Our research develops volumetric design techniques from computational finite element method (FEM) buckling analysis to update and extend stereotomy. Historically, stereotomy consisted of the geometric methods invented to design with stone volumes. Although massive masonry construction is rarely used now, architects still develop complex volumetric assemblies. Recognizing this, we have outlined a fresh strategy for contemporary stereotomy: construction with lightweight and preferably hollow volumes. The approach is developed here with two interconnecting studies that employ computational design methods, digital fabrication, and lightweight composite materials. The first phase develops a catalog of intricate volumetric tessellations from surfaces displaced by virtual FEM buckling analysis. The second phase uses this algorithmically generated catalog to design nesting, hollow volumes that stack into intricate assemblies. To test the stereotomic viability of our approach, study models were 3D printed, and a large freestanding prototype was built from FRP composites.
Buckling is an instability failure model—one of the fundamental mechanical phenomena governing structural design. Buckling deforms configurations of material through displacement. The phenomenon is capable of transforming axial tectonic structures and curved shells into exotically sinusoidal new configurations. Buckling is disastrous for structural integrity, but it produces wavelike displacements that are formally very similar to doubly-curved surfaces designed by architects using NURBS or subdivision surface modeling. Our research began from this observation and a curiosity to learn whether the intentional cultivation of buckled surfaces using computational FEM analysis tools might be valuable for the design of architectural constructions. Using Karamba 3D, we studied surface buckling patterning and developed a catalog of intricate tessellations.

To explore a relevant architectural issue, we subsequently tested whether these tessellations could develop contemporary stereotomic and volumetric construction techniques.

Stereotomy—the descriptive geometric methods and construction techniques once essential to successful construction in cut stone—has been marginalized to the status of historical footnote by the dominance of tectonic frame construction. While substantial load-bearing stone construction is unlikely to be revived, contemporary approaches to volumetric construction are on the rise as architects experiment with fiber-reinforced polymer (FRP) composites and other plastics. The Blobwall pavilion by architect Greg Lynn, made from rotationally molded plastic, and the Surface-to-Volume installation by architect Tom Wiscombe, made from composites, are two recent examples of this trend. Both point to a renewed interest in volumetric construction, but now with surfaces that flaunt their thinness. Our buckling design research explored this new development—stereotomic construction without stone solids—through the production of several prototypes.
After identifying that overlaid buckled surfaces form tessellations, several surface pairs with interlocking patterning that seemed suitable as templates for stereotomic assemblies were further developed into self-supporting architectural wall prototypes. The first designs were 3D printed in ABS plastic. The resulting prototypes are self-supporting and consist of interlocking, friction-fit stacked volumes.

Buckling even a simple wireframe produces a variety of complex symmetry types. These are best revealed by overlaying the deformed surface with a flat plane. Since buckled surfaces create displaced pockets of cupped space, a unique 3D rotational symmetry can occur: if a bulging crest appears on one side of an axis of symmetry, often the same displacement will occur as a trough on the opposite side.

Computationally buckled wireframes generated with Karamba 3D, a structural FEM analysis tool for Rhino. Buckling modes, calculated as Eigenmodes in Karamba and similar to vibrational frequencies, have a distinctive sinusoidal patterning.
The stereotomic assembly research culminated in the construction of a large-scale composite prototype measuring 6' tall by 10'-6" long. The self-supporting wall consists of thirty-two interlocking elements made from E-glass reinforcement and a high-strength epoxy resin matrix. The composite surfaces were laid-up in open-face, CNC milled foam molds, smoothed and coated with a Styrofoam protector and release agents.

The many symmetry types exhibited by buckled surfaces constitute a form of tiling. The displaced undulations of a buckled surface do not immediately form tiles, but tiles can be made by intersecting the displaced surface with a plane or by overlaying one buckled surface mode with another buckled surface mode. Here, one surface mode is toned black and the other white to make the tessellation patterns legible. A single wireframe can create a library of hundreds or more distinct displacements to form an extensive catalog of potential tessellations for design.

**IMAGE CREDITS**

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