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The Rice School amphitheater.

Creative Tension

University of Houston students build with fabric

THE ELEMENTARY-SCHOOL PERFORMANCES at the amphitheater behind the Rice School are modest compared to those at the Cynthia Woods Mitchell Pavilion. But the two venues share a common trait: a complex, high-tech fabric roof.

The Rice School amphitheater, big enough to seat a single class of elementary- or middle-school students, was designed by 13 University of Houston architecture students enrolled in professor Patrick Peters' design-build studio class. For the last 12 years, every summer, the program has offered students the real-world experience of conceiving and constructing a small structure for a local nonprofit group.

Last year, the students considered four possible sites at the Rice School, a public elementary school. Within the first three weeks of class, they had focused on the amphitheater, which was unused partly because it lacked shade. "It presented problems that had architectural solutions within the means we had available," Peters explains.

The students presented a scheme to the school faculty at the beginning of May 2001. A week later they came back with a final design, revised according to the faculty's suggestions. The collaboration thrilled Rice School principal Jocelyn Mouton. "Every time we met," she says, "the students were taking notes and listening."

By this time, the project had become unconventional. Overhead power lines hemmed in the site; underground pipes required a long span. Peters says they were left with no choice: "We didn't start out to do a fabric project. But by the time we got to that point, there was almost no other solution."

Having decided on fabric, the 13 UH students began their search for expert help at Hendee Industries, a Houston company. Hendee turns computer coordinates into patterns used to cut fabric sections, then stitches the sections and welds them into three-dimensional shapes. "It's a lot like making sails," says company president Bill Hendee.

Architects, of course, are rarely trained to make sails, and few attempt the tricky business. Hendee referred the students to fabric-structure expert William Murrell, owner of the New Jersey-based consulting firm Fabric Structures, Inc.

Murrell, a math major who switched to architecture in his junior year, launched his career at a military think tank, where he designed portable barracks; the idea was that a plane could carry an entire portable base. He found himself doing fabric extensions for aircraft hangars, then protective "bubble" enclosures for tennis courts. The bubbles stay inflated because fans keep the air pressure inside slightly higher than the air pressure outside. (A similar system holds up the Detroit Silverdome.)

In the early 1980s, Murrell began exploring tensile structures. Like "bubble" structures, these are made of a light fabric, but instead of air, masts or arches support the tightly stretched fabric. The tensile forces created by stretching the fabric are much larger than any other forces on the structure, including wind, rain, and gravity. At every point on the fabric surface, the built-in tensile forces are in equilibrium. That means that at every point, the fabric must curve — and curve not in just one direction, but two. The forces inside the fabric dictate its form.

Architects, of course, usually work the other way around — with structure following the architectural form — and the UH students were no exception. On a Friday in July they arrived at 4 p.m. in Murrell's New Jersey office. By 8 p.m., Murrell had concluded that the designs they'd brought were unworkable. "The cable forces were immense," he explains. "The columns were not in compression but in bending. What was wrong would be an interesting discussion."

Soon, though, the students found the right shape. This computer-intensive process is the most complicated part of designing a tensile fabric structure. "We call it form-finding," Murrell says, "and we treat it with some reverence. We don't make the shape; we try to find the shape. It's a mathematical procedure. Once you find the constraints, you try to find the inherent shape."

The students' amphitheater designs evolved into a pair of intersecting arches with the fabric stretched over them. That shape proved low enough to clear power lines, tall enough to avoid obstructed seating, and curved enough to satisfy the laws of gravity.

Back in Houston, in the last two weeks of July, Hendee Industries made the fabric, a vinyl-coated polyester that Hendee predicts will last 10 to 15 years. Cables run in sleeves at the edges of the panels. At the corners, those cables are attached to a plate, which is bolted to the arches. The UH students performed most of the labor, making patterns and cutting the fabric to shape. Hendee's staff used radio-frequency welding to fuse the fabric pieces together.

The fabric was ready by the end of summer, but after fall classes began, work slowed to weekend sessions. A building permit was approved the first week of August, a month later than planned. Foundations came next; in September a crew from W.S. Bellows Construction lifted the steel lifted into place, pro bono. The students did the welding.

At last, everything was ready for the big moment. On November 17, a Saturday morning, 2,000 pounds of fabric were rolled out on a dolly. Ropes had been stretched across the steel arches to cradle the fabric. Some of the UH students unfurled the fabric; others pulled it over the frame with ropes. Nobody there had ever raised a fabric roof before.

The fabric now draped over the arches, wrinkled like laundry, awaiting the tension that would snap it into place. At each corner, the fabric was bolted to a sleeve that slid over the steel pipe supports. Students hand-tightened a pair of 4,000-pound comealongs at each support to pull the sleeves down and stretch the fabric.

As Peters watched, the canopy's saddle curve emerged. "That was the first moment that fabric had a quality of being more than hung," he says. "It became something altogether different."

— *Christof Spieler*