Geometry and its Complexity: The

KLEMEN BREITFUSS PHOTO

By Margot Ammidown

INSET: MATTHIAS RIPPMANN PHOTO

Detail of thin tile vault designed by Lara Davis, 2010.

Inset: **Model of the amphitheater for Martin Luther King Jr. Park in Austin, Texas, designed by Philippe Block, Matthias Rippmann, and Escobedo Construction in collaboration with Ochsendorf, DeJong and Block (ODB).**

Art of Structural Tile Lives On

John Ochsendorf inspires students with the example of a master

PROJECTIVE GEOMETRY in perfect compressive equilibrium—it's hard for some people to get excited about that, much less understand what it means. Not for fans of Rafael Guastavino (1842–1908) and his son Rafael Jr. (1872–1950), who together or successively designed and built many of the great vaulted Beaux-Arts interiors in the United States in the late nineteenth and early twentieth centuries. Today self-proclaimed Guastafarians have a titular leader in John A. Ochsendorf, author of *Guastavino Vaulting: The Art of Structural Tile* and the curator of the exhibition *Palaces for the People: Guastavino and the Art of Structural Tile* at the Museum of the City of New York to September 7. What fascinates Ochsendorf, who is

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also a professor of engineering and architecture at MIT, are the spare masonry forms underneath the ornate finishes and their applications for contemporary architecture.

Modernism has its philosophical and aesthetic origins in the inherent beauty of pure geometrical forms, but few buildings of any style are as finely crafted and conceived in terms of the geometry of their structures, the spatial form of their interiors, and their innovative construction as those of the Guastavinos. So consider peeling away the beautiful glazed tile, metaphorically speaking, and looking underneath to see what Ochsendorf and his colleagues are so excited about.

Ochsendorf's interest in the masonry vaults and domes of the Guastavino Company is not solely academic. He's also a principal partner in the structural engineering firm Ochsendorf, DeJong and Block, otherwise known as ODB, which specializes in masonry, both in the preservation of historic buildings and in design and new construction. The firm has a taste for complex three-dimensional geometries and a mission "to reinvent masonry construction, making it economic, sustainable and relevant...by developing exciting new forms from traditional materials." An expert in the mechanics of stone vaulting in Gothic cathedrals, Ochsendorf has spent his career looking for historical construction systems that might have modern applications. He was introduced to the largely forgotten work of Rafael Guastavino as a graduate student and says "it was a formative experience." At first glance the spare, sinuous forms ODB designs in collaboration with architects and builders around the globe seemingly take little inspiration from the ornate Beaux-Arts classicism of the Guastavinos, but to understand what ODB, Ochsendorf, and his students in the Guastavino Project at MIT have been doing, it helps to understand something about the work of the Guastavino Company.

What most people don't realize when they are standing under the transcendent domes and vaults designed and built by the Guastavinos—which include ones in the Boston Public Library, Ellis Island Registry Hall, Cathedral of Saint John the Divine, the Oyster Bar in Grand Central Terminal, and hundreds of monumental train stations, libraries, government and university buildings throughout the country—is that they are not just standard structural framing with decorative tile finishes. The Guastavinos' vaults and domes were built using an ancient

ALASTAIR GOULD PHOTOS (2)

technique alternately known as timbrel vaulting, Catalan vaulting, or by the current and more descriptive, "compression-only thin-tile vaulting." Thin-tile vaulting originated in North Africa and was imported to Spain in the fifteenth century. Structurally, it is lightweight, strong, and less expensive than reinforced masonry (the finish glazed tiles not included). Traditional thin-tile vaulting is, as it sounds, just clay tiles as thin as half an inch and mortar, sometimes sandwiched in layers, but without steel, wood, or any structural reinforcement. Even large-span unreinforced thin-tile vaults and domes can stand up under tremendous weight loads despite having the proportional thickness of an eggshell—in other words, by magic. At least it seemed like magic to American officials who wanted to see the calculations required to satisfy modern building codes, so despite its potential for reinterpretation in modern architecture, the technique was doomed to oblivion in the United States.

But it was never entirely abandoned in Europe. By the late nineteenth century thin-tile vaulting was used in industrial buildings as a low cost way to create large open-span spaces. Antoni Gaudí used it extensively in his complex structures, including Sagrada Familia, and, conversely, Le Corbusier used it for a simple low-profile barrel vault in his modest but influential Maisons Jaoul. Nonetheless, in 2002, when Ochsendorf (then a new faculty member at MIT) started the Guastavino Research Project, thin-tile vaulting as a construction method had fallen into such obscurity in this country that no English language manual explaining it existed. Soon what started as a project to document the Guastavinos' Boston buildings expanded into an effort to understand the network of forces in thin-tile structures and to develop the computational methods to prove their strength so they could be built again.

Ochsendorf and his MIT team's first major project using thin-tile construction was a small events venue on Saint Margaret's Bay on the English coast known as Pines Calyx (2005). With a conceptual design by U.K. architect Issy Benjamin, Ochsendorf was brought on to direct the design and construction of the domes. Pines Calyx was conceived for maximum sustainability (as finished it is a carbon plus building—meaning it produces more energy than it

Pines Calyx, a sustainable events complex on St. Margaret's Bay, England.

The shallow dome at Pines Calyx was designed and constructed by John Ochsendorf with MIT Guastavino team members Michael Ramage, Wanda Lau, Meelena Oleksiuk, and Luke Voiland.

John Ochsendorf under the Guastavino vaults of Maseeh Hall at MIT, built 1901.

Free-form thin-tile vault structure designed by doctoral research assistant Lara Davis working with Philippe Block at the Institute of Technology in Architecture (ETH) in Zurich, Switzerland, 2010.

PORTRAIT: LEN RUBENSTEIN PHOTO BREITFUSS PHOTO consumes); its two small conjoined rotundas have rammed-earth walls made of local chalk and soil and unreinforced thin-tile domes with living roofs. The complex also demonstrates why thin tile is not just an exercise in structural historicism. "The construction estimate for building the domes in reinforced concrete was 30 percent higher," Ochsendorf notes.

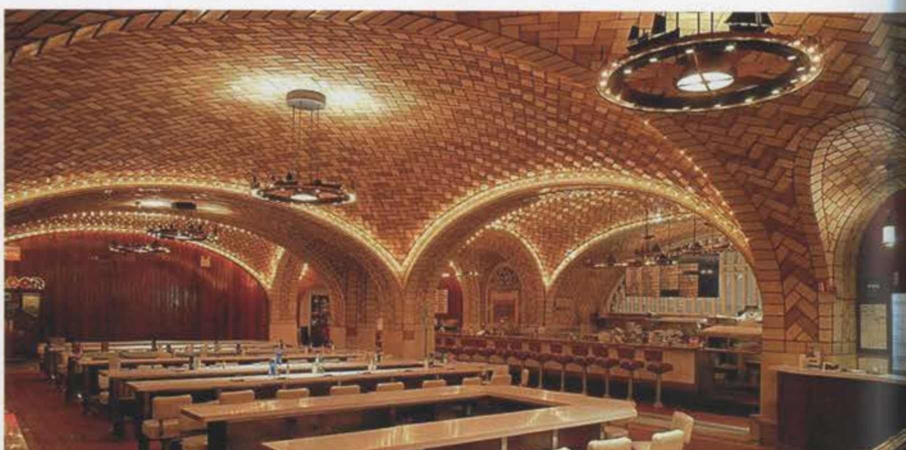
Not long after Pines Calyx was completed Ochsendorf was approached by South African architect Peter Rich, who had designed an innovative scheme for a national park building inspired by Pines Calyx. The collaboration of Rich and Ochsendorf and his MIT team members resulted in the Mapungubwe Interpretation Centre at Limpopo, South Africa, which won the 2009 World Building of the Year Award at the World Architectural Festival in Barcelona. In this case the tiles were composed of local soil and cement and made on-site from a formulation developed and tested by MIT engineer Matthew Hodge and South African researcher Anne Fitchett. The shape of the vaults was adjusted to improve their safety and stability by Philippe Block, a graduate student of Ochsendorf's whose PhD thesis was a software program to analyze the network of forces in complex unreinforced three-dimensional masonry forms. The free-form "parachute" vaults at Mapungubwe were an evolution in scale and form from Pines Calyx, but still within the realm of the traditional. Block's program augured something new.

The Guastavinos' vaults and domes were built using an ancient technique known as mbrel vaulting or Catalan vaulting

Ochsendorf has proved during his years of research that unreinforced masonry buildings don't fail because of weakness in the material, they fail because of instability in the form. By "form" he means the specific geometries identified by builders over the centuries—like the arch or the groin vault—that can carry tremendous weights when the load is evenly dispersed to the vertical components and carried to the ground—in other words when they are in equilibrium. With the advent of industrial materials such as prefabricated steel, the search for new stable geometries essentially stopped, in part because modern builders favored right angles, but also because of the difficulty in providing mathematical proof of the stability of complex forms before computers. Philippe Block's software program (now known as RhinoVAULT) allows for the design of far more complex geometries in unreinforced masonry structures than even those built by the Guastavinos. It also bridges the gap between engineers and architects by accommodating both design and structural analysis in one program. It is a revolutionary advancement for architectural design.

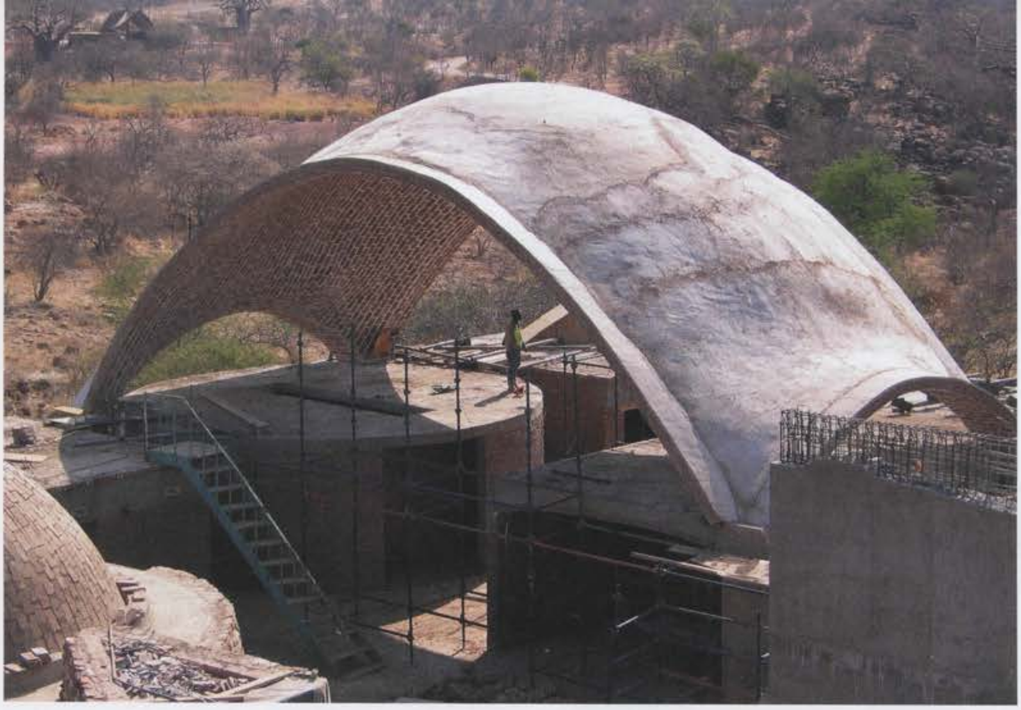
The first thin-tile vault in a free-form geometry discovered using Block's program was built a

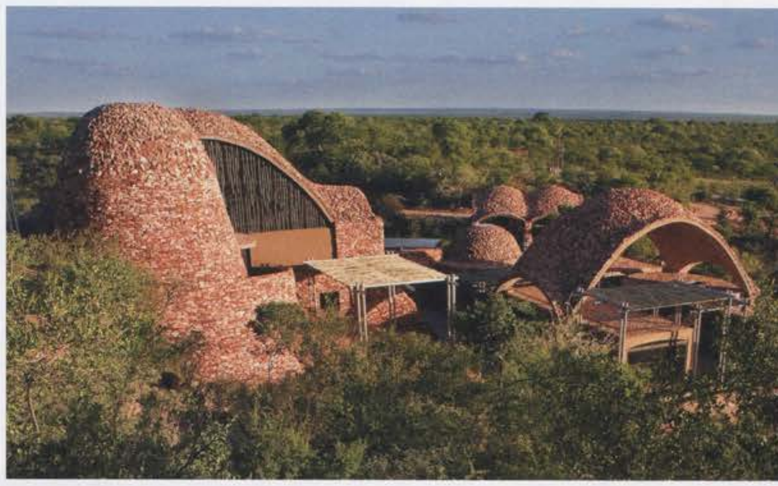
Rafael Guastavino Sr. standing on an unreinforced thin-tile arch during the construction of the Boston Public Library, 1889.



The Oyster Bar in New York's Grand Central Terminal exemplifies Guastavino vaulting.

RIGHT: MICHAEL FREEMAN PHOTO





PETER RICH ARCHITECTS

couple of years ago by MIT graduate Lara Davis, while serving as a doctoral research assistant at the Institute of Technology in Architecture of ETH in Zurich, where Block is now an assistant professor. In 2013 "Bricktopia" based on Davis's relatively small-scale prototype, was built in Barcelona by Map 13 architects.

When asked if he foresees large-scale public spaces being built again in unreinforced masonry in the United States, Ochsendorf's simple answer is "yes." Already in the detail design stage is a dry-set stone vaulted amphitheater for the Martin Luther King Jr. Park in Austin, Texas. Engineered in association with ODB, where Block is now a partner, it will be the most sophisticated large-scale unreinforced free-form curved surface design ever built.

Architect Louis Kahn described his theoretical holy grail as "spaces that rise and envelop flowingly without beginning, without end, of a jointless material white and gold." One may not be able to call thin-tile structures "jointless," unless you consider that when the mortar hardens, a continuous self-supporting shell is formed, but that is the source of Ochsendorf and his colleagues' fascination with them. That is also the strain of modernism that lies under the Guastavinos' beautifully ornate glazed tile work—no beginning, no end, form as continuous structure. It sounds like a religion, but if Guastafarians are a cult they should have a mantra, right? They do, and it comes in the form of a salutation—"Equilibrium y'all!" ■

A vault of the Mapungubwe Interpretation Centre in Limpopo, South Africa, under construction.

Local workers were trained by Pines Calyx veteran James Bellamy, and tiles were made on-site from soil and cement for the construction of the Mapungubwe center.

The Mapungubwe Interpretation Centre won the 2009 World Building of the Year Award at the World Architecture Festival in Barcelona.