Architects and fabric:
achieving greater material performance

An architect explores his relationship with designers and manufacturers, and the mutual labor of love required to produce a successful fabric architecture project.

By David Burke, AIA

Throughout history, fabric has been used to protect us from harsh climactic conditions, keeping out the rain, wind and snow. In the case of the Native Americans, fabric—first animal skins and then canvas—not only protected them from the weather but was the primary component in a flexible and lightweight structure, allowing them to move around and resettle.

In today's society, fabrics (and films) are being utilized in more innovative ways than ever before, achieving great success throughout the architectural industry. Manufacturers can produce fabrics of varying thicknesses and densities with specific finishes, colors and surface treatments, increasing the level of their capability. Used as roof structures or wall cladding, fabric not only keeps the rain out, it provides extra protection from the cold by increasing the building's insulation value, while also providing windows for natural light and environmental views. Interior applications use fabric to form walls and ceilings; and today, fabric is being used for acoustic and lighting applications as well.

Following discussions with manufacturers and designers, and through my first-hand experience as an architect with two significant projects, the Eden project and the Experimental Music and Performing Arts Center, it is clear that through the close collaboration among the client, architect and manufacturer, a material's performance can be drastically improved and economically viable, consequently offering more options to the industry and the people who design and build within it.

Pushing fabric performance

Fabric performance is becoming more specialized, and architects and designers have more stringent requirements for the fabrics with which they choose to build. Collaborative effort can keep all parties informed of the best choice of fabric, which is sometimes hampered by the inherent quality of the materials that designers have at their disposal to satisfy the project criteria.

Architen Landrell, a tensile structure manufacturer in Chepstow, England, works with a variety of fabrics but generally finds an architect's preference is durability. "Architects want their structures to last as long as possible," says Lance Rowell, chief operating officer. "PVC polyester and PTFE are very durable, and are most popular because of it. Other sought-after characteristics are light transmission, acoustic performance and ease of maintenance."

But often the right choice is hard to find—satisfying some criteria but not others. Clients are demanding more environmentally friendly fabrics these days, and PVC does not satisfy this growing environmental awareness. PVC manufacturing and its general use is considered hazardous by many, and although some manufacturers are making honest efforts to recycle their products by installing recycling facilities, the recycling process is imperfect and costly. For interior uses, however, a fabric's fire rating is the most important issue; keeping interior fabrics up to code will sometimes dictate the difference between two fabric choices. The working relationship of the client, designer and builder offers the best information, and opportunity, to achieve the greatest performance from the right fabric choice.

Lance Rowell believes in a collaborative approach to building design. "We prefer to work hand-in-hand with architects, getting involved at the early stages of design,

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The Eden Project of Cornwall, England, is a strange and wonderful attraction with biomes that total 23,000 square meters of space. The ingenious structures of the project are the result of architects, designers and manufacturers working together for a common goal.

All photos (Eden Project): William Houseman

when our experience [of manufacturing the foundation of the project—its tensile structure] is most valuable. A good working relationship, to us, can mean the difference between the success and failure of a project; by ensuring communication lines between architect and contractor remain clear and honest, a project can be completed smoothly and efficiently, offering the client the best product possible."

Two projects, due to their innovative structural foundation and design, specifically reinforce the importance of working well with the construction industry to push a fabric's performance further than before. The Eden project, completed in 2000, and the Experimental Music and Performing Arts Center, scheduled for completion in 2008, showcase the achievements of fabrics and film through good working relationships between team members in two very different applications. The materials used in each example have surpassed the expectations of the project's client, designer and the manufacturer.

Return to Eden

A popular visitor attraction, the Eden project in southwestern Cornwall, England, is designed with biomes comprised of a series of transparent green houses that enclose a humid tropics and warm temperate environment. The challenge to our team, Nicholas Grimshaw & Partners (now Grimshaw Architects, New York, N.Y.) was sustaining plant growth throughout the year in a temperate climate. Achieving maximum transparency was of utmost importance when developing the structure and cladding for the project, for the greater amount of daylight that the structure could allow, the more prolific the plant life growth.

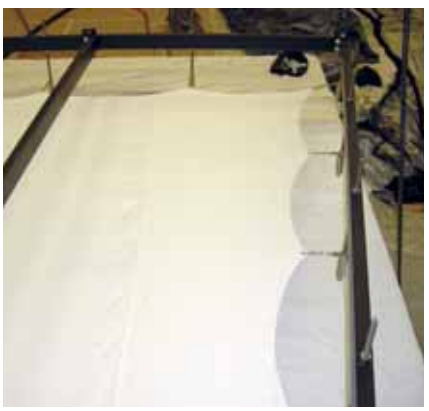
The structures are clad in ethylene tetrafluoroethylene (ETFE). ETFE is a film that has performed far better than glass when used in this application, as we discovered in a previous project as the designers of the Waterloo International Terminal in London, England. It has a greater light transmission and is far lighter than glass, requiring less structure to support it. At the time the project was built, the material's transparency in the visible and UV part of the spectrum was 95 percent and 85 percent, respectively. And in material terms, the film used less than one percent of the volume of material that would be used in a double-glazed solution (350g per square meter). Its lightness and transparency, coupled with the minimum structural requirements to support it, allowed a maximum penetration of light to the plants inside.

From the surrounding hilltops, the structures of the biomes seem to sprawl rather than soar, but on path level, they tower over visitors of the botanical gardens.

All photos (EMPCA): Grimshaw Architects

The interior beauty of the Experimental Music and Performing Arts Center, Troy, N.Y.

A detail of the framing and suspension system used, for both aesthetic and acoustic reasons.



Ceiling panel mock-ups developed by Adirondack enhanced the acoustics of the arts center.

The design of the structure and pillow systems was optimized by a close working relationship with Mero Structures (currently known as Novum Structures LLC of Menomonee Falls, Wis.), the contractor who was awarded the project. Bringing Mero into the design process at the earliest possible time enabled the Eden design team to utilize the experience of both designers and fabricators.

Initially the size for the biggest pillow was based on intuition—a feeling for what the largest achievable span was likely to be. There were incentives on all sides to design as large a hexagon as possible for various reasons:

- The larger the hexagons were, the lighter the steel would be, reducing costs for the overall building.
- The bigger the hexagons were, the more light could penetrate through, because the structural frames provided less insulation than the pillows and better thermal performance.

A hexagon side length of 5.5 meters, equating to a diameter of 11 meters, was set as the target. This resulted in pillow sizes of more than 75 square meters. Several cushion mock-ups were built to scale and tested in wind tunnels. It was discovered that the three-layer cushions were not strong enough to take the wind loading and uplift acting on the top surface.

The first solution attempted was to install reinforcing cables over the pillow to reduce the effective span of the material. While this was workable in principle there were a number of disadvantages: It was a relatively expensive solution, and was likely to cause chafing between the steel cables and the ETFE. Additionally, increasing the thickness of any individual layer may result in failure if the material becomes too brittle.

In one of the many round table discussions about the Eden project, a second solution emerged. Using a double layer of foil for the external surface (the part subjected to the most onerous load cases) would allow the two layers to work together to share the load. A second series of tests then was carried out using this method and established that the proposal would work with a relatively comfortable margin of error.

The strict performance criteria necessary to sustain and promote plant growth forced the design team to look at innovative solutions. The close working relationship between Mero and our team from Grimshaw Architects (New York, N.Y.) satisfied that criteria in ways that would not have been achieved otherwise. The experience of both manufacturer and designer, together with the ability to experiment with different methods of fabrication, produced a solution that was both innovative and economical.

Artful experiment

The Experimental Music and Performing Arts Center, currently under construction at Rensselaer Polytechnic Institute in upstate New York, uses a similar process to achieve greater performance from selected fabric. The concert hall ceiling of the center was designed by close collaboration of the architects at Grimshaw and acousticians Kirkegaard Assoc. of Chicago, Ill. While laboratory testing was performed by North Carolina State University, Raleigh, N.C., fabrication by Adirondack Scenic Inc. of Argyle, N.Y., began. Together, our team had created an acoustic baffle to clad the ceiling of a 1,400-seat concert hall. The design of the membrane was critical to the hall's overall acoustical performance.

In bygone days, fabrics were used for only the most practical reasons, providing warmth and protection from the weather. Today, however, exhaustive testing is used to create responses to the most specialized criteria.

Rather than applying the conventional method of installing a cumbersome baffle above the concert hall platform, we preferred to develop a discrete ceiling membrane that could achieve the acoustic properties needed without interrupting the elegant volume. A permeable ceiling treatment would allow selective reflectivity for certain

wavelengths of sound, while allowing others to pass through.

The fabric's porosity and density was of primary importance to its specification. More than 20 material types were tested by both electronic equipment and actual musicians and listeners. These materials included paper, rubber membranes, films and fabrics. The best acoustic performance was achieved by two fabric types: canvas and a synthetic fabric called Nomex™. The latter material is typically used for flame-resistant and high-performance applications, such as automobile racing uniforms, fire fighters' uniforms and power generation. Due to its flammability, then, canvas was eliminated, leaving Nomex as the only option.

Once Nomex was selected, thorough fabric testing began. Air permeability was crucial to fabric performance. The warp and weft were manipulated significantly to optimize the fabric's weave and acoustic infiltration, continually being tested and refined to achieve the optimal acoustic performance. Kirkegaard performed various preliminary tests in-house; then the testing lab at North Carolina State University College of Textiles tested the material's performance levels.

While fabric performance was being evaluated, the ceiling panel mock-ups were developed by the fabricators of Adirondack. The challenge was to develop a system of panels that draped the fabric without introducing high tensile forces, while also preventing wrinkling at seams and edges. If too much force was introduced, the fabric would act like a drum and counteract the acoustic properties already established. The framing and suspension systems of the fabric were critical in this evaluation: the first, a system of turnbuckles and eyelets, and the second, a system of steel rods placed within a fabric edge pocket, proved very useful for identifying the aesthetic and acoustic implications of the suspension system.

The Experimental Music and Performing Arts Center was a project driven primarily by specialized acoustic criteria. It was a perfect example of how a fabric's performance can go well beyond the options found in an off-the-shelf application. A team working together and focused on achieving highly specific results can arrive at an innovative solution, thus educating those in the industry and driving forward the concepts of fabric architecture.

In bygone days, fabrics were used for only the most practical reasons, providing warmth and protection from the weather. Today, however, exhaustive testing is used to create responses to the most specialized criteria. Fabrics are an important building material that will continue to develop in importance to architects, designers and manufacturers. It is important that the fabrics industry continues to be innovative with our choices, allowing us to respond to the growing opportunity before us. R

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