MOR~~PH~~FAUX: RE-SITING MODULAR CONSTRUCTION THROUGH ROBOTIC MANUFACTURING

JOSHUA BARD
University of Michigan

STEVEN MANKOUCHE
University of Michigan

MATTHEW SCHULTE
University of Michigan

HISTORICAL SHIFT TO PREFABRICATED BUILDING MATERIALS

Architectural plaster has had a long history of prefabrication. Ornamentation such as moldings and fixtures have traditionally been cast and profiled remotely from their final site of installation to shorten the time of completion or to control for difficult processes that would be complicated by direct shaping on their substrate. Because of plaster's inherent capacity to be cast and endlessly replicated, separate and re-usable formworks allowed precise copying of various ornamental forms.

With the advent of industrialized, pre-fabricated building materials, many on-site building methods were replaced. For example, in 1894, the year following Chicago's Columbian Exhibition and its famous White (plastered) City, Augustine Sackett invented "Sackett Board," a sheet-based building product that would all but render the craft of plastering in its many architectural applications obsolete. Just in time for Chicago's second World's Fair in 1933, the United States Gypsum company (USG), who purchased the Sackett Board patent in 1909, constructed its first building skinned almost entirely in Sheetrock™. Since that time, drywall has become a ubiquitous standardized building material and has had a drastic impact on the economic, environmental, and qualitative makeup of the built environment. In addition, pre-fabricated building materials like Sheetrock Modernist ideology, with its insistence on "truthfulness" in materials, certainly contributed to vilifying plaster's architectural uses, (Smith 2002). Plaster was rejected primarily because of its association with the cheap replication of neoclassical Beaux-Arts style architecture and its application as a faux finish in place of real stone. Commenting on the White City, Louis Sullivan set the stage for modernity's rejection of plaster, listing it as a "material of decay".

The promises of modular architecture (e.g. higher quality, increased efficiency, lower cost) often align with the logics of industrialized manufacturing and standardized building materials. The factory as a locus for these ambitions provides both a physical context for the efficient production of the architectural body and also an underlying framework influencing architectural ideation.

Industrially produced gypsum board walls and ceilings provided modern architects flat, regular surfaces, which emphasize pure orthogonal forms. Drywall's utility – it is fire resistant and easy to install – combined with a modern aesthetic quickly made it an industry standard. As a result drywall has become a quintessential material in the homogenizing tendencies of the standardized components of modular construction. The typical wall section has ceased to be a locus for variability in thickness, integrated color and finish, or decorative form in architectural design. Louis Sullivan later popularized the biological dictum "form follows function". But Sullivan failed to remind us, or to predict, that form often follows industry specifications driven largely by the availability of cheap material and optimized manufacturing. Prefabricated modern architecture tends to produce homogeneous flatness. This flatness is literally coded into our built environment, which is covered in a 5/8" thick film of fire rated gypsum wallboard.

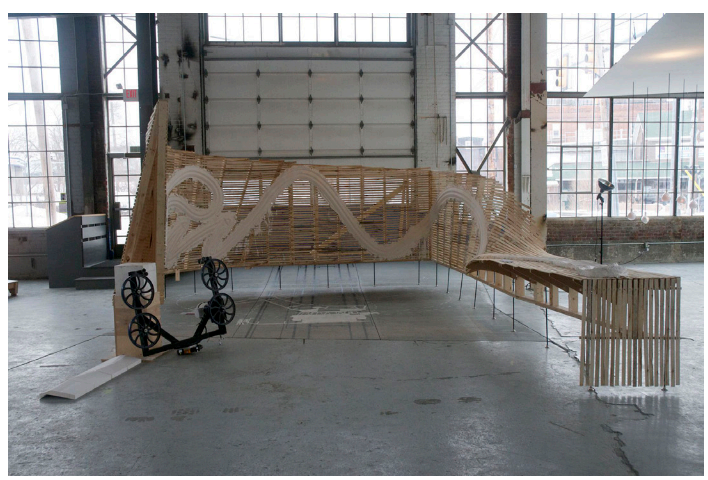

Figure 1. Mor~~ph~~faux demonstration construct, robotically profiled plaster on bentwood lath.

Mor~~ph~~faux uses the synthetic properties of plaster to challenge the ubiquitous flatness of prefabricated drywall construction in two significant ways.

Figure 2. Plaster compensating for the difference in digital model and real wood construct.

First by engaging the substrate directly and applying plaster to wood lath rather than relying on a sheet material, our research breaks the flatness of the wall plane (Figure 1). We found the use of wood lath rather than expanded steel mesh to be both ecologically friendlier (wood lath is an entirely biodegradable and renewable resource) and also offers the formal limitations of a ruled surface to work against.

Secondly, architects often struggle to resolve the conflicting spatial paradigms of the precise factory and the irregular singularities of the construction site. Sites are seldom flat; lines are seldom straight; corners seldom square. Filler strips, shims, and joints often negotiate the disparity in relative tolerance from the factory to realities in the field. Plaster has traditionally been used in multiple gauges (figure 2) to seamlessly blend joints in building elements, especially where disparities occur and as an adhesive with the ability to bridge gaps between on site discrepancies and prefabricated elements. While relying on a digitally modeled ruled surface designed to be made from bent wood we encountered site and material discrepancies that needed to be considered. Both during and after assembly, the newly formed lath wanted to spring back to its original shape, twisting the overall construct and deviating it from its ideal dimensions as provided in the digital model.

ROBOTIC MANUFACTURING CHALLENGES FACTORY TABULA RASA

Digital fabrication suggests alternative inroads to the problems of homogenization and the disjoint between the spaces of on-site vs. off-site production. One already established theme is the ability of CNC machining to push standardized manufacturing toward customization at an architectural scale. While the promise of "mass-customization" suggests one antidote to the ubiquitous industrial production of the built environment, many CNC machines actually reinforce the abstract datum of the factory through work cells sized to mass-produced sheet materials. The inherent dimensional limitation of these tools often trap designers in a translational loop between abstract, flattened cut sheets (sized to the work space of the CNC machine) and the tectonic assembly of the three-dimensional construct.

Transitioning from craft-based practices of applied architectural plaster where both additive and subtractive tools must be applied in the same work flow to the domain of CNC fabrication requires retooling traditional approaches to machining. Rather than associating individual operations with separate dedicated machines (e.g. CNC Router, Water Jet Cutter), Mor~~ph~~faux utilized a six axis robotic arm equipped with workstations positioned along a 30 foot linear external axis. Custom end of arm tooling was designed and fabricated to shape plaster in its multiple states. The robot was used as an open platform of programmable means anticipating the guiding telos of new tools. In each instance, we developed contemporary plaster tools to explore connections to tacit material knowledge and craft precedent and to provoke speculative making made possible by robotic motion.

Our research in robotic fabrication brings these constraints into clearer relief since the work cell of a robotic arm can be equal to that of a shippable module. Thus a robot can work at the scale of and directly in the three dimensional space of the architectural module. Furthermore, robots are becoming increasingly portable and may both operate within the physical limits of the factory and in situ at the construction site. This possibility begins to bridge the divide between conflicting logics of fabrication and installation.

In the case of the lath wall we designed aspects of the project directly in a digital model and assembled the full-scale construct in an exhibition space. We then separated the lath construct (pre-plaster) into five discreet sections and reassembled them in the fabrication lab where we robotically applied the plaster (Figure 3). Once the plaster was cured we sectioned a number of plaster keys from the continuous profile corresponding to the locations where the plaster crossed the joints between lath wall units. We then disassembled the construct for return transportation to the exhibition

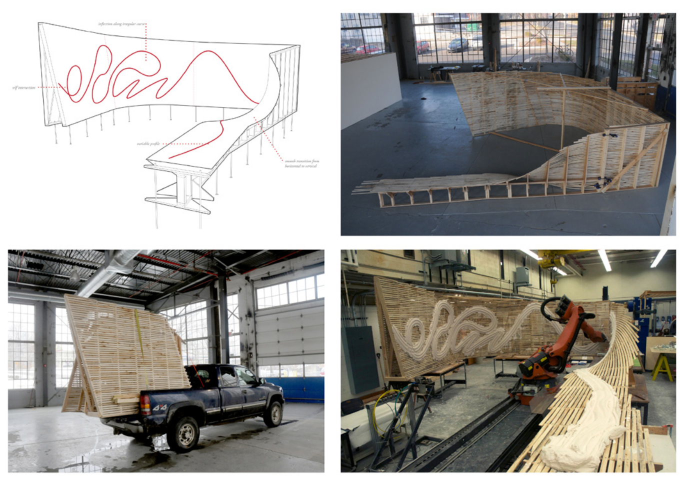

Figure 3. Digital model, wood lath construct on site, parts in transport and robotically applied plaster in fabrication lab.

site where final assembly was performed (Figure 4). Because of plaster's capacity to be seamlessly chemically bonded across cold joints, precast plaster elements can easily compliment onsite forming. We capitalized on this to reinserted the plaster keys and seamlessly blend them with onsite plaster filler.

The possibility of robotically working across multiple sites relies on the transitive space of digital models in robotic tooling. While the robot functions in a physical context it is programmed relative to the digital space of a constructed model. That model can contain multiple organizational spaces (i.e. the space of the factory and the space of the architectural site). Furthermore, with advances in digital scanning, digital models are increasingly adept at accounting for irregularities in site topography and organization making it possible to translate the specificity of the architectural site into the fabrication environment of the robot.

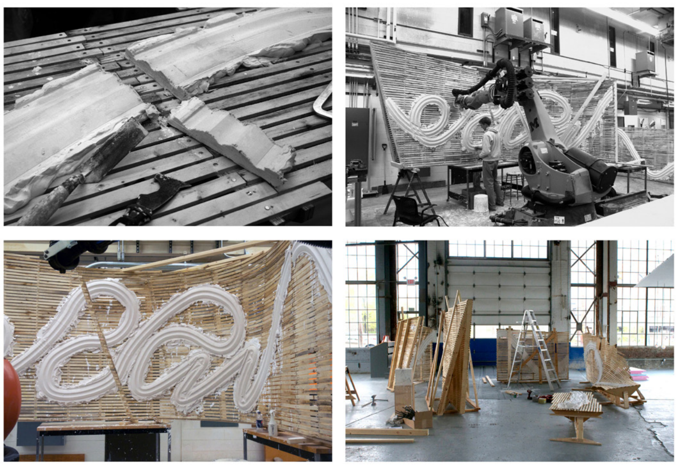

Figure 4. Plaster keys removed from construct for transportation and separated elements on exhibition site.

In the case of Morphfaux the full-scale lath and plaster wall was designed for an offsite exhibition. The piece was simultaneously designed in the space of the robot (taking into account its dimensional limits and path of travel) and the space of the exhibit (adjusting for a sloping floor and irregular footprint). Detailed digital models were used to shape the lath wall to its multiple sites and to produce tool paths to be followed by the robot in the space of the laboratory. These geographically distinct but logistically relevant spaces were combined in a digital context to create a synthetic site of design and fabrication without flattening the geometry to a series of cut sheets whose components would then be reassembled in the space of the final artifact. Instead plaster was applied directly in the three dimensional orientation of the wall. Work at this scale required use of the robot's external axis a 50' track bisecting the work space of the lab. This configuration proved viable during the research but Morphfaux anticipates increased mobility in robotic fabrication where plaster could be applied on-site, (Figure 5).

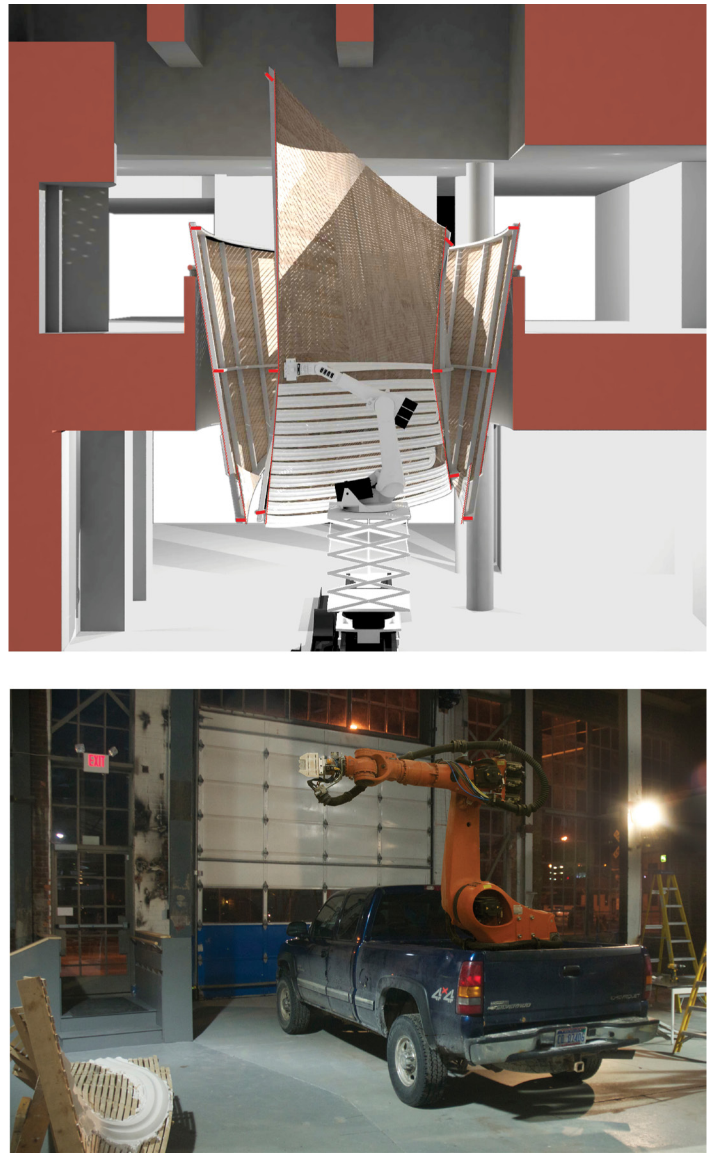

Figure 5. Speculations in portable robotics.

CONCLUSIONS

At its core Morphfaux is a research project that attempts to challenge the lack of diversity ever present in our built environment and most often associated with—and blamed on prefabricated architecture. It is our claim that the invention of drywall and other sheet goods was a primary ingredient in the homogenization of built and prefabricated form and that robotic fabrication provides fundamentally new ways of conceptualizing the built environment and reconsidering the role of plaster as a rich, contemporarily relevant architectural material. The return to plaster, an ancient architectural material, through the lens of robotic fabrication finds commonality with many contemporary prefabricated projects. For instance SHoP's 290 Mulberry uses brick, a material traditionally associated with on-site labor, to assemble custom pre-fabricated panels. Or

Gramazio & Kohler's Gantenbein Vineyard where robotically stacked bricks form large scale patterns across the structures pre-fabricated wall sections.

Contemporary construction methodologies are becoming increasingly indifferent to the diverging logics of on-site construction and off-site pre-fabrication. What is more, there may be an operational synthesis afoot which makes the translation between the two virtually seamless.

REFERENCES

Smith, C. (2002). The Plan of Chicago, Daniel Burnham and the Remaking of the American City. Chicago: The University of Chicago Press.

Perez, S. (2012). Towards an Ecology of Making". In Matter: Material Processes in Architectural Production. eds. Borden, G & Merideth, M. London: Routledge.