Breaking the Mold: Variable Vacuum Forming

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Our research explores the growth of surface complexity through careful attention to program and performance criteria. This emerging complexity and associated gains in performance are promising. Despite this, we are repeatedly confronted with the realization that the costs associated with production limit most applications. While the aggregation of repeatable units with variation from one unit to the next is achievable at a low cost through subtractive fabrication technologies (CNC milling, laser cutting, waterjet cutting), it is more difficult to realize through casting or forming technologies (concrete casting, injection molding, vacuum forming). This is because formwork is not adaptable. Once a mold is produced, typically at a high cost, that mold makes one component only. If variation is desired, a new mold must be fashioned for each new component. With the projects Hexwall and VarVac Wall, we put forward a simple question: can an intelligent, adaptable vacuum forming mold be developed that allows for difference from one component to another without the necessity for multiple molds? Our project takes its queues from the work of architects ranging from Le Corbusier (Phillips Pavillion) and Miguel Fisac (exploration in fabric formwork) to recent projects by Mark West and Andrew Kudless (P-Wall). Our research positions our design efforts strategically at the front end of the fabrication process. Our goal is to develop a cheap and malleable tool that allows for endless variation in a fabrication process where variation is typically impractical.

Variable Vacuum Forming (VarVac) promises to increase the architect's control over the molding process by introducing adaptability into the mold (where there previously was none), and reducing the cost and waste associated with molding materials. We suggest VarVac offers a novel and substantive contribution to the discourse surrounding custom fabrication processes and the potential for new, coincident relationships between program and material arrangement. Our research proposes that variability in the production of architectural components can be achieved as easily and efficiently as repetition and consistency. By decoupling monetary economy from formal repetition, many of architecture's long-standing limitations can be undermined and vigorously challenged. Digital tools like Grasshopper and Kangaroo allow us to predict material behavior, lending control to the improvisational manipulation of skin. The bottom line is that our research is not just about the development of new material production technologies. Rather, the systems we have developed set the groundwork for the interrogation of more conceptual architectural themes. Moving forward, we intend to foreground an argument that inextricably joins a technically oriented line of research such as ours (introducing flexibility where there previously was none) with larger, weightier issues of timeless and broad importance (like the relationships between program and material, surface and structure, production and implementation). Only with such lofty goals in mind can this type of research resonate with a wider audience and maintain relevance within a larger architectural discourse.

CREDITS

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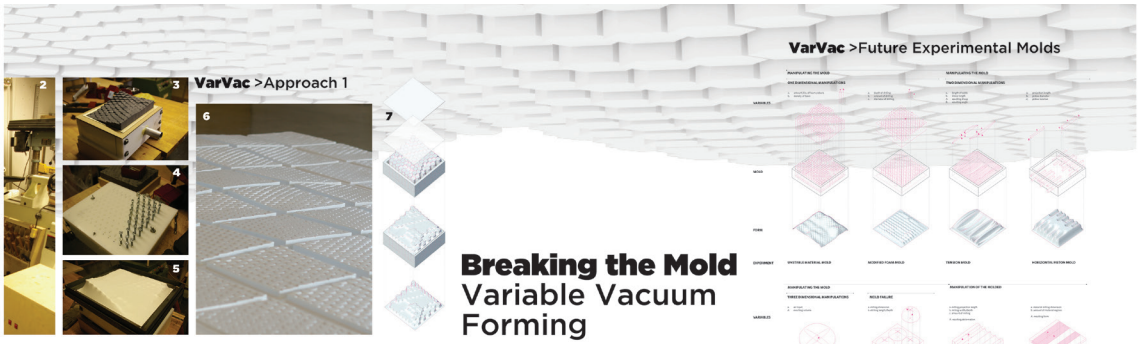


Breaking the Mold
Variable Vacuum Forming

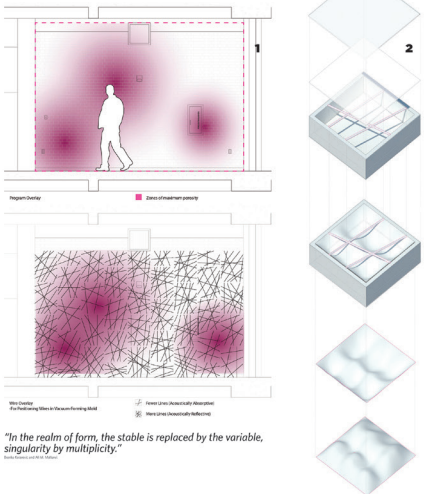
Variable Vacuum Forming (VarVac) promises to increase the architect's control over the mold by introducing adaptability into the molding process (where there was none), and reducing the cost and waste associated with molding materials. We suggest VarVac offers a novel and substantive contribution to the discourse surrounding custom fabrication processes and the potential for new, coincident relationships between program and material arrangement. Our research suggests that variability in the production of architectural components can be achieved as easily and efficiently as repetition and consistency. By decoupling monetary economy from formal repetition, many of architecture's long-standing limitations can be undermined and vigorously challenged. Digital tools like Grasshopper and Kangaroo allow us to predict material behavior, lending control to the improvisational manipulation of skin. The bottom line is that our research is not just about the development of new material production technologies. Rather, the systems we have developed set the groundwork for the interrogation of more conceptual architectural themes. Moving forward, we intend to forego rundan argument that inextricably joins a technically oriented line of research such as ours (introducing flexibility where there previously was none) with larger, weightier issues of timeless and broad importance (like the relationships between program and material, surface and structure, production and implementation). Only with such lofty goals in mind can this type of research resonate with a wider audience and maintain relevance within a larger architectural discourse.

Hexwall panels are a one-to-one replica of the mold on which they were produced (stable). VarVac suspends the heated plastic in the air, thus the resulting shapes of its panels are quite unpredictable (unstable). VarVac post-processes the plastic on the CNC router after it is molded. Strategic cuts in the panels, tied to their shape, provide opportunity to reveal subdermal layers. Despite its ability to generate complexity, VarVac requires far less material and machine intelligence to produce than Hexwall (*one mold replaces dozens*). A crude "varied cable mold" made of wire and plywood **(5)** generates a pillow-like sheet of formed material. One of the newly formed panel is modification with a hot-wire **(6)**. A finished panel post cutting **(7)**. An acoustically heterogeneous wall was constructed and installed in an architecture school office. This was the second installed prototype using the VarVac system. **(3,4,8,9)**. A diagram illustrates the assembly logic of the VarVac system **(2)**.

(1) Digitally mapping the geometry of the wall by overlaying a program on existing conditions. Zones of high porosity indicated in magenta. A wire mesh is generated from this information. The number of lines indicates acoustic properties Canvas with more lines are more reflective and fewer lines more absorptive). These generate wire patterns arrayed in individual molds which were prototyped to test material response **(10)**.

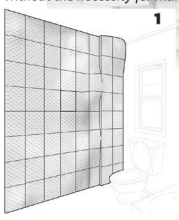
The Problem: Vacuum-forming molds can be made out of a variety of materials ranging from MDF (medium-density fiberboard - **right**) to cast aluminum or composite materials, like fiberglass. Molds are generally quite costly while the parts they produce are relatively inexpensive due to the economics of mass production. Despite advances in production technologies, variation can be difficult and costly to achieve, especially in casting or forming fabrication (concrete casting, injection molding, vacuum forming). This is because the formwork required for casting or forming a material is not adaptable. *If variation is desired, a new mold must be produced for each unique component. This negatively impacts the aggregate cost of the job.*

VarVac >Approach 2



"In the realm of form, the stable is replaced by the variable, singularity by multiplicity."

"An intelligent, adaptable mold that allows for difference from one component to another without the necessity for multiple molds."



In our past research, we have explored vacuum forming as a method for producing low-cost, complex architectural surfaces. The cost of the mold and its inflexibility has prohibited aggregation without-reference. To remedy this, we worked to develop a more sophisticated and cost effective mold that allowed for endless variation in a fabrication process where variation is typically impractical.

Images of the Hex-Wall project
(1) The initial mapping of Hex-Wall. A white, back-lit, topographically active surface grows and shrinks in sectional thickness according to local changes in program. **(2)** A CNC-controlled armature adjusts the height of each hexagonal pin before the plastic is shaped. The robotic armature adjusts pin heights after each draw, driven by a spreadsheet extracted from a Rhino model. **(3)** A dynamic mold made of 1" Hexagonal rods. **(4)** Adjustable pins. **(5)** A failed test piece. **(6)** A detail image of completed wall components. **(7)** HexWall molding process diagram.