Digital Risk, Materialization of Digital Media

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Abstract

To practice architecture today is to reach across centuries of disciplinary divisions that have removed us from material. It is not surprising that many celebrated contemporary projects are clearly derived from the shaping of a visual experience. The tactile and the haptic have been degraded in favour of productivity, technology and unlimited virtual iterations. Recent developments in digital fabrication applications have opened new opportunities for designers to reengage with tools and materials. For architects that have leveraged this technology, there still exist digital protections that do less for the value of their outcomes and more for their industrialized efficiency. When one pushes for the optical and practices only the theoretical component of design, it is done at the expense of matter in space[1] (Adamson, 2007). While computers can simulate architectural space with efficiency, they do not account for the human sensory feedback required to diligently craft material. In an impressive argument, Malcom McCullough has asserted that the operation of digital technology defines a new dematerialized craft[2] (McCullough, 1996). The tactile shaping of material was viewed to have a parallel digital equal in computer clicks and bits. McCullough maintains that the act of craft can occur entirely in the virtual realm, regardless if the work results in a physical artefact. Although widely accepted within the discipline of architecture, McCullough's assertion negates the inherent resistance realized by the use of material and the productive failure induced by making. In a pre-digital context, David Pye clarified related distinctions between craft and industry by defining the craftsmanship of risk and the craftsmanship of certainty[3] (Pye, 1968). The craftsmanship of risk achieves quality through a calculated risk of personal skill, while the craftsmanship of certainty requires preplanning and careful mechanical implementation. Digital media described by McCullough further mitigates what Pye defines as risk by subjugating material awareness with safe digital simulation. This paper will engage both the digital and the analogue through a case study that provides insights into the role of digital tools that embrace both material risk and digital control. The digital tool is based on an open-source Delta 3D printer configured to print ceramic clay (figure 1). The principle that guided the tool's design was to have distinct tasks relegated to the computer and to the human hand. The 3D printer's design intentionally allows risk, it embraces failure and negates standardization. The craftsperson is not simply an 'operator' of a computer tool, but is instead engaged in a risky negotiation between the material and the digital. There is value in looking closely at dematerialized and traditional craft, not only through the lens of outcomes and their quality but also how said qualities negotiate the benefits of risk. The insights of both Pye and McCullough are now converging in a post-digital context that raise new questions about how risk is defined and used in the creation of craft objects. The case study profiled will suggest that digital craft need not subjugate material knowledge, and will translate how digital risk can be used to extend our understanding of craft.

Figure 1: Custom ceramic printer

Craft, industry and risk

Craft is typically defined as a skill that has been practiced to achieve consistent outcomes. One might think of a potter at the wheel consistently creating the same vessel to near perfection, or a welder fusing steel that can achieve an expected shear load. Most agree that craft is achieved by practice and that it provides consistent outcomes that are exceptional. The Encyclopaedia of Diderot & d'Alembert described craft as the 'name given to any profession that requires the use of the hands, and is limited to a certain number of mechanical operations to produce the same piece of work, made over and over again.'[4] (Gendzier, 2009)

Preceding organized industry, the ancients used utilitarian objects solely created by artisans. In the absence of industry, craftspeople played a defined role within society – tending to a body of knowledge handed down through generations of masters, journeymen and apprentices. The Industrial Revolution interrupted the relative stability of craft through mass-production machines and the division of labour. The cultural response was to preserve and protect the hand crafts, and this manifested in the political writings of Marx, and the critical writings of John Ruskin, which were aligned with the Arts and Crafts movement. These reactions were rooted in an appreciation for craft that differentiated it from industry. The duality of industry and craft set up opposing views of material culture. On one end, the view of craft was nostalgic and sought material links to a pre-industrial past, on the other was the view of modern efficiency defined by speed and egalitarian distribution of product. It is true that many of the craft processes and artefacts share lineage with their pre-industrial precedents, but it is important to understand that modern craft is not a result of the past; modern craft is a manifestation of industrialization itself developing alongside industry, both benefiting from the other[5] (Adamson, 2013: xiii-xv). The opposition between viewpoints only reinforces the importance of both.

David Pye clarified the distinctions between craft and industry by identifying 'the craftsmanship of risk and the craftsmanship of certainty'[6] (Pye, 1968: 20). The craftsmanship of risk is a process where the quality of the result is frequently at risk during the process of making and is dependent on the judgment and care

exercised by the maker. The craftsmanship of certainty requires comprehensive planning of the process prior to manipulation of the materials, with all variables predetermined and pre-tested to the greatest extent possible. These definitions still hold true today, in that they define the primary differences between industry and craft by highlighting industry's aversion to – and craft's requirement for – risk.

Industrial efficiency and the degradation of risk

Our understanding of time and efficiency as a variable of labour fundamentally changed with the advent of the industrial revolution. In a preindustrial world, time was regulated by daylight and labour was only mandated by need. Industrialization brought mechanized labour and, as a result, time and production no longer followed the natural cycle of the day but a clock that measured output and efficiency. A great challenge in the early days of industrialization was training workers to abide by the clock and a new mandate of efficiency. As industrialization matured, so did workers' understanding and dependency on the factories and wages they supplied. Time spent working was no longer measured by the quality of the artefact but in the number of pre-engineered artefacts produced. In America and Western Europe, it became a measure of a person's value and led to common Puritanical descriptors, such as 'work ethic.' This cultural shift from the agrarian to the industrial provided obvious benefits to human existence, eventually providing wealth to a new class of citizenry. Countering this benefit were new problems that arose, such as pollution, labour, exploitation and mechanized warfare.

To achieve this new-found efficiency, the industrial complex worked vigorously to eliminate risk. Risk was equal to laziness when formulating efficiency. However, there is value in evaluating the benefits of risk and what we have collectively lost by eliminating it. Risk is essential to all craft by regulating our progress and providing the necessary feedback from our errors. Risk can also be managed by the experienced craftsperson by allowing for necessary feedback to improve their craft. Prior to the advent of digital technology, most making involved risk or sought to eliminate it altogether. As defined by David Pye in a pre-digital context, the craftsmanship of certainty and the craftsmanship of risk were two distinct modalities of work; not that Pye argued that the two could not be combined, but prior to digital technologies, most artefacts fell clearly into one of the categories. The variables of risk today are no longer so clear. Digital technology has introduced a level of control that allows the craftsperson the opportunity to use risk as a positive variable while also maintaining an acceptable level of efficiency. For risk to be positive it must be manageable. The craftsperson must have a command of the tool and material to a level that does not leave them a victim of risk, but rather a benefactor of the feedback the risk provides.

Wedgewood, Ford and the isolation of risk

Wedgewood Pottery was one of the first instances of the systematic division of labour. Taking place in the 18th century, Josiah Wedgewood sought to raise productivity by dividing labour in a way that ultimately isolated the craftsperson from the entirety of the process. Wedgewood distributed the sequenced process of clay pottery between separate workshops and divided tasks between specialized workers. This was not done on what is thought of as an assembly line per se, but in a single 'factory' containing workshops for each step in the process. Doors to the workshops where intentionally misaligned to discourage a craftsperson from interacting with others working on different steps in the process. The consolidation into Wedgewood's factory was significant because it departed from the prior system of 'put-out shops'. This system relied on dividing the production of craft objects between individual workshops, where each workshop was typically maintained by a master craftsman along with their journeyman and apprentices. Put-out shops would be located adjacent to each other for ease of shipping and shared labour of lower

skilled workers. This would lead to urban and rural districts that specialize in garments, metals and other crafts. These districts can still be seen in many urban areas today. However, Wedgwood still depended on skilled craftsman who had specialized knowledge in a portion of the process while not having detailed knowledge of unique techniques, ingredients, or patented processes. All of the steps in the creation of the pottery as a whole would remain secret. Wedgewood had legal patens, but – like today – those were difficult to enforce, and many times lawyers would be the primary beneficiaries of the intellectual property. Therefore, Wedgewood Pottery relied on secrecy. Significantly, Wedgwood's labour separation was a first step in degrading the centuries-old process of apprentice, journeyman and master craftsman. Prior to industrialization, craft objects where made by master craftsman and the knowledge was maintained through the apprenticeship system[7] (Allitt, 2014: L9). Master craftsmen would accept apprentices in their workshops who would spend years learning the skills, tools and secrets of a given trade. Apprentices were often times the children of the master craftsman, or came to the master craftsman by way of a child's family willing to compensate for their instruction. Regardless of the relation, the apprentice would live and work with the master craftsman for several years until they rose to the level of journeyman. A journeyman would seek work from multiple master craftsmen and maintained a certain level of autonomy. In preindustrial times, an ambitious journeyman would build the capital necessary to purchase the tools and workspace required of a master craftsman. Then the cycle started once again along with the knowledge maintained within the craft. It is necessary to recognize the impact that industrialized division of labour had on the craftsperson. However, it is important to note that many of the divisions of labour and resulting specializations were created by master craftsmen, and the skill and craft imbedded in each specialization was still present and serving as an early example of craft developing and evolving alongside industry[8] (Adamson, 2013: 22). Furthermore, Wedgewood's division of labour into specializations isolated the risk in production. Having the very best craftsman who would perform a specialized task repeatedly lowered the inherent risk when compared to a single craftsman responsible for all stages of the work. The result was higher production with high quality results.

Industrialization of the trades not only divided the labour of the craftsman but created a much larger barrier of entry for the journeyman. With new technology and the advent of the factory, goods had become less expensive, requiring production on a larger scale. The required volume necessitated a much larger initial investment. The result was comparable to the narrowing of who became a master craftsman and who remained a journeyman. This progressed aggressively into the early 20th century, culminating in Henry Ford's assembly line.

Ford consolidated knowledge from multiple disciplines and distributed it linearly along an assembly line. Ford's assembly line, derived from early meat processing systems, not only divided labour - it de-skilled the labour required. Each person working was doing a small – many times mundane – task that culminated in a vehicle, yet no individual task required a high level of craft or skill. Ford benefited from the process of carriage-making because it was highly complex and relied on multiple disciplines and craft trades. This allowed Ford to abstract tasks and simplify them so that workers were unaware of the role each of their tasks played in the assembly of a vehicle[9] (Giedion, 1948 :115-126). The true power was not in the products but in the consolidation of personal knowledge[10] (Crawford, 2009: 37-53). This allowed Ford to hire unskilled labour to assemble his cars at a lower price. The personal knowledge of the carriage maker was no longer valuable or marketable. By de-skilling and dividing the labour, Ford all but eliminated the risk in the creation of a vehicle. Unlike Wedgwood who still depended on a specialized craftsperson, Ford relegated the "skill" to mechanization, and de-skilled labour to the worker. There is evidence that Ford understood this and was motivated by this new-found truth. He famously said: 'If money is your hope for independence you will never have it. The only real security that a man will have in this world is a reserve of

knowledge, experience, and ability.' The word 'reserve' is curious, in that it implies that it is beyond any one person's capacity to have more, so that it must be acquired from others. This quote is often used as inspirational to young people for them to seek education and self-betterment. Carefully read, it does not seem so generous; it appears to inform us of his arguably negative impact on the craftsman of America.

Digital craft

The use of digital tools for communication, design, and fabrication to produce craft objects has profoundly influenced material culture. The most apparent influence is in the limitless possibilities of generating complex forms. The computer allows for unlimited possibilities and complexity that are not dependent on the material world. Digital modelling tools such as Rhinoceros and Grasshopper are acting in response to the demands of digital practice. Perhaps the most profound influence is the streamlining between digital design tools and digital fabrication tools. What is designed can now be readily and directly fabricated using digital technology. Practicing digitally has created a process-based change to craft disciplines.

The Digital Revolution has brought numerous remarkable and productive virtues, but it has also introduced some potentially inhibiting deficiencies. Most profound is the increased abstraction and tendency toward loss of human touch introduced with digital tools. Because electronic digital tools are ultimately based on numeric control, they require specialized knowledge of an abstract set of commands and symbols. Digital tools do not yet emphasize intuitive and physical interaction and response. They require constant precision, and inhibit most rough estimation. Digital tools can create a world unto themselves, with a tendency for an operator to lose themselves in a self-referential world of simulation and required procedures divorced from representing reality or intuitive process. The tools have a tendency to guide the craftsman, not the craftsman guiding the tools. 'Outcomes often resemble abstract mathematical models more than haptic experiences defined by a craftsman through real material and specific historical lineage and context'[11] (Stevens, Nelson, 2015: 09).

Although debated within the academy and popular culture, this study does not exclude media, material or tool types, rather it debates the use of the digital and the hand in a productive negotiation, viewing craft as a process or activity rather than a category[12] (Adamson, 2013: xxiii). When viewing craft through the lens of processes – rather than categories such as pottery, weaving and metalsmithing – the processes become complex with the loss of the binding traditions embedded in the trade. As early as the 19th century, craft was most commonly viewed through its material and disciplinary category. The material artefacts produced where guided by 'conservative' links to a 'traditional' past[13] (Adamson, 2013: xvii). This view of craft, fair or not, did provide the craftspeople a set of longstanding and generational knowledge, and more importantly, principles and limits to guide their work.

The word 'craft' has evolved along with these changes. Now, disciplinary activities ranging from surgical procedures to brewing beer are self-categorizing as craft. Richard Sennett describes Linux systems programmers as 'a community of craftsmen focused on achieving quality and doing good work'[14] (Sennett, 2005: 29). Preceding Sennett, Malcolm McCullough explored the idea of virtual and dematerialized craft, asserting that 'digital practices seem more akin to the traditional handicrafts, where a master continuously coaxes a material. This new work is increasingly continuous, visual, and productive of singular form, yet it has no material' [15] (McCullough, 1996: x). The pre-digital tactile shaping of material was viewed to have a parallel digital equal in computer clicks and bits. McCullough maintains that the act of craft can occur entirely virtually regardless if the work results in a physical artefact.

Craft evolved through incremental improvements while maintaining a connection to the past. However, the social, economic and global change that has upended many handcrafts has occurred so quickly that we are just now beginning to understand the immense complexity and opportunities that are provided to a craftsperson engaged in the use of digital technology. Scott Marble observed that digital processes in design have evolved into three distinct systems[16] (Deamer, Bernstein, 2010: 39-43). The first is the replacement of formal geometry with mathematical algorithms. Prior to the virtualization of geometry, craftspeople shaped material by hand. These shapes can now be mathematically defined, controlled and generated in unlimited quantities. Second, the designer has new control over organizational complexity. This allows for designs to have imbedded data ranging from cost to weight, thereby extending the craftsperson's control over production. The third, and most significant for this study, is the development of digital fabrication. This development now provides the link between McCullough's dematerialized craft, allowing for materialization of digital media. Most significantly, this materialization is controlled by the direct actions of the craftsperson.

There is value in looking closely at dematerialized and traditional craft, not only through the lens of outcomes and their quality, but also the process variables engaged by both crafts. It would be impossible to identify and list all specific actions, variables and decisions made in common by materialized and dematerialized craftspeople. However, the creation of craft always includes the variable of failure. There is no greater teacher than immediate consequences for our actions and the clarity and impact of these consequences that enlightens the wise craftsperson to further their skills. Dematerialized virtual craft has protected the craftsperson from these consequences, allowing for decisions between correct and incorrect to be simply toggled by a software command without material repercussions. Digital fabrication introduces material to the digital and provides the material resistance necessary for corporeal craft. However, as these processes have improved they have reduced the risk associated in the manipulation of material. It is certainly riskier to fabricate material where undoing an error is not an option, rather than working in a safe, virtual environment where decisions can easily be reversed. Yet, the digital tools used by most craftspeople are ones developed and predicated on the principles of industry: reducing risk and increasing speed. Within the system, there is an opportunity for intentional disruption by creating productive digital risk.

Digital risk

Certainty and absolute efficiency is the desire of industrialization – not of craft. Material craft, regardless of media, is inherently inefficient, but it is within this 'lost-time' where the material is shaped and the craftsperson is given the space to meditate with their movements, actions and errors. It would be pious to rebuke McCullough and dematerialized craft by simply stating that you cannot have a practiced craft without material. It would be short-sighted to believe that craft cannot exist with a keystroke toggle to remove error; only true craft is governed by material resistance. It is not the intent of this essay to claim one practice more virtuous, but to situate itself inside of a productive tug-of-war between the digital, the human and the material.

Digital risk is the wilful action of a designer to allow him or herself to fail due to a material behaviour and human errors while fully engaging in digital applications. This action is not intended to be less productive, but to allow for productive learning that eliminates useless iterations. To embrace digital risk is to allow the designer to speed up by slowing down. To make errors in the present is to avoid larger errors in the future and to embrace the truth that only material can provide.

Anyone who has failed and been punished by a table saw or an angle grinder can attest that errors are not easily undone. In most cases, this failure is due to material resistance. The craftsperson is pushing the tool through material and it resists; if a blade is not held true it resists. No matter the error, the material is the final judge. Material and our desire to shape it provides conflict, and the skilful craftsperson has the ability to work the material with the least resistance. This leads to the common comment 'they make it look easy'. It is not; it is earned skill that turns material resistance into an artefact of beauty. Material resistance is the communicator of failure in traditional crafts and this lesson is transmitted to the craftsperson independently with consequences. The craftsperson does not decide they are wrong and undo or redo, they are told they have made an error and they pay in lost-time, material and sometimes injury. This consequence is absent from virtual simulations. The digital designer can make quick and fluid decisions about proportion, scale, and form, but this fluidity does not extend to judgments regarding material, density, fit and finish. This leaves the digital craftsperson to speculate, and in some cases guess, how the material will respond. To avoid material and assembly errors, many craftspeople rely on case studies and abandon material experimentation, relying on manufactured tectonics as opposed to a haptic crafting of materials. The identified shortcomings of the digital processes provide a territory to investigate digital risk and its potential benefits.

Case study: digital ceramic bricks

The desire to experiment both with material risk and digital control motivated the makeLab – the digital fabrication laboratory at Lawrence Technological University – to create a tool that embraced the two. The lab proposed and built a 3D printer to design and fabricate custom ceramic masonry units. The 3D printer's design intentionally allows risk; it embraces failure and negates standardization. The digital tool is based on an open-source Delta 3D printer configured to print ceramic clay. The principle that guided the tool's design was to have distinct tasks relegated to the computer and the human hand. This was accomplished first by using the printer's ability to control movement of the ceramic extrusion in the x, y and z directions. Therefore, the computer was used to virtually shape the proposed artefact and to accurately move the extruder along a path directed by G-code output. The hand of the craftsperson controls the material and is at risk while operating the tool. Before printing, the clay must be mixed to the correct viscosity (figure 2). The mix cannot be explained through simple mixing instructions and the craftsperson must consider multiple factors. Along with the composition of the clay, the volume of the print, how long the clay will be in the extruder, and height of the artefact all factor into finding the correct viscosity. After practice and failure, the viscosity can be judged with tacit knowledge where the craftsperson knows and feels 'when it is ready'. The clay is pushed through a chamber using compressed air where the air pressure determines the flow rate of the clay. The flow must be synchronized with the speed of the x, y, z movement of the printer. The air pressure also cannot be calibrated with a standard measurement; it must be monitored by the craftsperson who slowly adjusts the pressure responding to dry or sticky portions of the clay batch. If the pressure is too high the stratifications of clay will press over the edge of the layer below, too low and the clay will not flow.

Figure 2: Mixing clay prior to printing

The craftsperson in control of the printer is not simply an operator of a computer tool, but is rather in a risky negotiation between the material and the digital. The digital tool exhausts its users; they move between mixing clay to hours of closely monitoring the clay distribution. All of this is done with a high likelihood of failure. When the craftsperson is in sync with the tool, the clay runs smooth and the craftsperson is able achieve a valuable result. The imperfections of the produced artefact are only evidence of risk (figure 3).

Figure 2: Early attempts at hand control of clay flow rate

The first phase of the study was to determine material, geometrical and scale limits of the printer. To better understand the relationship between skill, risk and the craftsperson's interactions with the tool, one graduate student was assigned to the task. A multitude of prints began that initially all ended in failure with uncertainty of cause. Each print was methodically documented with evaluations by the student (figure 4). As the student's skill improved, the prints become more consistent and lower levels of failure were achieved. This allowed for higher risk prints to find limits of geometry and scale, in many cases printing until failure was the objective (figure 5). The student reflected: 'The larger the print is, the more control of the process you need to have to achieve a successful print'[17] (Knauss, 2017). Over time, a knowledge of printer limits, material understanding, and the skill of the student were aligned. This allowed for a design challenge to test the process of digital risk and its relevance and usefulness in the design of custom masonry units.

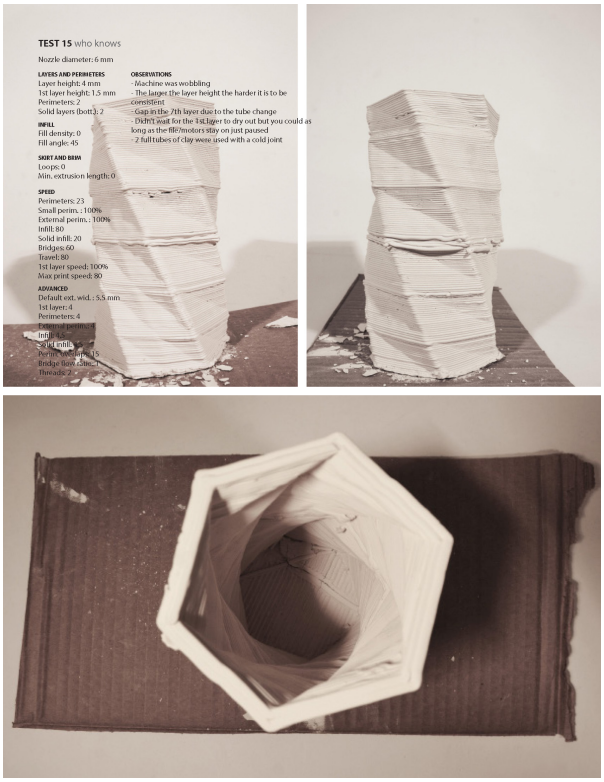

Figure 4: Test documentation

Figure 3: Printing to failure

To test the skill of the student and the tool, a study was created to design and print twenty four unique masonry units (figure 6). Each unit would need to align with its adjoining unit, and each was shaped using the geometrical limits tested in prior experiments. The collection of units shows remarkable consistency, yet on closer inspection the variable of hand control is revealed (figure 7). Most significantly, the study shows that tool behaviour can be learned and responded to accordingly, thus managing risk to reap its benefits without total loss of productivity. As a result, many things that were considered a risk when the student first began the case study were no longer a factor due to the student's mastery of the processes.

It became clear that the student had achieved mastery of the tool and had become a craftsperson yielding consistent, exceptional outcomes. When asked what the student learned as a result of this process, the student answered, ‘craft.’

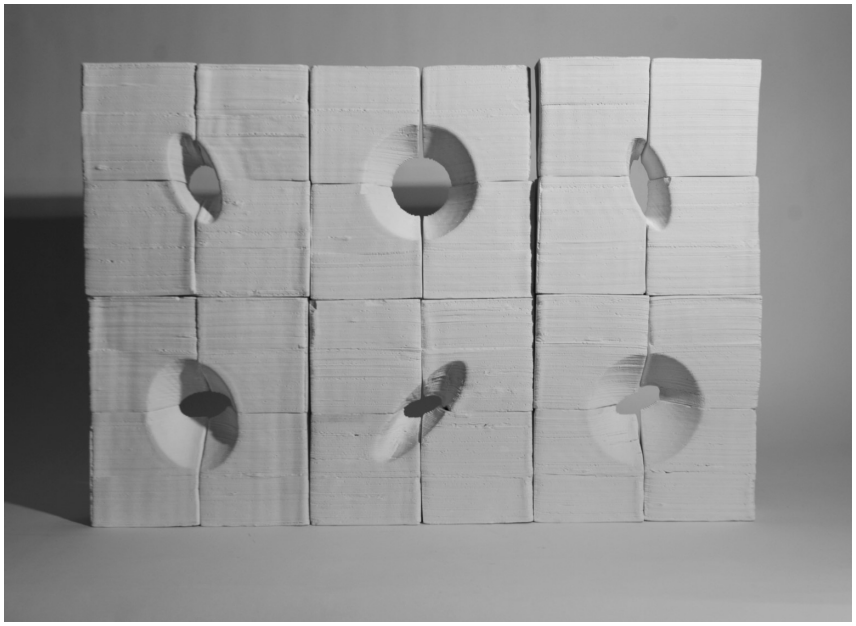

Figure 4: Printed collection of masonry units

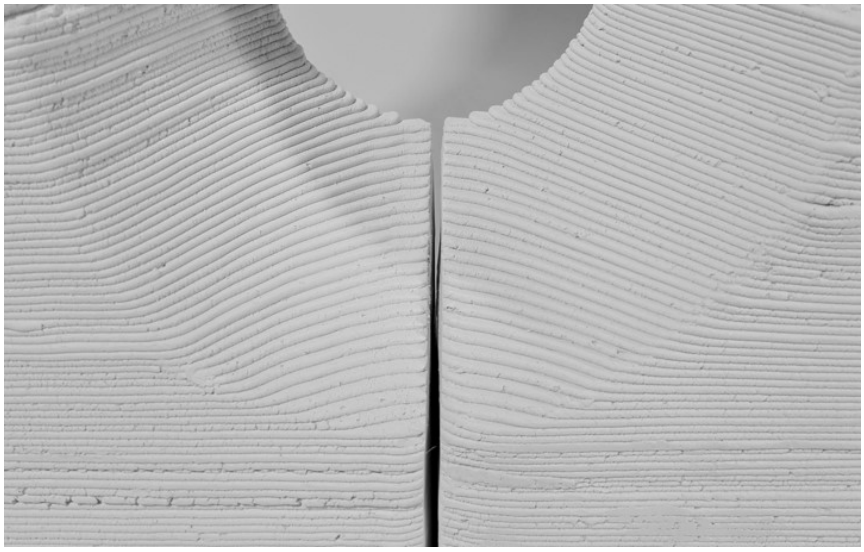

Figure 5: Consistent outcomes achieved

Conclusion

It is important to reflect on the premise of this study and to reinforce that it is understood there is an easier way. The study participants know, and have access to, tools that could print a perfect ceramic unit every time without fail given adequate preparation. Without fully understanding the study, one might offer suggestions of clay augers or other extrusion technology that would supplant the human hand and allow for greater control. This is understood, but purposely not used to create the experiment necessary to test the value of risk when using digital tools.

The findings of this study show that there is promise in the value of risk when aligning the human hand strategically with a digital tool. However, this study was only the first phase in understanding this complex phenomenon. Despite the outcome of the masonry unit collection, the project struggled with tool consistency. It is important to note that the tool was designed with human interaction intended but not fully understood. Currently, the research has evolved and a new 3D printer has been designed and built that includes more control by the user. Features such as a foot pedal that controls an air bleed valve gives further control to the craftsperson. Stronger x, y and z axis construction reduced vibration and increased the consistency of the dimensional direction of the extruder. By enhancing the tools consistency and the nuance of the human controls, early data show that failure is rare, and when it does occur it is most likely human. Most significantly, the new printer and the craftsperson's control over its performance is allowing for the design of unique objects and axial movements that allow for a fluid response by the craftsperson. This is allowing for the creation of outcomes that are unique and represent the synthesis of the digital and the human.

To some this may seem a pointless task; after all, you can manufacture similar objects at a low cost. This perspective is framed with industrialized logic and warrants our attention. As digital tools continue to proliferate so do the standardization and globalization of our design outcomes. In our profession, it will become harder, if not impossible, to design authentically within our culture, time and place. Digital modelling and simulation has given the digital designer a freedom, one that can seduce our visual senses at the cost of all others that make us human. Let us all take some lost-time to think and meditate on our failures – not to be too quick to undo – and to embrace the risk of creating something of value.

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