling with a state-of-the-art performance facility. Having designed permanent and seasonal outdoor performing arts facilities for thirty years, we immediately realized that with the local snow load requirements would not allow for a permanent fabric structure and that the facility was too big for a smaller seasonal roof that needed to be dismantled each winter. What to do? We had used cable nets with fabric when we needed to take high snow loads, but 100 lbs a sq ft with drifting of up to 200 lbs in areas was enormous. It was at this point when we started thinking of alternative materials. If we replaced the fabric with a steel cable net and used a rigid material like wood which can take high vertical loads, we had a chance. In developing this idea, we felt that the wood was very much in keeping with the materials near the site and that through the wood, it tied into the surrounding buildings (fig. SV siteplan). The copper skin was added when we realized that the wood was relatively flat in some areas and steep in others. The copper roofing allowed us to maintain this differential in slope and added another earthy touch to the ephemeral cable structure. For the audience area, we designed a soft membrane roof which is installed each year in the spring and gives the facility the sense of an outdoor room (fig. Section).

Peripatetic Facilities

Early on with our work on rental tents, we understood that one of the great qualities of membrane structures is the lightness of its weight and that much like the traditional circus tents, these structures were excellent as traveling and deployable facilities. We have categorized these facilities as three different types: truck deployed, 'bale ring' tent structures and inflatables. After the NSO pavilion which was previously mentioned, in 1987 we were asked to develop a traveling facility to the Metropolitan Opera and New York Philharmonic which would tour all the parks during the summer in New York City and could be set up in one day so it could perform each night during the summer at a different park in New York City. Working in collaboration over two years with the theatrical designer Peter Wexler, we developed a facility which consisted of 7 trucks (fig. Trucks) that could drive to any of the NYC parks and could be assembled in 4 hours with a crew of 11. It was named after the Chairman of the NY Philharmonic the Carlos Moseley Pavilion who introduced free concerts to the parks.

Originally we worked on a series of schemes using a pyramid-frame structure consisting of four hydraulic cranes that docked in space. No manufacturer would allow standard cranes to do this, so we replaced them with three eighty-six foot long custom truss masts. We came up with an underfold apparatus on the front two trailers and a double-back device for on the rear trailer. From this arrangement, our design took shape. Six semi trailers plus three rental dressing room trucks transport the complete facility from park to park. These trailers hold all equipment necessary for setting up and dismantling the pavilion, including forklifts, hydraulic opening devices, and winches (fig. elevation). The vehicles have been completely rebuilt to carry concrete foundations, meet all interstate highway regulations. In fact, the allowable weight of the trailers for highway travel ultimately determined the exact surface area of the overhead tensile fabric shell. Each of the tree main trailers carried one of the trusses which contained fixed lighting positions. The central trailer contained a 40 x 80 ft stage that folded out hydraulically and the tensile membrane roof.

Our design approach to this project was to allow the engineering of the mechanism dictate the forms and geometry of the structure. We consciously tried not to create arbitrary architectural compositions, letting the steelworks express its essential character (fig. Detail). The fabric membrane took its shape from the reflective acoustic requirements and the need to provide rain cover for the performers. The resulting design became a mixture of architecture, industrial design, and engineering.

Circus technology has been developed over the past few hundred years and allows large open spaces with structurally efficient fabrics. The circus tent is truly an extraordinary kit of parts that merges building integration in its completed form with an installation process. We have been inspired by both the classic European "chapiteau" [2] and the American "big top"[3] which are designs that have been honed over the past hundred years. The beauty of the circus is as Charles Eames has said, "there is a strict hierarchy of events and an elimination of choice under stress, so that one event can automatically follow another. The layout of the circus under canvas is more like the acropolis than anything else." This "elimination of choice under stress" gives the circus and this technology an efficiency of material vs. span that is unequaled in most buildings.

In 2003, we designed a traveling exhibit for Harley-Davidson's 100 anniversary tour, called 'Open Road 2003'. We were contacted by the exhibit design firm Pentagram to develop a 150 diameter exhibition space which could be set up in 12 hours. Using the circus tent technology allowed us to create a structure that had a museum interior, the graphics of Harley, and a one week turnaround time. We designed a series of "bale rings" which took the form of a motorcycle chassis which used electric winches to raise the tent structure (see fig. perspective). The exhibition facility traveled throughout the United States and Europe ending up in Milwaukee for the anniversary festivities and yet it used the circus technologies, it didn't feel at all like a traditional circus tent.

From this project we went on to design many other traveling facilities including an inflatable project for the Dyson Company who wanted to showcase their new vacuum cleaner product the DC-15 with an event launch. This product used a revolutionary ball instead of wheels to drive the vacuum cleaner which allows for much sharper turns in the vacuuming process. Our firm was contacted by an event planning firm on behalf of Dyson to design a portable event and exhibit structure. Based on our history with portable buildings, we developed the ball concept as an air supported inflatable structure held down by a steel tetrahedral ring (fig. Dyson 1). The tetrahedral frame created an eight foot double wall service zone which housed electrical distribution, air handling equipment and ballast foundations for the structure. Entry into the structure began with a lightweight lattice portico which joined onto the tetrahedral frame and opened into a large 85 foot diameter dome shaped space where the exhibit began. The exhibit continued along a curved ramp which ascended a full floor until one reached a spherical geode which contained a small cinema. The cinema showed a 360 degree film about the new product (fig. Dyson 2).

By using pneumatic technology, the entire structure was assembled on site at Lincoln Center in three days. The event and subsequent exhibition continued for four days and the structure and exhibit was dismantled in two days. Generally in portable buildings, the exterior space is filled with the services such as temporary power and HVAC. Using double skin fabric walls on the first floor, a clean exterior and interior space was maintained. We also developed water ballast anchors allowing the installation to occur without the transport of concrete foundations which are typical for temporary structures.

Building Skins

When we think of building skins, we probably think of Frank Gehry's curved titanium cladding such as the Symphony Hall in LA, but building skin today is far more complex than just free-form compositional packaging. Building skins are environmental filters, they are boundaries of personal property and they act as the transition between inside and outside. They are becoming a more important element of the architect's design and the available types of skins are more numerous and complex than ever before.

During the past decade FTL has been involved with developing fabric membranes as part of building skins starting in 1998 with a shading skin integrated into a glass curtain wall for the Central Library in Phoenix Arizona. Twenty four 75 foot long vertical shade panels consisting of a polyester/PVC shade cloth descend the north wall of the library. The shade panels are designed to block direct sunlight in the early mornings of the summer months. The open-mesh, warped shade cloth created a "brise soleil" shading effect on the north wall of the library and gave the building an elegant diaphanous facade through the interplay of the fabric shading and glass curtain wall. The panels used custom machined stainless steel fittings which tied into the glass mullions. FTL also developed the design of solar-powered products which was the focus of an outdoor exhibition at the Cooper-Hewitt National Design Museum's "Under the Sun: An Outdoor Exhibition of Light" in the summer of 1998. As one of the pioneers of incorporating photovoltaic technology into designs, FTL developed a 32-foot-high tensile structure exclusively for the exhibit. Using flexible, thin-film photovoltaics bonded to a translucent fabric, the structure was the first demonstration of PV embedded fabrics as a tensile structure (fig. Under Sun perspective). We continued with the development of this technology including tenting systems for the military with embedded PV's and in 2006, FTL Solar was formed to develop this thin film material in fabric applications for military and traveling facilities.

Building skins have been used as infrastructure projects in the US with projects such as the new campus at Arizona State University in Phoenix and the new Rosa Parks Transit Center in Detroit where the membrane roof acts as a water collector (fig. Rosa section). FTL created an urban plaza, covered by a sustainable skin to define space, washed with day lighting and harvesting rain water which transformed the infrastructure into a sculptural environment. There was a much needed desire to create a iconic public space which energized the urban fabric, helping in uplifting a run-down part of the city and developing a design that was a drastic departure from the old.

The new Rosa Parks Transit Center includes a passenger terminal, a roof canopy covering a drop off and outdoor waiting area which will play a pivotal role in providing alternate means of public transportation to the greater Detroit area. FTL developed a design approach that uses flowing canopies to create an active visual space and naturally day light space which challenges the conventional notion of roof where the membrane both hovers 50 ft in space, and in other areas brought to ground and to act as a giant water collector. To create rhythm, the proposed scheme was broken down into seven repetitive bays, each approximately 110' long and 50 ft wide. Each bay is comprised of two trusses, an A frame and fabric which is pulled down, transforming the roof into a wall and encompassing a courtyard. With the advent of the new ETFE foils, the development of building skins have now become an even more important element of textile architecture.

In looking back over the last 30 years, textile architecture in the US has moved from small stand alone pavilions to become architectural elements of larger projects where the woven textile skin becomes an enclosure which is sometimes porous, sometimes translucent, sometimes a water collector, all layering as a new building technology. This trend is reflective of a world trend and although the US was very influential in the 70's as a leader in this technology with the advent of PTFE glass fabric and large scale projects such as the Jeddah Hadj Airport, globalization has flattened this trend and US architectural projects are really no different than anywhere else in the world. Designers, fabricators, engineers and installers work across all international boundaries and the notion of a uniquely American or European approach to lightweight structures has faded with parts of each tradition being incorporated into worldwide approach.

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[1] Tanglewood is the summer home of the Boston Symphony Orchestra and a premier outdoor acoustic facility in the Berkshire Mountains founded by Serge Koussevitsky in 1940.

[2] this term comes from the French word meaning capital of a column

[3] The big top refers to a 3 centerpole, hundred ft plus wide circus tent using a bale ring technology of installing the center poles first and lifting the fabric up the poles on steel rings sewn into the fabric.