REAL MATERIAL ETHEREAL

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Plywood and LVL Research House

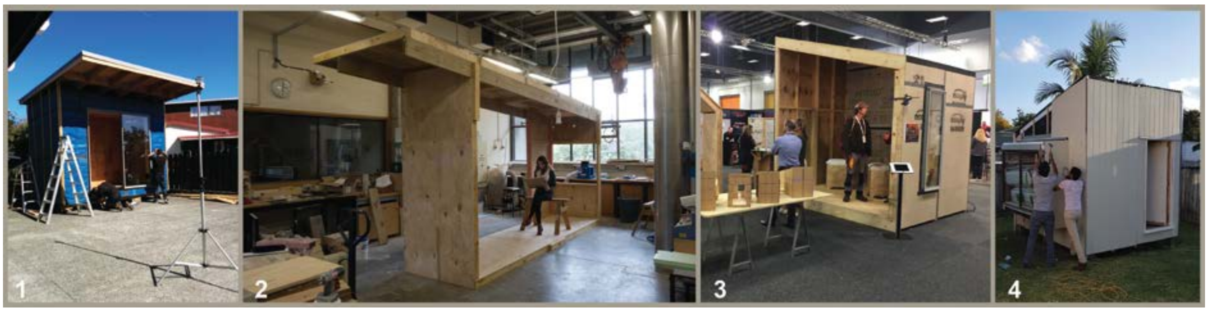
Abstract

The premise behind creating the plywood and LVL research was to investigate how architectural design students could 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 assembly process. The method required the students to base designs in 3D modelling software, around the parameters of standard construction products. Designs were then fabricated by students in a campus workshop under the guidance of certified experts. Through this, hands-on lessons were learned relative to fabrication and site timeframes, physical tolerances of materials and fixings, assembly line mentality, and how to improvise systems to achieve required results. The contribution to knowledge found that when building in the virtual realm for the intent of building in the physical, the knowledge, instincts and skills of contractors and engineers plays a vital role in having a holistic approach to design.

Introduction

The production of the Plywood and LVL research house was a collaboration between researchers and students from the two Auckland architecture schools – Unitec Institute of Technology and University of Auckland. The original research presented within this paper steams from the work completed by the University of Auckland Transforming Cities thematic research initiative, 'EDFAB: Eco Digital Fabrication. The purpose of the EDFAB initiative was to investigate how a layperson may be able to assemble the digital fabricated CNC components to create a housing structure. The intention of EDFAB is to remove some of the stigmas surrounding prefabrication, such as the use of technology like CNCs, robots and laser cutters being too complicated, or that prefab is sub-standard to current building practice. EDFAB does this by investigating ways technology can enhance labor, design process, productivity, organization, and quality - in a way that avoids estranging from the use of construction professionals, and standard materials.

The research allowed for a 10sqm EDFAB 1.0 'plywood centric' proof of concept house to be built at the 2014 Whau Arts Festival. In 2015, researchers teamed up with students at Unitec Institute of Technology, to subsequently an array of full-scale 10sqm plywood and LVL prototypes that were displayed at architecture and construction expos. In total, it led to two iterations, in which is sort to reduce waste, simplify design complexities and obtain industry feedback within the design process. The most recent proof of concept, EDFAB 4.0 to be built by students and researchers was the 65sqm dwelling that is intended for long term use.



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EDFAB Iterations. 1 – EDFAB 1.0 case-study structure for Altus Windows Systems. 2 - EDFAB 2.0 prototype development of #1, incorporating LVL beams. 3 – EDFAB 3.0 exhibit for Prefab NZ. 4 – EDFAB 3.5 test sleep-out for private residence.

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EDFAB 4.0 near completion.

Cross-disciplinary Research

The design and fabrication of the EDFAB 4.0 required a variety of cross-disciplinary stakeholders. 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 prefabricated modular panels at Unitec's Architecture workshop. The second, the construction team, was composed of onsite building professionals and was tasked with the assembly of the prefabricated panels, and the installation of conventional foundations, cladding and plumbing systems employed in the research house.

Designer-maker

The term designer-maker refers to the process of an individual – or group – who both design and build their product.[3] The relationship between act of design and actions of making, is it requires the transfer of conceptual data to the processing of physical material. The advantage of a designer engaging in manufacture, can result in a stream process between the idea, and the built product. The problem that faces design-makers when working with software, is that there is an inability for design programs to incorporate material tolerances and properties. This left the Designer, to make up for this when creating physical artefacts within the virtual world. This requires a design-maker to attain the skill of a builder to ensure quality outcomes are produced.[4]

Building in your backyard.

Research into EDFAB, investigates how everyday designer-makers can work with simple materials and automated technologies to create housing, or other architectural products. In essence, the research adopts the principles of the 'Third industrial Revolution', where the technological innovations, can allow for individuals or groups to set up their own personal 'backyard', or 'suburban' advanced workshop.[5] These spaces can be equipped with CNC routers, robotic arms, 3D printers, laser cutters, and more conventional building tools.

Methodology – Design Method

The design method employed required the students to ask themselves the following questions when developing the EDFAB 4.0 research:

1. To understand their contribution to the iterative EDFAB research.
2. To investigate, pursue and dabble with fabrication technology at their disposal.

3. To distinguish their role within the entire design-build process.

Students contribution

The students involved in EDFAB 4.0 firstly was required to study and understand the previous EDFAB iterations. For the most part, it required the students to talk to existing EDFAB researchers and industry advisors. New challenges, specifically around untested elements required the students to seek advice from new alternative sources.
It was important to the students to engage with the act of prototyping as it enabled them to calibrate the limitations of the fabrication machinery, and the selected plywood and LVL materials.

Digital Fabrication Technology

A laptop computer was the most prominent machine the students engaged with. The students found that it allowed for; design development with CAD software, communication between different stakeholders, organising fabrication activity, and to program and control the CNC milling of Plywood. To ensure time lines were met, the students decided that only plywood sheeting and the assembly jigs would be cut on the CNC router. All other aspects were guided by non-digital technology, compound saws were used to cut LVL components to length and assembly was completed by hand.

Division of Labour

The research house required collaboration between industry professionals - such as architect, engineers and carpenters - and architectural students. 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 shop drawing for manufacture, and designing the kitchen and the internal fit-out. In turn, this allowed the students to be in total control of all offsite fabrication and onsite installation activities. To ensure there was quality control, the engineer was present and responsible for authenticating and scrutinizing each panel that was manufactured, and adhered to the approved documents required by regulatory authority. The foundations, transportation of the panels, onsite assembly the panels and cladding were left to contractors due to regulatory and intuitional policy. Throughout the build, industry professionals from Carter Holt Harvey, Holdfast, and Resene, were on hand to give advice on their product application and installation.

Findings

The learning outcomes of the research can be divided into three major aspects. The first, is analysis and development from previous EDFAB iterations. The second, to measure tolerance and accountability of the fabrication space, and the third is to reduce and re-use waste.

Learning from the past

The student's study into the pervious iterations highlighted a deficiency in the assembly process. In turn, the development of an assembly table jig was devised to aid them to assemble the components that made up a modular panel. To ensure the Jig was accurate, all the components for the assembly jig were CNC milled. To speed up CNC milling of plywood sheets, the students developed a CNC milling technique to cut multiple layers of plywood at one given time. The process was development to an approach to CNC mill thin dimensionally unstable plywood from the EDFAB 3.0 project.

The students also learnt that they had to consider future onsite actions of other trades people, such as electricians and plumbers. Their action lead to designing redundancies within their shop drawings to allow for predetermined holes for wiring and plumbing installation. The use of 'draw-wires', for example, will enable the electrician to install wires with the final finished internal layer already affixed.

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Installing ‘draw wires’, enable electrician to pull cables up once panels were erected.

Measure of tolerance and accountability of fabrication space

The assembly process highlighted the requirement for the layout of the workshop space to be thoughtfully and precisely setup. 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 small in number, it overall affects compromised the alignment of final panels within the structure. Once the problem was identified, the students used of laser levels to align jigs and storage surfaces, ensuring both the assembly and storage processes were well managed. Ultimately, this technique reduced error and discrepancy during the assembly process.

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Using laser level and 0.5mm malthoid tape to ‘pack’ support elements.

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.

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Students using thicknesser-planer to reduce LVL expansion.

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Discrepancies in plywood dimensions.

The plywood elements bore similar issues, at times being simply too difficult to hide the material inconstancy. This resulted in the students chamfering the edges to each individual plywood panel (see image below). 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.

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Edge Chamfering of Plywood to alleviate plywood issues – resulted in unique design feature.

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 (image…) 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 desirable.

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Using waste LVL and plywood to construct kitchen cabinetry and detail elements.

Conclusions

The fabrication of the EDFAB 4.0 proof of concept raises many questions on the future of prefabrication from a technological, and a professional standpoint. 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 training, resourcing and investment by the institutions into the students played a major factor to ensure a quality outcome was produced. The process is an experiment in synchronising 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 organisational planning, from the arrangement of production line technique, to timing and speed of site assembly. This lead to a greater understanding of how theory does not always work, how to calculate realistic timeframes, and how to improvise systems to achieve goals. The contribution to knowledge found that with the movement from a digital plan, to a true form, came the realisation that automation cannot replace the instincts and knowledge of skills held by contractors and engineers. Experiencing the physics of the literal act of building, may change the approach to digital design, perhaps even change the interface, and actions of design software, to a more organic and holistic process. Education into prefabrication requires a more holistic type of education from a designer-maker perspective. Like the African proverb – “it takes a village to raise a child,” in this instance, the collaboration of the existing knowledge of a trained few, shared to the many involved, was the crux of the success of this construction project.

Endnotes

[1] Yusef Patel, *EDFAB Structures.* Auckland, 2019

[2] Neill McCulloch, *EDFAB 4.0.* Auckland, 2019

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[4] E Krygiel, *Fabrication Architecture : Selected Reading in Digital Design and Manufacturing.* (New York: Princeton Architectural Press, 2010), 45-56.

[5] A Parvin, "Architecture (and the other 99%): Open-source Architecture and Design Commons," *Architectural Design, 83(6)* (2013): 90-95

[6] Neill McCulloch, *Draw Wires.* Auckland, 2019

[7] Neill McCulloch *Thicknesser.* Auckland, 2019

[8] Neill McCulloch *Plywood Errors.* Auckland, 2019

[9] Neill McCulloch *Edge Chamfering.* Auckland, 2019

[10] Neill McCulloch *Waste Usage.* Auckland, 2019