REAL MATERIAL ETHEREAL

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Carter Holt Harvey Woodproducts Research House: a collaboration between student design – makers and a local building contractor

Abstract

Carter Holt Harvey Research House was a summer – school programme designed for architectural students to digitally design and fabricate a small dwelling in conjunction with construction professionals. The design required students to formulate a digitally sponsored construction system whereby small to medium enterprise (SME) construction contractors can collaboratively contribute to the assembly process. In turn, the student's autonomy was preserved, and regulatory approvals could be gained. The method required the students to use 3D modelling software around the parameters of defined construction materials, using digitally controlled, and standard construction tools, to create prefabricated panels ready for simple and fast assembly. The process is an experiment in synchronizing the rhythms of human and machine capabilities, in an effort to cause efficient and accurate constructions. The findings showcase that the students faced challenges in organizational planning, from the arrangement of production line technique, to timing and speed of site assembly. The students learned that their design details and envisioned fabrication process did not always meet expectations. To ensure for a successful outcome, the students were required to learn how to improvise and amend the fabrication process. The contribution of the research found that the skills and instincts held by contractors and engineers is difficult to translate to digital concepts, until experience with material manipulation can be learned. The possible outcome may be amendments to the integration and strategies of digital planning.

Introduction

Advances in personal computing are challenging the social protocols in the way the designer may participate in making activities. Digital technology is changing the way humanity lives and conducts business. Today, this is generally recognised as the third industrial revolution. There are commentators who argue that the third revolution alternatively took place in the 1960s with the advent of accessible computers, and the fourth revolution in fact begun at the turn of the twenty-first century with the integration of the internet, smaller and more powerful devices and machine learning.[1] Whether we are experiencing the third or fourth revolution, the founder of MIT's Centre for Bits and Atoms, Neil Gershenfeld,[2] suggests that the traditional models of business and education are being challenged through the speed and availability that allows anyone to take part in producing tangible objects, or obtaining information on-demand, wherever and whenever they want.

1.2 Building in the backyard.

Engaging with technological innovation is no longer considered an overly expensive exercise. Current trends point to a future whereby local – backyard, or suburban enterprise can thrive alongside larger factory production. Small groups or individuals can set up advanced design workshops armed with CNC routers, robotic arms, 3D printers, laser cutters, and the more conventional hand-held tools.[3]

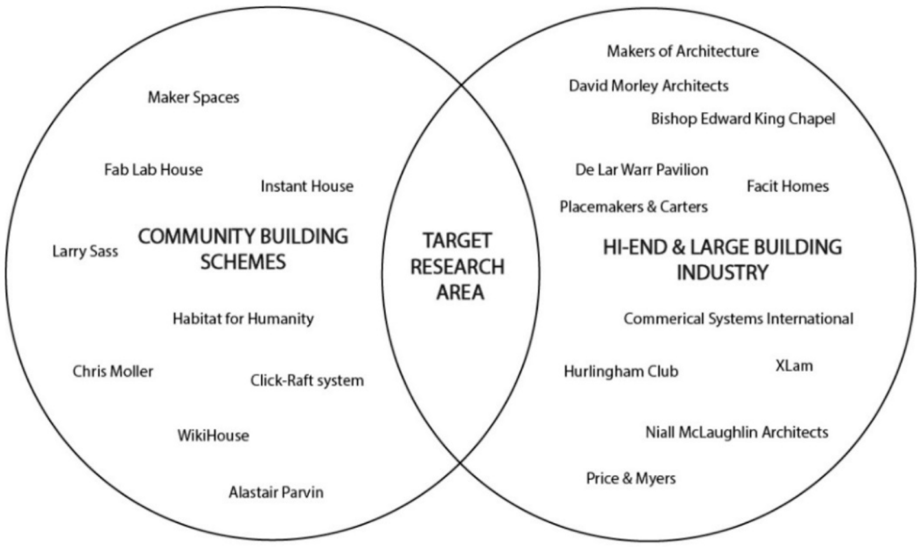
Various community-oriented maker-spaces and commercially-run digital fabrication services now cater to individuals with varying backgrounds and levels of experience. Online resources and communities can allow anyone to develop the necessary digital skills and expertise to converse with automated machines without any associated cost. This concept of sharing knowledge is not new: Walter Segal's self-build system is a testament to this, existing well before online open-source initiatives became commonplace.[4]

Globally, there are various design innovators investigate DIY digital building, such as Alister Parvin Wikihouse system. In the United States, Innovator Larry Sass from the Massachusetts Institute of Technology explored how digital technologies and plywood could be used to solve community housing problems through digital fabrication and social enterprise. In 2008, Sass presented *The Instant House* at the 'HomeDelivery' exhibit at the Museum of Modern Art (MoMA) in New York. The results of the research identified that plywood is an extremely dynamic material with the ability to be an effective medium for the production of easy-to-handle structural and ornamental two-dimensional components. This ethos contributes to the instant house being a simple low-cost proposition that can be constructed by community volunteers who have little access to building tools.[5] The design and detailing of the Instant House is purely an exercise to investigate what is possible to resolve a housing problem.

The UK-based Facit homes is an example of a small group of skilled professionals that produces bespoke modular plywood homes using basic CNC technology.[6] Facit systems is based on assembling customised two-dimensional CNC plywood components that come together to form three-dimensional modular panels – or 'chassis' – that act like oversized Lego blocks. Once these panels are put together to form the structural core of the building it is made watertight using conventional building methods. What is significant in this system is that it humanises digital fabrication, by allowing non-skilled workers to participate and get their hands dirty, as seen in the construction of their Hertfordshire House. To ensure this can take place, Facit has developed its own mobile factory, where a CNC router is encased in a shipping container, then manufacturing and assembly takes place on-site.[7]

Locally, New Zealand hosts a variety of individuals developing Plywood centric CNC housing systems. The most famous, Click-Raft, has been developed by architect Chris Moller. Architect and senior lecturer Guy Marriage, interestingly, has imbedded a Click-Raft system to create floor and ceiling panels for his 'Bach on the Bay' dwelling.[8] The findings suggest that when just the material cost is considered, the Click-Raft system is more expensive. Only when volunteer labour and aesthetic appearance has been measured, is the Click-Raft a worthwhile investment.[9] The Wellington-based design-build firm Makers of Architecture, have taken a capitalist approach, and utilised digital fabrication technology to develop innovative construction systems with materials such as CLT and Plywood, for the production of bespoke architecture.[10] Unlike Facit Homes, Makers have tapped into both local backyard and large factory production to create a hybrid profit-driven approach.

The target research area for the Carter Holt Harvey (CHH) Research House is, therefore, seeking to find the midground between the community opensource architecture and the bespoke. It is therefore important to find a balance between conventional and digital novelty.



Automation in architecture and the target research area.

1.2 Research Question.

The research question "How can students use simple digital fabrication technology – such as CNC routers – add value to conventional timber frame construction in New Zealand?" guided the CHH Research House programme. The industry material sponsors, CHH, has worked with Unitec Institute of Technology over the past three years to develop the systems to work with both building professionals and their product range that consists of plywood rigid air barrier systems, plywood internal lining systems and Laminated Veneer Lumber (LVL) products.

2.0 Design Method

The design method applied to the research predominantly centres around the use of digital fabrication tools. There was an expectation that efforts by the students would be directed toward building an experimental housing prototype.[11] A qualitative approach, therefore, is best suited to provide useful information that is related to activities and attributes[12] that require human-based non-quantifiable ideas, judgements and processes. The process is purely iterative and required CHH to work with students over several years to develop a tangible system. The process of designing the CHH research house was by no means linear, but an iterative process where design concepts did not follow a pre-determined given order. Instead students prototyped as many times possible to ensure quality thinking takes place. The process was seen by their research supervisors to be a useful research tool to interrogate a specific design question[13] that required both design-fabrication research to take place.

It was important that the students were guided through the design to fabrication process. The programme, therefore, involved a variety of cross-disciplinary associates such as architects, engineers and carpenters. To ensure the research project met health and safety regulations, the team was split into two core groupings. The first, the design team, comprised of the architect, engineer, architectural researchers and students. The design team's responsibility was to design and prefabricate modular panels at Unitec's Architecture workshop. The second, the construction team, was composed of trade professionals and was tasked with the assembly of the prefabricated panels, and the installation of conventional foundations, cladding, electrical, and plumbing systems employed in the research house.

Due to time constraints, the students were required to relinquish aspects of regulatory design to the architect and engineer. The students, however, were solely responsible for the formulating and designing the CADCAM shop drawings (Computer aided design / computer aided manufacture) for manufacture and designing the kitchen and internal fit-out. The foundations, transportation of the panels, onsite assembly of the panels and cladding, were left to contractors due to regulatory policy.

3.0 Findings

The learning outcomes of the research can be divided into three major aspects. The first is analysis and development from previous iterations. The second, to understand that the assembly process of the CHH Research House and the third is to reduce and re-use waste.

3.1 Previous Iterations

The development of the CHH plywood and LVL research house was a collaboration between researchers and students from the two Auckland architecture schools – Unitec Institute of Technology and the University of Auckland. The original iteration dubbed 'EDFAB: Eco-Digital-Fabrication' investigated how a layperson may be able to assemble digitally fabricated CNC components to create a compliant housing structure. The intention of the project was to remove some of the stigmas surrounding digital prefabrication. EDFAB does this by investigating ways that technology can enhance labour, design process, productivity, organization, and quality – in a way that avoids estranging from the use of construction professionals, and off-the-shelf materials. The initial research allowed for a 10sqm EDFAB 'plywood centric' proof of concept house to be built at the 2014 Whau Arts Festival. In 2015 and 2017, students designed two subsequent 10sqm plywood and LVL iterations named EDFAB 2.0 and 'Living Pod' (or EDFAB 3.0) respectively. These two iterations sought to reduce waste, simplify design complexities, and obtain industry feedback within the design process. The iterations worked off of a premise of CNC milling plywood components to create modular boxes. LVL portal frames were added, to provide much-needed structure and flexibility to the construction system. The most recent proof of concept is the 65sqm occupied dwelling, the CHH Research House (EDFAB 4.0), sort to resolve deficiency in the assembly process found in the previous iterations. This was done by reducing the dependence on CNC plywood components and investing assembly table jigs. The final construction system designed for the CHH Research house discarded the portal frame design, for a hand-cut LVL timber-framed and CNC plywood lined panel.

Assembly Process

To ensure the assembly process was efficient, the students designed a tabletop jig to assemble the modular plywood and LVL panels. To ensure the jig was accurate, all of its components were CNC milled. The assembly process highlighted the requirement for the layout of the workshop space to be thoughtfully and precisely set up. The assembly of the prefabricated panels on their respective jigs, for example, was hindered by having uneven concrete floors. When the problem was not accounted for, the respective panels were assembled asymmetrically and were misaligned. Although this discrepancy was a minor variation, its overall effect compromised the alignment of final panels within the structure.

Once the problem was identified, the students used laser levels to align jigs and storage surfaces, ensuring both the assembly and storage processes were well managed. Ultimately, this technique reduced error during the assembly process.

To speed up CNC milling of plywood sheets, the students developed a three-step CNC milling technique to cut multiple layers of plywood at one given time. The first step required multiple sheets of plywood to be firstly screwed on to the CNC bed. The second step was to use the CNC machine to pre-dill all the holes into the plywood sheets required for assembly. The third step was to transfer the screws to the pre-drill holes, to allow the final perimeter milling to take place. The process not only improved efficiency but also increased the number of ply sheets that could be milled. In order to reduce the number of time electricians and plumbers needed to be onsite, predetermined holes for wiring and plumbing were milled into the plywood during the CNC process. To further reduce the time of the electrician, students embedded 'draw-wires' during the assembly process, to enable the installation of the electrical-wires with the final finished internal layer already affixed.

Despite the digital control of precision machinery, the engineered timber elements were affected by moisture within the workshop. This lead to a large selection of LVL framing to lose its dimensional stability. The tolerance had to be processed and reduced is size, with the help of a thicknesser-planer. The plywood elements bore similar issues, at times being difficult to hide the material inconsistency. This resulted in the students chamfering the edges to each individual plywood panel. In some cases, the builders had to remove the plywood elements to ensure alignment and aesthetics were not compromised, by using an alternative panel-to-panel fixing method.

Reducing waste

To reduce waste, all offcuts were processed and re-used. Digital technology can provide the opportunity for all the large plywood offcuts to be catalogued and re-used elsewhere in the house. Everything from the kitchen cabinetry, architraves, skirtings and interior doors were constructed from leftover LVL and plywood offcuts. The downside to this approach is that it requires a large investment of storage for the excess material, and in labour to process the material to make it suitable for use.

Conclusions

The fabrication of the CHH Research House proof of concept raises many questions on the future of prefabrication from a technological, and a professional standpoint. Some of the findings may be used as a platform for research into designs of greater complexity, or different materials and method. Potential research may also be done to include more complex automated tools – such as using a robotic process to cut LVL, or roll forming technology for steel framing automation.

The students involved in the project discovered that there is a great deal of planning, engineering, and pre-construction of a building that cannot be automated. The learned instincts and skills of engineers and carpenters involved with the project provided questions on how to integrate or develop an organic 'feel' into the approach to software use.

Endnotes

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Laser-levelling work and storage spaces

Draw-wires for electrician


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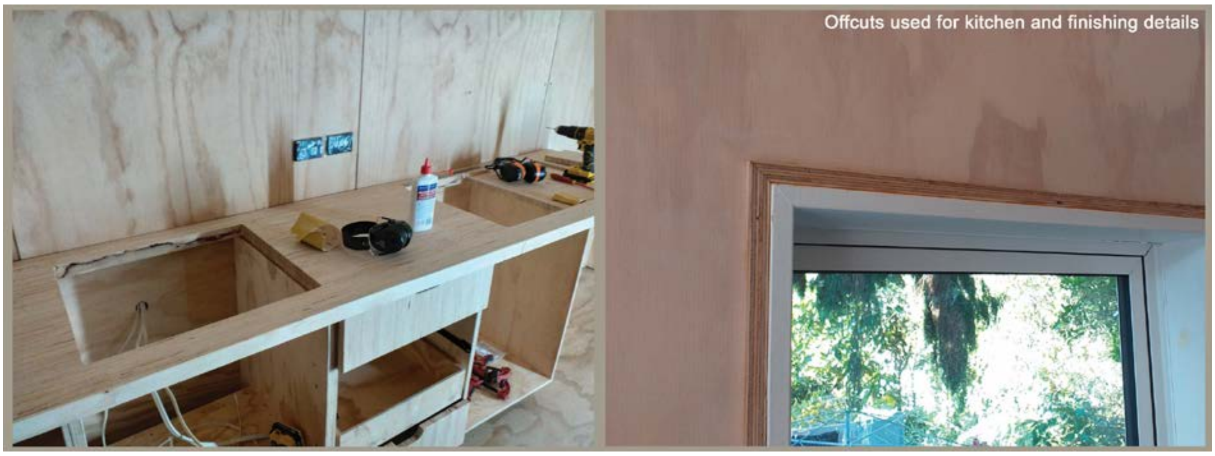
Offcuts used for kitchen and finishing details