The Digital Corbeled Wall. A Pedagogical Approach to Digital Infrastructure and Traditional Craft.

James Stevens*a, Ayodh Kamathb, Komal Sharmac

*aLawrence Technological University
bLawrence Technological University
cIndependent
*Corresponding author e-mail: jstevens@ltu.edu

Abstract: This paper investigates a pedagogical approach to the digital by revealing the contemporary, globalized infrastructure of design through engagement with local traditional craft in India through a workshop style course. The process of the workshop exposed the principles of digital vernacular, identified as a way of designing and building that integrates the contrasting technologies and techniques of designing and making seen around the world. By exploring the intersections between seemingly opposing concepts—traditional masonry and computational design—this paper exposes opportunities for the future integration of handwork, craft, and technology.

The workshop approach highlights how abstract values like material knowledge and craft skill can inform a design algorithm to generate a parametric model of a wall. [Figure 01]. Taking into consideration perspectives of the various participants, the paper will examine several layers of learning. It will conclude with an explanation of pedagogical strategies for learning about digital infrastructures and an argument for re-examining digital fabrication not just as a futuristic practice, but for its pragmatic utility here-and-now. Most crucially, the discussion makes a suggestion towards the future of design and the future of education, and why it is of value to involve designers and architects in the practice of making.

Keywords: Digital Fabrication, Making, Traditional Design, Parametric Design, CNC machine
1. Introduction

This paper is represented by four groups of thought: an architect and professor from the United States, an architect and educator from India, a design journalist as observer, and a local skilled mason. The academics of the group conceived of this collaboration because we are perpetual students of design, makers with a passion for experiences that test the capability of our skills, our thinking, and our tools. As educators, we continually provide learning experiences for our students and collaborate with them on a range of design projects that test context, material and our culturally preconceived notions of design. We value design education that involves the act of making for the immediate and natural consequences of its process and its outcomes. As author David Pye (1968, p.27) has noted, “Design, like war, is an uncertain trade and we have to make the things we have designed before we can find out whether our assumptions are right or wrong.” Our pedagogical strategy is to lead students through experiences that simultaneously engage the real and the representational in a productive tug-of-war.

Our theoretical framework, the Digital Vernacular, guides our pedagogy (Stevens, 2015). It is a theory defined by practice and inspired by our own struggle to make what we have designed. We recognize that digital tools are embedded in contemporary design practice and are rapidly being integrated with all phases of design and making. We also recognize that design traditions are embedded in vernacular architecture with principles founded in the memory and transfer of community knowledge and collaborative processes of design. Our inclusion of the mason as an equal within our team of experts was critical to our process to ensure his knowledge was fully presented and engaged with by our students.

In this essay, we illuminate the origin and premise of the Digital Vernacular through the lens of a specific design project, The Digital Corbeled Wall. We reflect on the questions raised through the
process and outcome of this project and through lessons learned that have influenced students and faculty.

2. Illuminating the Digital Vernacular

We believe that sound education and meaningful design is based on learning from the past and fully engaging with the present. Design innovation emerges when time-tested principles are synthesized with available technologies and unique circumstances of time and place. These ideas are often contrary to contemporary design and academic practices that place primary emphasis on digital tools in the service of free-ranging expression and abstract representation. Global digital unification has generated a powerful desire to express new ideas in architecture independent of regional place and time, which has fostered a voracious appetite for a new global architecture built around common ideas, not common places or techniques. Students and faculty are influenced by these desires. We have found that design education challenges digital hegemony with physical tangibility and feedback to provide a more critical focus and meaningful perspective (Stevens, 2014).

The practical capabilities and seductive qualities of digital toolsets for design and fabrication have transformed all disciplines of design and altered the historic traditions embedded in each practice, which originally privileged the hand skills and learned traditions of the maker within a local context. To reconcile the contradiction of an abstract digital environment with concrete local circumstances, we have developed a theory and mode of practice we call the Digital Vernacular. The Digital Vernacular is an idea that combines vernacular design principles of the past and digital technologies of the present with goals of joining widely available digital tools with community knowledge to generate appropriate innovation in a contemporary design context. By vernacular we specifically mean the common building morphologies, construction preferences, and material availabilities that have developed in a particular culture, place, or climate. The use of the term digital embraces both numeric digits in electronic form and the Latin term *digitus* related to the fingers of the hand. We should foster the use of computers and computer driven tools as well as use of the most accessible tool, the human hand.

Prior to the Industrial Age, when design and making were aligned, master craftsmen within the vernacular trades created most designed goods. The Industrial Age, and most recently the Information Age, shifted the role of the designer away from that of master craftsman to a professional knowledge worker (Evans, 1995). As a result, a divide between design and making occurred. This shift changed an essential part of the designer’s role in the process and also the way in which students of design learned. By degrading the symbiotic relationship between mind and hand and limiting the exposure to immediate design consequences, students and architects have become the operators of tools that often only represent design, not tools that produce tangible design outcomes. By immersing students in design and making processes and activities there is greater opportunity to operate the tools for both design and making in productive harmony.

Our design decisions only come to bear on us directly when we build. By building what we design we must take responsibility for the immediate consequences of our decisions and our actions. The computer has leveled a new complexity on the design. It can too easily remove from us an awareness of scale, tolerance, and tactility by providing a universally-scaled world that is always level, square,
and untouchable. The computer, in effect, dictates that the world should match the abstract coordinates of our software, which is rarely a reality. In the example of a CNC machine, it is requisite that raw material be first processed down to nominal dimensions in order to meet its milling limits.

Technological developments have shifted the current economic model of design and making by providing the opportunity to re-establish this lost connection. They have provided new opportunities for design and making workflows supported by digital tools. The innovative processes used to create digitally fabricated design objects are just now emerging with some clarity, and these parallel the confluence of readily accessible digital technologies with traditional methods. These technologies call for a more robust understanding of not only romanticized notions of the future but of sound design principles rooted in the historical and evolutionary development of architecture. We believe it is important for students to internalize this perspective in their educational experience.

To practice the Digital Vernacular, a designer must initially establish, through careful observation and analysis, one or more guiding vernacular precedents. Principles may be gleaned from a precedent through the recognition of design responses to particular circumstances. A vernacular design principle must be time-tested and be part of common or populist knowledge (Stevens, 2015). Once a valuable precedent is selected, these principles set in motion a Digital Vernacular design process unique to each situation and context. The most valuable criteria for selecting a precedent is if the student recognizes clear, relevant, and interesting principles that can guide their design. The ultimate evaluation is what the design student does with the precedents and principles and how they guide the definition of a design or proposition.

The Digital Vernacular is a pedagogical approach that provides specific insights into the process of design, fabrication, and construction of physical outcomes. The selected project, The Digital Corbeled Wall, demonstrates the variability and resiliency that digital fabrication provides in terms of scale, character, and construction methods guided by vernacular precedents and principles.

3. Project Explanation

The approach is explained through a narrative of a three-week workshop in India that involved architects, digital fabricators, parametric modelers, and a mix of Indian and American students. This team collaborated with a pair of local masons to construct a geometrically complex mud brick wall. The workshop was positioned in the pre-modern notion of craft and a post-digital notion of design, between a pedagogical approach of learning-by-doing and a grassroots approach to design practice. The team designed and utilized a parametric software to model a prototype and describe the complex three-dimensional geometry of the wall. This parametric model was constantly evolving and re-making itself in response to the physical wall, the hand of the mason, and the variations in the non-industrial materials. The adaptive choreography between the mason, the students, and architects revealed an alternative practice model where knowledge doesn’t flow in a linear format of digital-to-physical, but a back and forth between the two, where each informs the other, doing what each does best.
It was the result of a synchronized process of laying bricks determined by a parametric model, measuring and logging the positions of the laid bricks into an algorithm, milling the bricks, and in totality, achieving the desired corbelled effect through open dialogue amongst the masons, architects, and students.

3.1 Place and Time

When working in the Digital Vernacular, principles of place must have profound influence on the designer. We take it as self-evident that each work of design has the potential to be responsive to the particulars of each place where a design is to be situated. This responsiveness is a mandate for the Digital Vernacular. Place is defined in The Digital Corbeled Wall project by recognizing the unique physical and ephemeral characteristics of India and the vernacular mud brick. These characteristics include both the visible as well as the unseen, including recognition of the hidden economic forces from the West that degrade Indian craft traditional and cultural history.

3.2 Guiding Precedent

In selecting a precedent for The Digital Corbeled Wall the student and faculty considered the place and time and the digital tools available to create a nonlinear wall. The challenge not only required coordination of the digital script with the mason but also to use a CNC machine to modify a large number of bricks to conform to the designed form. This led the students to a process from 17th century England, where it was common to remove clay from pre-fired bricks in a process called “cut and rubbed” or gauged brickwork. Brick makers would take a standard unit and, using a wood jig, would rub the clay to remove material to create a unique profiled shape with specific practical and aesthetic characteristics. This process created brick units that could form twisting chimneys, roof coping, and other ornate masonry features common at that time. Using the process of the Digital Vernacular the design students studied this historic example (precedent), identified that it is a thoughtful and measured removal of material to create custom units that perform a specific role (principle), and then proposed a new masonry design employing a removal process from a hand formed unit using digital tools and techniques (proposition). This process guided the students to achieve mass customized masonry units using sound principles and processes established in the vernacular tradition while employing appropriate traditional and contemporary digital tools all while collaborating with a local mason.

3.3 Aligning Tools, Materials, and Skills

The guiding precedent, the sensitivities to place and time and the process of the Digital Vernacular only prepared the team for the design challenge, it did not define it in detail or even provide a visual image of a potential outcome. The Design Challenge was only conceived as a collision of the tools, materials and skills available. Therefore, the team set out to define a wall within these limits and opportunities. What ensued was a series of proposals and tests to verify feasibility. The mason engaged with the students to find the maximum corbeling for the mud bricks. [Figure 02] Students worked with the primary fabrication tool, a CNC machine designed to fit into a suitcase that was transported by the students to India from the US. [Figure 03] Given the tool had been built and tested in the US the students did not know how the mud bricks would respond to the milling. Initial tests proved it was feasible and the machine was modified onsite to allow it to mill the header of the
mudbrick. Students used these tests to inform a series of scaled models using wood blocks and clay to represent the bricks and mortar. [Figure 04] Through physical testing the variables were defined and used in the creation of the parametric model.
Figure 2. Finding the maximum corbelling limits of the masonry.
Figure 3. A CNC machine designed to fit into a suitcase was transported by the students to India from the US.

Figure 4. Students testing scaled models using wood blocks and clay to represent the bricks and mortar.
3.4 Parametric Model

The parametric model used for the workshop was developed during the course of the workshop itself. The model was developed after observing the construction of a test wall by the masons. The aim of the test wall was to build as many courses as possible while corbeling each course as far out as possible till the wall collapsed. This test gave us knowledge about how far and for how many courses we could corbel before needing to balance the wall by corbelling back in the opposite direction. Using this knowledge, we created a curved non-uniform rational basis spline (NURBS) surface with curvatures within the limits of the corbeling as the wall design.

This NURBS surface formed one input for the parametric model. The other input parameters were dependent on the irregularities of the sun-dried mud bricks and the response of the masons – the length, width, and height of each individual brick, and the position of each brick as placed by the masons. The positions of the bricks were recorded through the X, Y, and Z coordinates at two corners of each brick measured from a datum line using plumb bobs and right angles.

The on-site student team recorded their measurements on a cloud based spreadsheet. The data from the spreadsheet was input into the parametric model in real-time by a second team of students. The parametric model virtually placed each brick relative to the designed NURBS surface and sliced any portions of the bricks that might be projecting beyond the surface. The resulting sliced brick shapes formed the output of the parametric model.

The sliced brick geometry was shared through the cloud with a third student team operating the CNC router to shape the bricks. Once milled, the bricks were returned to their original positions on the wall, as placed by the masons, using the measured coordinates of the two corner points. The masons then spread mortar on the bricks and began the next course. [Figure 05]

![Figure 5. Left to right: positions of bricks recorded, NURBS surface sliced bricks, bricks returned to original positions on wall.](image)
4. Stakeholder Interviews and Outcomes

What resulted was a Digital Corbeled Wall that undulates along a curve, sometimes obediently and sometimes abruptly. Each brick was placed with the aid of the digital script, while the skill of a mason then re-informed the script based on the requirements of the material. When the bricks went beyond the prescribed corbel distance they were milled by the CNC. This gives the wall its unique milled marking with curved patterns that match the typography of the surface. [Figure 06] Understanding the process and the stakeholders allows the designer to see each brick in a struggle to align with physical and virtual commands. Its appearance also taught an important lesson to the students: sometimes design is not conceived of visually and predetermined by our genius alone. Design is a result of conditions, tools, and material realities that are many times outside of our control. Although it took the majority of the project for the students to see this potential and to let go of their preconceived notions, all understood when the final wall was complete.

![Image of a Digital Corbeled Wall]

Figure 6. Milled markings match the typography of the surface.

A significant outcome for The Digital Corbeled Wall was the diversity of people who collaborated and brought unique sets of knowledge. One of the participants, Sujauddin, has been working as a mason for over 35 years. His father was a mason and his sons are following in his footsteps. He works in the construction business with traditional masonry techniques, and takes pride in his expertise of making domed structures (Gumband), the Mughal tower (minar), and floral and filigree patterns.

It became clear early in the project that the students and faculty depended significantly on Sujauddin’s material knowledge and skill. Before building the actual wall, the team decided to build a test-wall to find the maximum number of mud bricks that can corbel before they overturn. The measurements from this test wall were crucial. It is difficult to arrive at such figures from first
principles because of variables such as stickiness of the mortar. Sujauddin, in retrospect, talks about this test wall and says: “We did five courses. At one place there was a little extra weight, so we tried to balance it by putting weight on the opposite side. I expected it to fall any time after the fifth or sixth course, but hoped that it would stand. By the time we did the tenth course, it was down.” That Sujauddin could speculate what would practically work, how many layers of bricks would stand, and at which point they will fall over, is knowledge that comes from experience, that could perhaps be called instinct or tacit knowledge developed over a period of time of working intimately with brick and mortar. [Figure 07]
Similarly, the skill of laying bricks might appear fairly straightforward to onlookers, but like most craft forms, the simplicity is rather deceptive. On one occasion, Sujauddin and his sons were absent from
the site, so the other members tried to lay a set of bricks themselves. It took them three times as long and it still turned out uneven. This is not to imply that students of design are inept at laying bricks, but to bring attention to alternative sets of knowledge that are an inherent part of the system, yet theoretically they are dismissed or ignored in progressive experiments and arguments. For example, a student may be adept in the design of a building but lack awareness of what is actually represented by the poche in their architectural drawing. One innate purpose of building this wall that emerged was to shorten the distance between textbook knowledge and practical know-how and to sensitize students—future architects, designers, thinkers, policymakers—towards the value of traditional knowledge systems.

In the time lag between milling the bricks and laying them, Sujauddin and his sons could be seen waiting patiently, sitting in the shade, observing the little army of architects, designers, coders, professors and students, puttering around with their measuring tapes and plumb bobs. In conversation with Sujauddin after the project was over, his remarks were a mix of curiosity, optimism and self-awareness. “I expect that down the line, these machines will play a big role in our work.” Does that worry him? Sujauddin answered: “These craft traditions are age-old and time-tested, and they will be taken care of, as they always have been.”

In this seemingly casual remark by a craftsman perhaps the essential purpose of a project like this is reflected. A purpose that is bigger than the wall, the codes, or the workshop. In the words of authors Wilkinson-Weber and DeNicola (2016, p. 2), the exppanse of such research has been captured. “We believe that research on craft and artisanship has the potential to open up new and evocative questions about the ways that we construct some of anthropology’s most critical contemporary concerns: technology, access to markets, means of production, control over work practices, tradition and innovation, urban and rural spaces, human rights and the environment to name just a few.”

Apart from the overall aim of the project, different agendas were at play. Another participant, a student at CEPT, Kaninik Baradi, has assisted his parents, both of whom work in the construction business, and has hence witnessed the local context closely. He concludes through our interview with him that construction projects are primarily driven by economically viability. He wants to find a way to work with concrete, which is cheap and easily available, and employ local labor, again a resource at hand, but be able to create diverse, new forms with it. “One of the challenges we face in both traditional masonry and in concrete formwork is that you have to build very rigid, square boxes because they are cheap.” In combining the two—digital and hand work—Baradi believes that you can create opportunities for the craftspeople to remain a part of the process, as well as create architecture that is more efficient, sustainable, and aesthetically variable. “The advantage of a method like this is that it is not tremendously expensive to build something more complex. You can make it respond precisely to your site conditions,” says Baradi.

For Ayodh Kamath, a similar agenda informed his exploration: how to make the most of digital tools and local craft techniques, especially in a context that does not have complete standardization. In the Western context, a seamless transition and integration of digital calculations and physical construction can be expected because the materials and conditions of working are highly standardized. But that may not be true of many local contexts like India. Contrary to textbook
understanding of digital technology, that it is perhaps appropriate only for highly developed working contexts, Kamath wants to find ways for digital technology to be beneficial to semi-standardized working conditions. Primarily because digital tools offer their own sets of freedom and power. “The primary advantage of designing on the computer is being able to iterate and evaluate designs easily and quickly. It’s much easier to change digital geometry than it is to change a physical object. There’s no undo button in the real world,” he says. An implication of this in local construction contexts speaks to Baradi’s earlier point as well, that with the help of digital tools you could build out of the concrete box, so to speak, and know beforehand—before actually building it and employing resources—whether it will work or not.

Among the students, there could be sensed an anxiety around the success of the project; that their measuring is imprecise, that it’s taking too long, that there was a lag between transferring information from the physical to the digital modes, and how efficient that was. Yet to an outsider, it seemed that what looked like idling was time and space made available for discussion, for thinking things over, for considering other options. The time taken up in measuring, milling, trial and error, and re-doing, was not entirely time lost or wasted. Instead such hands-on learning impacts a student at a deeper, more involved level than reading case studies in a textbook.

When the wall was complete the students, faculty and the masons gathered together to have a final reflective discussion. The students agreed that working with digital technology and with something as traditional as un-fired mud bricks; a material that is readily available in the context, suited to the climate, and indigenous to the mason was challenging and upended their understanding of how digital technology engages with material. This shift in understanding was particularly true for the American students that have worked their entire academic careers only using manufactured standardized materials. Further, the students expressed a new appreciation of the benefit of combining computational tools of architecture in a culture and economy that is primarily labour driven. They discussed the potential for the process used in the workshop to acknowledge labour, skill, and craft traditions and how that might prevent them from being made obsolete by conventional one-size-fits-all modalities of design imported directly from the West.

In a final reflection, Stevens admits, “Ayodh and I were possibly the least bothered about the artefact, the wall itself. Our priority was understanding the process and steps and how those variables impact us.” The implication being that the final product may not always be the endgame, the process itself is where the learning occurs, where the possibilities and challenges are grasped and addressed.

References
Coyne, Richard. (1999). Technoromanticism: Digital Narrative, Holism, and the Romance of the Real. Cambridge, MA: MIT. Print.
Crawford, Matthew B. (1997). Shop Class as Soulcraft: An Inquiry into the Value of Work. New York: Penguin, 2009. Print.
Evans, Robin. (1978). Translations from Drawing to Building. Cambridge, MA: MIT. Print.
Evans, Robin. (1995). The Projective Cast: Architecture and Its Three Geometries. Cambridge, MA: MIT. Print.
Llach, Daniel Cardoso. (2015). Builders of the Vision: Software and the Imagination of Design. New York, NY: Routledge. Print.

McCullough, Malcolm. (1996). Abstracting Craft: The Practiced Digital Hand. Cambridge, MA: MIT. Print.

Pye, David. (1968). The Nature and Art of Workmanship: David Pye. Cambridge: U. Print. 27.

(Ed.) Wilkinson-Weber, Clare M. and DeNicola, Alicia Ory. (2016). Critical Craft: Technology, Globalization, and Capitalism New York: Bloomsbury. 2.

Stevens, James and Nelson, Ralph. (2014). "Digital Vernacular: Practice and Pedagogy." Working Out, Thinking While Building: Papers from the 2014 Fall Conference. Washington, DC: ACSA, 2014

Stevens, James and Nelson, Ralph. (2015). Digital Vernacular: Architectural Principles, Tools, and Processes. New York, NY: Routledge. Print.

About the Authors:

James Stevens is an Associate Professor and Chair of the Department of Architecture at Lawrence Technological University, College of Architecture and Design, where he is Director of makeLab. James is a IDAUP XXXII Cycle PhD candidate, Polis University + Ferrara University, Italy

Ayodh Vasant Kamath is an Assistant Professor of Architecture and Digital Design and Fabrication Technologies at Lawrence Technological University and a PhD candidate at the University of Pennsylvania.

Komal Sharma is a design and culture writer based in Mumbai, currently writing for Indian newspaper Mint, Lounge. She has previously contributed to Herman Miller and Metropolis Magazine, New York, and Architectural Digest and Vogue, India.

Acknowledgements: The authors would like to acknowledge the thoughtful work of the student and mason participates of the workshop along with the support of Lawrence Technological University, Michigan, USA and CEPT University, Ahmedabad, India.