MASONRY VARIATIONS:
THE STONE CURTAIN

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STONE FOUNDATION HOME PAGE

by Matthew Redabaugh

Industrial stone technology, the thinner and thinner material it produces, new methods of application and the modern designs deriving from these have transformed our illustrious craft of stonemasonry in many respects. As a member of the Stone Foundation, I fully understand, appreciate and share this group's love for traditional structural stonework. Even so, I want to share with you my recent involvement in an interesting and technologically challenging project in which our revered stone was turned it on its ear, pushed out of its usual context and taken to a place where, until now, it had never been and given a whole new function.

Last year I had the opportunity to participate in what proved to be a once in a lifetime experience, a unique event called *MASONRY VARIATIONS.* Sponsored by the International Union of Bricklayers and Allied Craftworkers and the International Masonry Institute in conjunction with the National Building Museum, this was a remarkable exhibit/demonstration of masonry design and craft skills, a challenge to traditional materials and the ways we traditionally use them. *MASONRY VARIATIONS* could be considered a logical progression or extension of IMI's Masonry Camp, a program wherein architectural students and apprentice masons are given the opportunity to work hand in glove, exchanging the designer and builder roles.

Four architects were paired up with four masons and given the goal of creating structural/sculptural pieces in four masonry materials —stone, brick, terrazzo and aerated autoclaved concrete— that would be installed and exhibited at the National Building Museum. I was partnered with Jeanne Gang, AIA, of Studio Gang from Chicago, to work with our assigned material, stone. The task, as presented by the exhibit curator, Stanley Tigerman, AIA, was to take the assigned masonry material and push it into the next millennium. The parameters of the challenge were quite loose: Design and construct a hut-like structure (with an inside and an outside); give your masonry material a futuristic application; push the envelope. The project took nearly one year.

Jeanne Gang's design took stone, a material that performs best when subjected to compressive loads, and put it in tension, linking piece to piece in a series of chains to create a shell-like form, her *Stone Curtain.* The entire construct, comprised of 620 individual pieces, is 18′ tall and weighs 2000 pounds. It hangs in tension from the brick dome of the ceiling, stone from stone, without any sort of support or frame!

She chose to use thin material, nominally 3/8″, not only for the weight factor but because she wanted to exploit/explore its translucency and use that to enhance her design. By our second meeting, she had the dream-inspired design concept of a "stone curtain". The basic mechanics would be modeled on a jigsaw puzzle, with individual interlocking elements (key and key-hole) in this particular case hanging stone to stone from the ceiling with no frame or back-up walling system.

It was imperative to conduct a battery of tests to determine if we could in fact hang stone in tension. Initially the professor of Materials Testing at the Illinois Institute of Technology was certain that we were wasting our time. According to him, stone in tension "would fail at a force of 100 pounds". When push came to shove, or in this case to "pull", we proved him wrong —when we pulled the stone, it failed but at 700 pounds of force! That exceeded everyone's expectations and satisfied Thorton-Tomasetti Engineers, Inc., the engineers for the four individual projects of the exhibit. When word got out that we were "pulling stone apart," students and faculty alike stopped by for a peek. No tests existed to determine stone's strength in tension; there had been until now no need for such tests.

As a fail-safe in case of individual stone fracture, however, we were directed by the engineers to reinforce the backs of the pieces with epoxy resin and fiberglass. One of the many things the architect had brought to my attention is that historically humans have always, until fairly recent times, built with composite materials such as adobe or plaster adding horse hair and other substances. As, more and more, we incorporate such modern materials as epoxy/fiberglass and carbon-fibers, we could be said to be returning to this mindset.

To achieve translucency, the architect wanted to use onyx but that was too expensive and too unstable. Ultimately, a marble called *Bianco Limone* from Turkey was chosen, a tightly constituted, fine crystalline calcium carbonate that gave out a resounding ring when struck with the knuckle. Gang appreciated this age-old technique, which she called "thumping," for sounding the stone to determine its quality.

For a time it seemed that desired level of translucency would not be attainable because of the epoxy/fiberglass reinforcement. To solve this dilemma, I deduced that if we were to hone the backs of the pieces, the degree of translucency would increase. The resulting level of consistency would, in effect, reduce the surface area, therefore allowing more light to penetrate the stone, rather than being refracted by an erratic and coarse-sawn surface. A simple test using a light meter and a halogen lamp proved this point. Before and after honing readings proved that we could achieve 30% more light penetration, and translucency was now back in the mix.

But what effect would the resin and fiber-glass backing have on this hard earned translucency? We applied a very transparent epoxy and finely chopped fiberglass to the honed surfaces and were relieved to find that the translucency was still considerably greater than that of the original stone before treatment.

The clock was ticking. We were introduced to the project in late November 2002, with a scheduled opening date of October 16, 2003. There were less than 11 months to carry out all of the testing, evaluations and changes, the drawing of each piece for cutting, the material fabrication, building a centering and removing it after hanging the stone. With so many uncertainties and so very little time for all that needed to be done, this design challenge had high potential for failure.

In the Middle Ages, a form of applied geometry called *Stereotomy* evolved that was specific to the cutting and shaping of building stones. Fortunately we had access to the modern day version of this process, *Computer Aided Designs* or CAD. With the use of this computer technique, the architects were able to translate information from their drawings to fabrication tasks such as cutting the intricate pieces and helping to configure the wooden shell. Bear in mind that although the computer speeds up the process, the knowledge and skills comparable to those of the ancient cathedral builders are still demanded.

Given the time constraints, the complexity of the process and all that was required to fabricate each element of the stone curtain, I wanted to have a certain level of indigenousness. That is to say, I needed all the principal players to be close to the National Building Museum, the installation site. The stone was secured from a distributor 20 miles east of Washington (ARC Stone, who donated nearly half of the material), the fiberglass and resin came from Fox Industries, 56 miles to the northeast and the water-jet cutter, LAI Laser Applications, Inc. was not far from Baltimore. Given the potential for breakage and/or miss-cut stones among 600 individual pieces, we needed to be able to get our hands on replacements immediately. There were no extras made because each piece was unique unto itself and could not replace nor be replaced by another.

The *Stone Curtain*, being a shell or arch-like structural form, would necessitate the use of a temporary wooden frame similar to the centering used in arch or dome construction. This centering would have to adhere to the dictates of a grid with level and plumb, yet still reflect the exact complex curving configuration of the stone form.

MODUS OPERANDI*:*

Selection for Quality:

The stone tiles from Turkey were 16" x 16" x 3/8". Each one was "thump" tested, sounded to determine if there were any hidden cracks. Those that failed to resound with a definite ring were discarded. (With over 600 pieces, we used a metal chisel, not the knuckle.)

Sorting/Shuffling:

The stones were held up within inches before a strong halogen lamp to determine translucency level and color. Those stones that were 80% translucent (some pieces had inclusions which were very opaque—these were discarded if more than 20%) were sorted by color. We had 5 distinct colors occurring: blue, blue-green, white, yellowish and beige. These color separations were then "randomly" shuffled to avoid the potential for any single color based splotches or areas to occur within the fabric of our curtain.

Honing:

The stones were placed face down on area covered with wet sheets of gypsum boards (this gave a surface with suction to hold the pieces fast to the ground). Then, using a Clark floor re-finisher with open screen abrasive pads, the backs of the stones were ground to a honed finish.

Lamination:

The honed stones were then delivered to Fox Industries for fiberglass lamination. By adapting their techniques to our needs[,] we were able to accomplish this in 30% less time than would normally be required. This helped keep us on schedule.

Centering:

Construction of the centering began off site. Drawings for the centering were developed by Yu Ting Chen in Chicago and e-mailed to a print shop in DC where I would pick them up.These drawings were unique in that they were printed full scale on 3' x 10' sheets of paper. These were adhered to 3/4" and 1 " plywood and the forms cut and assembled. At some point, I discovered that the drawings were off by over 2"! Frantic to locate the error, I called Yu Ting and then the printer before finally realizing that the culprit was—the weather. It was August in Washington, and the extreme heat and humidity were causing the paper to expand as much as 3/4 " in 3'! Subsequently all drawings were rolled and covered with plastic.)

Water-jet Cutting:

The laminated stones were delivered to LAI to be cut with water-jet. This is a company that primarily does government contracts for aerospace, but I was able to convince them to participate.