DEVELOPMENT OF A WOODEN ADAPTIVE ARCHITECTURAL SYSTEM: A DESIGN-BUILD APPROACH

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ABSTRACT: The design-build of a Wooden Adaptive Architectural System is part of a larger research-creation project on Adaptive Architecture (AA) [1] exploring the entire design process leading to a fully adaptable three story high 1:3/4 wooden structure. This system allows the easy manoeuvrability by the occupants of walls and floors in x, y and z directions in order to adapt the space to their environmental and functional needs. The omnidirectional mobility criteria challenged conventional building techniques and led to an innovative all-wood rigid node. Extensive prototyping using digital fabrication allowed the team to optimize the node assemblage and precision through parametric experimentation before proper production. The Wooden Adaptive Architectural System, made of 2000 prefabricated sticks measuring as little as 1 ¾” x 1 ¾” x 24” provides fully adaptive space configurations and be easily deconstructed, transported, and reassembled in totally new building shapes.

KEYWORDS: architecture, design-build, adaptability, wood, prefabrication

1 BACKGROUND

Evidence suggests that people are intrinsically active participants in buildings whereas modern architecture mistakenly speculated that people were passive actors in controlling their environment [2]. Adaptive Architecture challenges the designer to explore all possible ways to improve adaptive opportunities of the inhabitants by structural, enclosure and behavioural adaptive opportunities according to diverse environmental conditions. The design-build of the Adaptive Architectural System illustrates the importance of the notion of embodied agency at every level of architectural design to re-establish the connection between the intelligent human agent and the environment through our inherent tactile oriented thinking as suggested by Pallasmaa [3]. The exploration of an easily transformable space by human force alone called for the optimisation of a simple orthogonal system of posts and beams and moving panels acting as a rigid frame without the aid of diagonal bracing that would impede the free transformation of the space.

2 METHODS

Ancient Chinese wooden architecture proved that it is possible to design a rigid yet elastic wooden structure providing continuity and fit while allowing a complete liberty in internal partition layout. According to Sandaker et al. [4]: “the stiffness of the structural elements provides stability, although in a flexible way, just like in a branch-to-trunk tree joint.” The characteristics of the wooden joint, its strength, flexibility, toughness, and appearance thus derive from the properties of the materials and the skill of the craftsman. Timber frame structural elements, prefabricated in the craftsman studio, were traditionally preassembled, numbered, and disassembled for final manual erection on site. It is precisely this ‘building for disassembly’ attribute of timber framing, combined with digital prefabrication, which constitutes most promising research avenues in the field of sustainability. It reintroduces all the advantages of a renewable material within the efficiency of modern prefabrication techniques.

Figure 1 presents the development flow diagram of the adaptive architecture wooden rigid node. Each sub-figure represents a particular iteration of the rigid node development answering structural, functional or aesthetic considerations. The development demonstrates the necessary trade-offs and constant adaptation negotiated by the craftsman in balancing these three conditions when considering the actual fabrication of the joint. As an embodied agent animated by a multisensory sensibility and a subjective judgement, the craftsman continuously plays on three fronts to deliver an optimized artefact integrating complexity in a seemingly simple solution. Along the way several struggles occurred between the objective deterministic knowledge of the scientist and the subjective empirical intuition of the architect. Two anisotropic node prototypes were built out of two types of engineered wood,
laminated veneered lumber (LVL) and laminated stranded lumber (LSL) using state-of-the-art Computer Numerically Controlled (CNC) cutting and milling to optimise accuracy. The elastic and maximum resistances of these two types of engineered wood were tested using ASTM test protocols for their respective compression and flexion resistances, tearing threshold and hygroscopic dimensional variations. The prototyping process identified the main advantages and limitations of this prefabricated construction system. The anisotropic node option provided large horizontal surfaces that facilitate and improve security of the construction team. The physical properties of hardwood LVL, in particular its relative dimensional stability compared to softwood LVL and LSL confirm that this option was best suited for outdoor application. Moreover, the directionality of its laminated plies conveys the direction of the actual forces at stake in the assemblage. Aesthetically, LVL allows a clear reading of the individual sticks composing the assemblage and the appreciation of its precision manufacturing.

**Figure 1: Flow diagram presenting the development of the bespoke node for the purpose of Adaptive Architecture.**

### 3 RESULTS

Fabrication was divided in two major phases: workshop prefabrication and in situ assembly. The former celebrates the machine-made efficiency and precision whereas the latter focuses on human agency. Prefabrication made assembly on site efficient by providing small human-scaled elements easy to fasten. Apart from its inherent superior product quality, the prefabrication process allowed the project team to build AA on a tight schedule. The entire prefabrication took the equivalent of 10 weeks but the actual erection on site took only 4 days. Once built (fig.2), AA initiated a brand new dialogue between architecture, landscape and inhabitants. This structure allows the inhabitants to constantly reinvent this dialogue in the flesh of architecture by adapting itself seamlessly to diurnal and seasonal cycles. The actual inhabitation and transformation experimentations of AA are presented elsewhere.

**Figure 2: In-situ assembly process and the resulting fully adaptable space allowing walls, roof and floors movements in all directions.**

### 4 CONCLUSIONS

According to Stacey [5], the new digital paradigm may well represent the epitome of embodied agency in facilitating a seamless process between imagination and fabrication where thinking and feeling become contained within the process of making. The prefabrication of small, precise and easily handled building components maximised the tactile learning of the students with the reassurance that everything would fit perfectly. More than a mere multidisciplinary exercise, the design-built experience was clearly transdisciplinary and asked a good dose of adaptability from every participant. The Wooden Adaptive Architectural System developed here according to new adaptive theories on environmental comfort, could find a more practical application for remote or human shelters due to its low cost, portability, and easy erection.

### REFERENCES