Education by Design

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Performative Ornament: Computational and Material Logics of Repetition and Difference

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ABSTRACT

This paper describes a series of research seminars investigating the contemporary capacities of architectural ornamentation in the context of computational design and digital fabrication technologies. The pedagogy explores potential overlaps between ornamental systems and logics of performance-driven design, challenging students to formulate a critical agenda vis-à-vis the relationship between the two. How can material assemblies produce innovative, symbolic, or communicative visual effects while also addressing specific performance criteria? What kinds of new aesthetic, figural, representational, expressive, and spatial qualities can emerge from such a synthetic approach?

The material focus of this research is on processes of casting and forming—workflows that allow for the production of difference within repetitive systems. Parallel to the material research, students develop robust digital, parametric models that enable iteration and evaluation of the work both qualitatively and quantitatively. Within this hybrid workflow, students develop wall systems of modular yet variable components that respond to specific performance criteria, such as daylighting, visibility, or acoustics.

By cultivating a fluency across analog, digital, material, and virtual modes of working, the pedagogy suggests one way to meld computational thinking with architectural design. The projects demonstrate an understanding of how to correlate larger-scale performance criteria with design decisions at the scale of the individual component. The emphasis on proof-of-concept prototyping insists that students grapple with material realities of tolerance and assembly. And the positioning of the research within the historical discourse on ornament encourages students to think strategically, intentionally, and critically about how they integrate computational processes into their work.

INTRODUCTION

Design computation is a contested topic within architectural pedagogy. Nearly thirty years into architecture's digital turn, the computer's disruptive role persists, as increasingly accessible software and hardware continue to recalibrate the discipline's paradigms of design, fabrication, construction, authorship, labor, and liability. In the academic setting, debates abound as to how to teach tools like parametric modeling and digital fabrication. Are these computational methods simply a vocational component of architectural education, taught via tutorials as a skill-building exercise? Should they be integrated into studio pedagogy as subject of primary research and focus? How do we negotiate the virtual artifacts of design computation with the physical matter of the real world? And how can computational methods interface with established disciplinary practices of architecture?

This paper discusses a pedagogical agenda for merging computational thinking with architectural practices, developed in a research seminar called Performative Ornament, taught at California College of the Arts from 2014 to 2017. The focus of the seminar—the renewed role of ornament in the context of new technologies of computational design and digital fabrication—challenges students to employ digital tools in the production of modular wall prototypes that articulate a relationship between ornament and architectural performance. The hybrid structure of the course encourages students to work across media and technique, merging seminar and studio formats, virtual and material methods of design experimentation, and digital and analog forms of making. As a case study of applied research through critical inquiry and proof-of-concept prototyping, the seminar offers one possibility for a synthetic approach to design computation in architectural education.

THEORETICAL CONTEXT

Computing Form and Performance

Although computational logics have always been latent within architectural thinking, digital technology (and the vast computational power it brings) did not achieve widespread adoption in the architectural profession until the 1980s and 1990s. Within this relatively brief history, one can identify several divergent attitudes towards the technology and its integration into architectural practice. These often skew towards one of two poles: the form-driven project and the performance-driven project. On the one hand, there is the impulse to leverage computational power to pursue ambitious formal experimentation and expand architecture's geometric and spatial possibilities. Much of this work germinated in academia in the 1990s, in pedagogical experiments such as the "Paperless Studio" at Columbia (Allen 2012); it continues today with the ever-increasing virtuosity of digital formalists like Zaha Hadid Architects, whose current principal Patrik Schumacher advocates for a totalizing stylistic regime predicated on computational form (2010; 2012). On the other hand, there is the more technocratic desire to use computational tools to optimize designs for efficiency or other performance metrics. Examples of this tendency include the increasingly common workflows of energy modeling and daylighting simulation employed to optimize aspects of buildings such as massing and facade design (Marble 2012).

This binary can be particularly acute in academia, where formal experimentation is often pursued in design studios or courses focused on representation, while the more technically-focused topics of optimization and performance-driven logics are typically confined to building technology curricula. Furthermore, it is rare for any of these techniques or processes to be studied in history/theory courses, which would allow for the interrogation of such practices in comparison with previous paradigms of designing and making architecture. The Performative Ornament seminar attempts to bridge these disparate realms by introducing techniques of parametric design and fabrication in a synthetic way that is informed by aesthetic, technical, and theoretical discourse.

Tectonics and Variation

The study of parts, commonly referred to as *tectonics*, is an opportune means for critically positioning computational practices within architectural design. Described by Adolf Heinrich Borbein (1982) as "the art of joinings," the term tectonics refers to how architecture is actually made: the parts that constitute a building, and the relationship between those parts, each other, and the overall whole. On a fundamental level, the architect's role in materializing a concept into a building can be understood as one of selection, specification, articulation, and mediation of parts such that they cohere into a functional and compelling whole. The tectonic encompasses structural concepts and construction processes, but it also reflects more intangible qualities and decisions made by the architect in formulating the whole (Sekler 1965).

By focusing on tectonics, specifically the logics of scale, repetition, and variation of parts, the Performative Ornament seminar seeks to mediate the divergent tendencies that characterize design computation—the pedagogies of form and performance. The computer's primary advantage in the context of architectural design is its ability to process information with great precision and speed. When extended to tectonics, computation enables the calculation of large quantities of parts, and the deployment of variable behaviors across those parts with great ease (Carpo 2014). This *parametric* capacity presents an opportunity for considering logics of variation: how difference takes form through material and geometric properties, and how performance criteria can drive such difference. Is parametric variation produced merely for its own sake? Or can it be driven and optimized by performative metrics such as light, air, sound, energy?

Ornament and Craft

Layered onto this operative emphasis of tectonic logics is a discursive engagement with histories and theories of architectural ornament. In addition to their performative potential, building components can possess expressive capacities that transcend the technical and the quantitative to take on communicative agency. The role and legitimacy of ornament has played a pivotal and contentious role in architectural history, particularly in the wake of modernism's dogmatic rejection of ornament and decoration as taboo, superfluous, and excessive (Loos 1929). Farshid Moussavi has noted how Adolf Loos's disavowal of ornament was fueled by the modernist bias for the universal over the individual, for standardized repetition over the differentiated qualities of traditional ornamentation (2006). But the advent of computational design and digital fabrication in architecture, particularly its profusion of intricately patterned facade systems and variable componentry, has undeniably revitalized ornament as a site for contemporary architectural research. By juxtaposing questions of ornament and performance, the course charts potential resonances between the two, interrogating how ornament might be newly relevant. Is ornament a secondary, independent layer, merely applied to architecture? Is it integral and embedded within the expression of a building's structure and material logic? Or is it, as critic Robert Levit (2008) has written, "the condition of architecture itself"?

If the tectonic relates to the logic of a building's parts, and the ornamental pertains to the communicative and expressive capacity of those parts, then it is craft that governs how those parts are made, who makes then, and how they are assembled. An irony of architecture's digital turn is that the proliferation of technologies of variation and customization (in realms of both design and manufacturing) has revived the bespoke, which modernist logics of standardized mass production had supposedly eliminated (Carpo 2011). The computational paradigm and its economies of variation have upended traditional contingencies between labor, automation, standardization, and customization (Maxwell and Pigram 2012). Mass customization, ushered in by access to computational power and machines that can easily process variable components, echo pre-digital notions of craft, which valued the uniqueness of handmade artifacts as superior to that of the standardized and machine-made (Pye 1968). It is in this strange sympathy between the pre-modern and the computational that there exists the potential to reposition craft as a negotiation of the complex entanglement of tectonics, ornament, and architectural performance.

PEDAGOGICAL STRUCTURE

Although nominally an elective seminar in the Design Media curricular sequence, the Performative Ornament course is structured in a hybrid manner to incorporate aspects of both studio and seminar. The majority of time is dedicated to conducting design research through drawing and making, but this work is supplemented with regular readings, case study presentations, and discussions sessions that seek to foster a broad, critical understanding of the rich history of ornament in architecture. This aspect of the class, which includes readings by Adolf Loos, Robert Venturi and Denise Scott Brown, Farshid Moussavi, John Ruskin, and others, fosters a critical awareness that helps the students better position their own design work within broader architectural discourse.

The design research agenda is pursued through two projects. The first, a three-week drawing exercise, uses the work of 19th century designer and polymath William Morris as a platform for rigorously understanding logics of standardization and variation. Morris's famous wallpaper patterns, produced by standardized printing presses in his factory at Merton Abbey, are notable for their uncanny ability to conceal the repetitive tile through a sophisticated mastery of geometry, form, and ornament. This project challenged students to reverse engineer Morris's patterns by carefully discerning the repetitive tile and then identifying opportunities to introduce variation across the field. The intent is to explore the latent tension between standardization and variation in Morris's work, and to build upon this tension by subtly introducing variable behaviors that produce compelling visual effects.

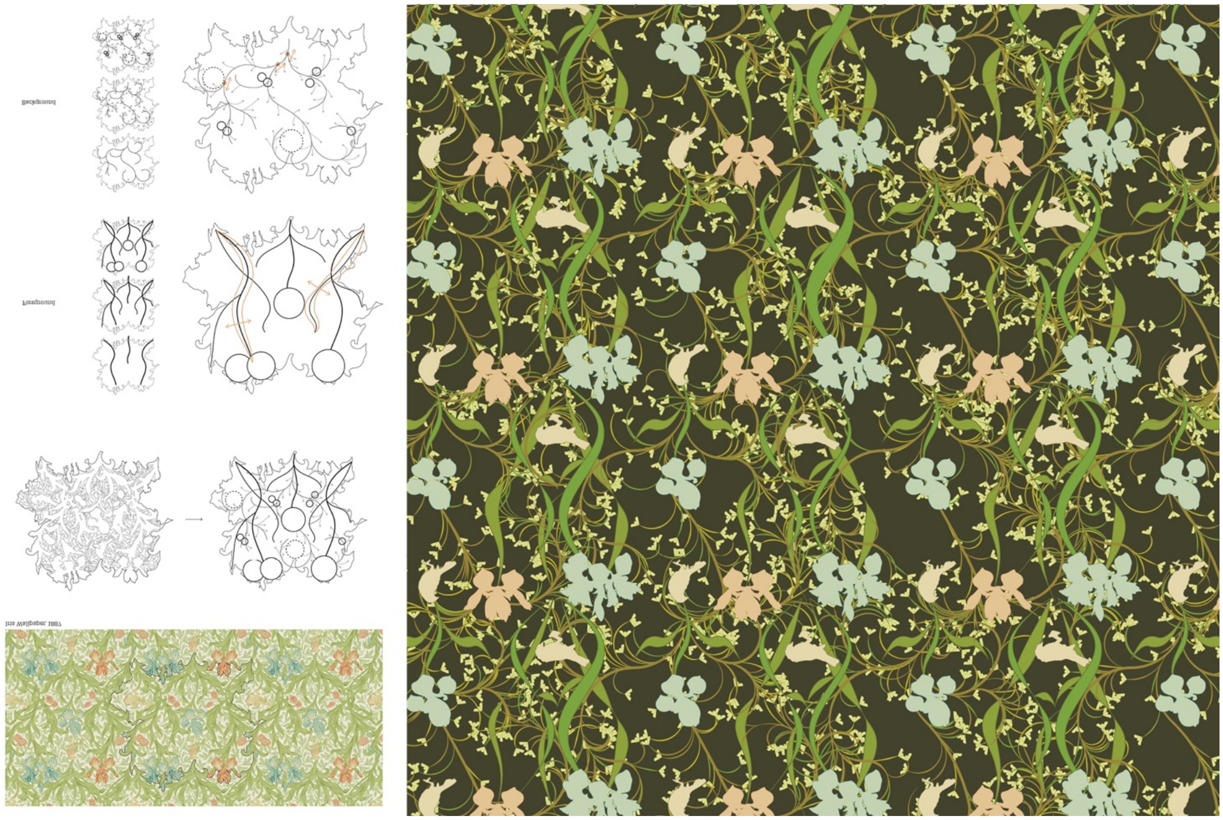

Figure 1. Diagram of tiling logics derived from William Morris wallpaper pattern (at left) informs reinterpretation of the pattern (at right).

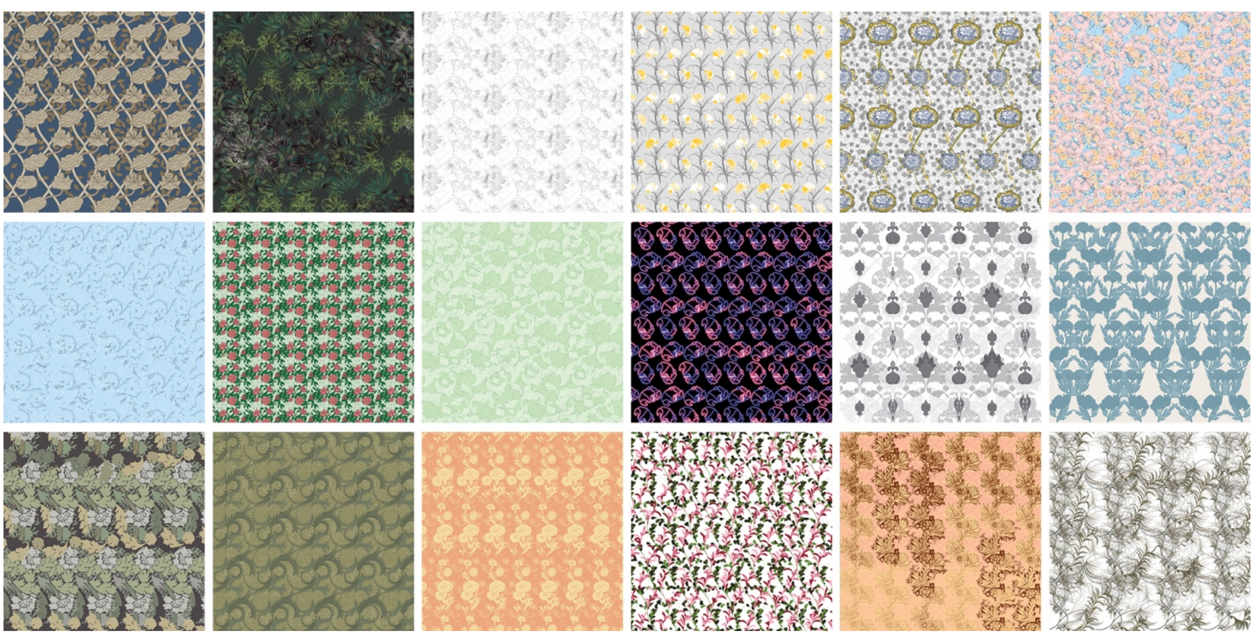

Figure 2. Catalog of reverse engineered wallpaper patterns derived from the work of William Morris.

The second project, which occupies the majority of the semester-long course, asks students to design and build full-scale wall prototypes that demonstrate innovative and critical approaches to the notion of architectural ornament. Working in teams, students are expected to formulate a clear agenda vis-à-vis the role of ornament in contemporary architecture, and to address the following provocations:

- What exactly is the communicative role of ornament? Is it representational (or figural, or literal)? Does ornament communicate information that is legible and recognizable? Or is it driven by more abstract notions of affect and non-representational sensation?
- How can the relationship between performance and aesthetics be designed, and not prescribed? Is it possible to overlay logics of optimization and logics of sensation in a synthetic manner, such that one does not command the other? How can computational design and digital fabrication tools assist in this endeavor?
- Can we design the relationship between standardization and variation in a way that advances an argument about performance and ornament? How can we negotiate material and dimensional constraints, which typically mandate some form of modularity, with the possibilities of mass-customization?
- What is the role of computation in the design of this system? What is computed digitally? What is computed physically? What is fabricated by a machine? What is fabricated by hand? What are the implications on conventional understandings of labor, craft, production, and assembly?

The material focus of the research is on processes of casting and forming—workflows that allow for the production of difference within repetitive systems. Techniques and devices such as jigs, molds, dies, and stencils become the locus for merging analog material processes with advanced methods of digital fabrication. The intent here is to revisit traditional notions of craft—perhaps best articulated by David Pye as the "workmanship of risk," in which "the quality of the result is continually at risk during the process of making" (1968, 20)—in the context of contemporary methods of design and production. By negotiating processes of standardization and repetition with the introduction of variation or "risk," students develop sophisticated understandings of how and when such behaviors can and should be introduced.

Parallel to the material research, students develop robust digital, parametric models that enable iteration and evaluation of the work both qualitatively and quantitatively across larger extents. The ambition is to develop a system that can produce novel effects, but in a controlled way, calibrated to respond to demands of architectural performance. Within this hybrid workflow, students develop wall systems of modular yet variable components that address specific performance criteria, such as daylighting, visual privacy, or acoustics. The projects culminate in a full-scale wall prototype accompanied by drawings that speculate on performance at a systemic scale.

CASE STUDIES

An examination of student projects from the course demonstrates the range of outcomes and responses to the pedagogical brief. Several teams focused primarily on designing reconfigurable and adjustable molds as a way to embed as much potential for variation as possible into a device of mass production. *Concrete Veil* (Figure 3) utilizes thermoformed plastic to capture the dynamic behaviors of melting and drooping plastic into static molds that can be switched in and out of a larger jig that casts two-sided concrete modules. The geometry employed in the thermoforming process is calibrated across module types such that the resultant grooves produce continuities across the disparate modules, producing a kind of global musculature throughout the suspended wall. Similarly, *Ornamental Bipolarity* (Figure 4) uses a mold comprised of reconfigurable, laser cut wood parts that can be rearranged in order to produce modules with different qualities of figuration and fenestration. The mold yields modules that are different on each side; one side is crisp and sharp in its definition, while the other side is smooth and bulbous as a result of a fabric formwork liner.

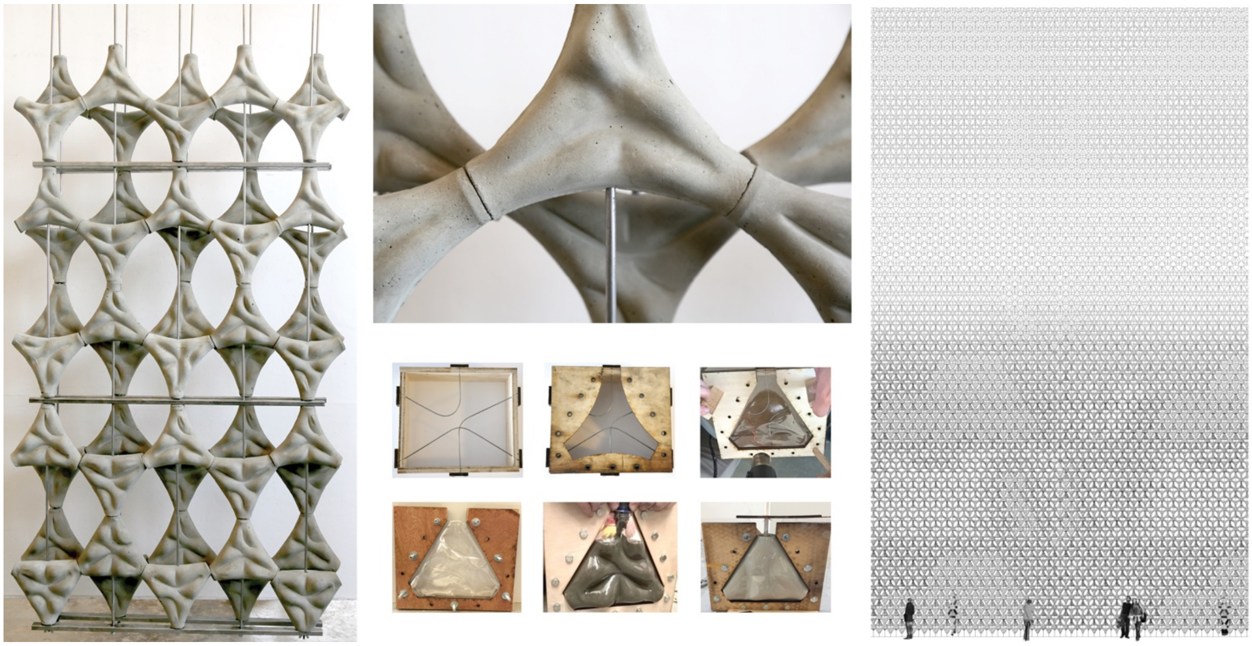

Figure 3. *Concrete Veil.*

Figure 4. *Ornamental Bipolarity.*

A number of students experimented with tooling and material processes as a locus for invention and production of new ornamental effects. *Hide & Ink* employs fabric-formed variable modules that are silkscreened with a “tattoo” that is produced with a variable laser cut stencil. *Wind Wall* utilizes CNC routed molds to translate the toolpath in both positive and negative reliefs, creating highly tactile modules designed to modulate airflow in different ways. And *Perceptual Gradients* relies on a complex process of CNC routed positives and slip-casting to produce a set of lightweight, hollow ceramic modules intended to evoke bunches of grapes. The translations across materials and media imbue the modules with a dual reading that is dependent upon proximity. Each of these examples demonstrates the productive territory of working amongst and between various modes of design and production: analog, digital, manual, automated.

Figures 5, 6, 7. *Hide & Ink, Wind Wall, Perceptual Gradients.*

Several projects integrate additive manufacturing into the mold design as a way to embed additional complexity, resolution, and variation into the module. *Volatile Mutations* (Figure 8) employs 3D printed positives to construct reconfigurable molds that can be adjusted by shifting the sequence and arrangement of the mold components. The cast modules capture the unique geometries of the original 3D printed positives, and their organization at an architectural scale is coordinated with a digital model that deploys modules according to degree of transparency of the interstitial apertures. Importantly, the parametric model allows for iteration and visualization of different wall iterations, and it also outputs mold assembly instructions to ensure that the cast components correspond the global logics of variation. *Transfidelity* (Figure 9) makes similar use of 3d printed components in the design of a composite mold. But unlike the previous example, which focused on transparency and light transmission as the primary performance criteria, this project explored notions of graphic performance in its visual and material translation of a pattern sourced from William Morris. The composite mold produces two-sided modules in which the precision of the 3d printed components conditions one side, and a fabric liner introduces risk and the loss of resolution on the other.

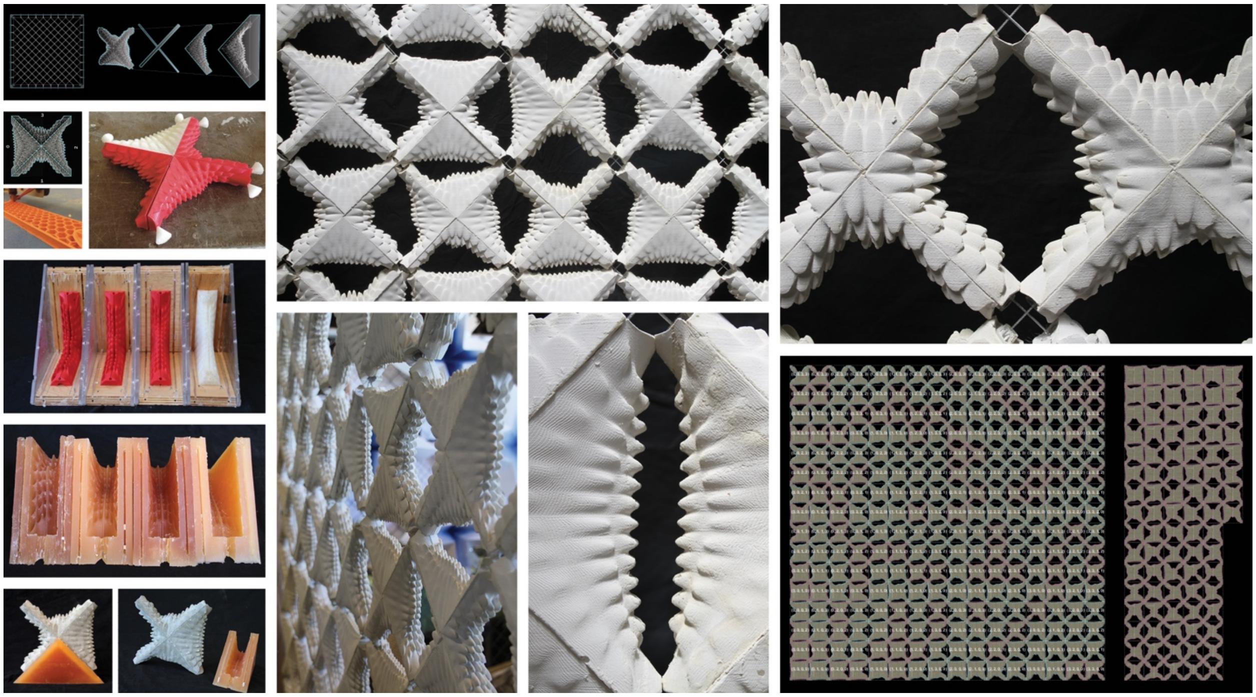

Figure 8. *Volatile Mutations.*

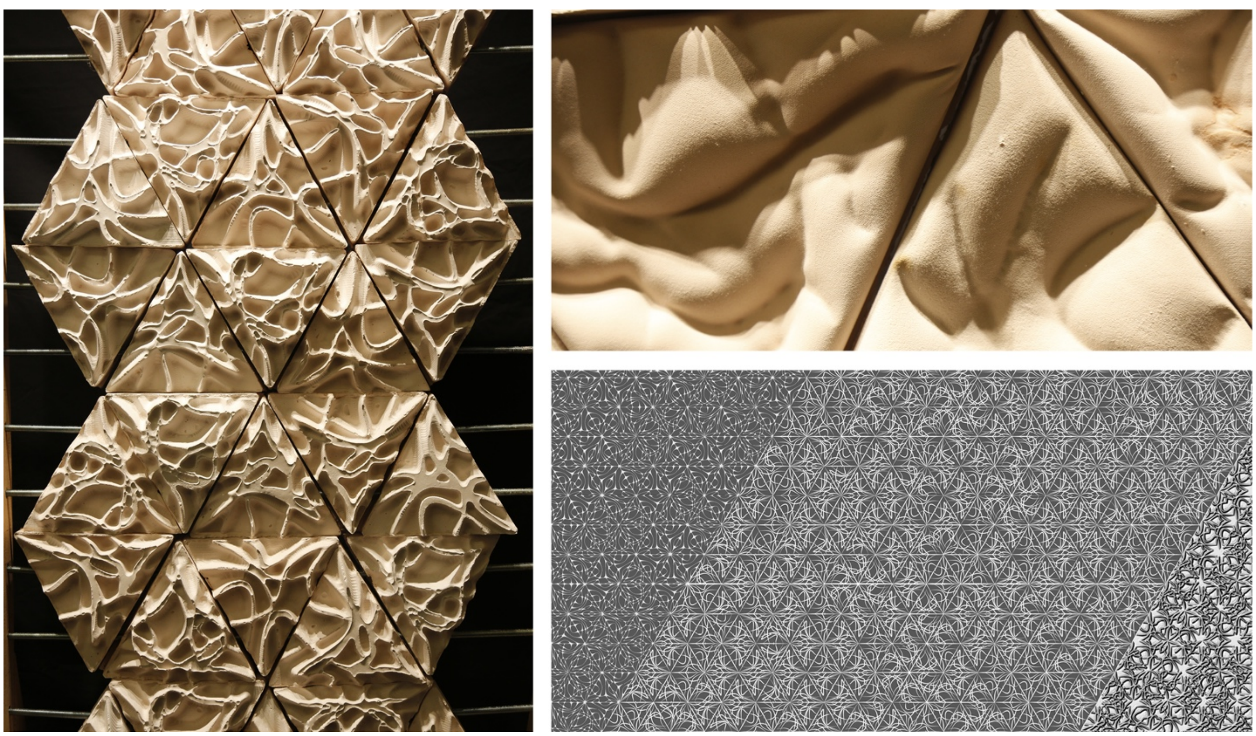

Figure 9. *Transfidelity.*

CONCLUSIONS

Three semesters of the Performative Ornament seminar provide a critical mass of student work that demonstrates several important pedagogical lessons. The hybrid studio/seminar format that integrates readings and historical case studies has been an effective means to foster a critical sensibility among the students, who were able to articulate the goals of their projects with confidence and knowledge grounded in discourse of ornament, craft, and computation. Asking students to articulate the relationship of standardization and variation in their work—and to materialize this relationship through iterative testing of molding and casting processes in conjunction with techniques of digital fabrication—resulted in a fairly rigorous and sophisticated understanding of the possibilities and limits of variability in architectural tectonics. And requiring that projects reach proof-of-concept stage through full-scale wall prototypes provided valuable and essential lessons in tectonic questions of tolerance and assembly, as well as the hands-on experience necessary to formulate attitudes toward craft in contemporary practice.

In regard to the work's depth in developing techniques of performance-driven design, most of the students took an intuitive approach to understanding the relationship between variable componentry and performance objectives. This was largely due to the lack of bandwidth in a one-semester elective for a deep foray into advanced optimization and simulation software packages, particularly as much of the energy and labor efforts in the course were directed towards the production of large-scale material artifacts. While the digital models were instrumental in quantifying metrics such as overall percentage open, or material volume and weight, the time constraints of a single semester did not allow for a more robust phase of analysis or optimization. This is certainly one area of improvement for future iterations of the course, which could perhaps emphasize optimization workflows by focusing on one specific technique or performance criteria to drive the work. For example, evolutionary solvers linked with a daylighting or thermal analysis package could be used to iterate through the parametric model to find the optimal solution for variable apertures in a wall, relative to environmental performance.

Nevertheless, in its cultivation of a fluency across analog, digital, material, and virtual modes of working, the pedagogy of the Performative Ornament course suggests one way to meld computational thinking with architectural design. The projects demonstrate an understanding of how to correlate larger-scale ideas about performance with design decisions at the scale of the individual component. The emphasis on full-scale, proof-of-concept prototyping insists that students grapple with material realities of tolerance and assembly. And the positioning of the research within the historical discourse on ornament in architecture encourages students to think strategically, intentionally, and critically about how they integrate computational processes into their work.

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