HoloWall: A Windbreak Wall Using Salvaged Timber with Mixed Reality Aided Construction

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INTRODUCTION

HoloWall is a wall assembly installation that integrates mixed reality (MR) protocols with nonuniformly sized lumber to develop a customized hollow-core cross-laminated timber (HCCLT). Referencing traditional windbreak shelters in agricultural landscapes, the HoloWall is a repository of cultural traces for the emblematic and utilitarian windbreak walls that protect livestock and buildings. Constructed from locally sourced salvaged wood, the prototype sat loosely between trees in the Arts Quad at Cornell University to provide shelter from prevailing wind across the valley. The prototype develops a material language of lamination that peels away in calibrated gradients to generate structural and visual porosity.

In conjunction to MR tools, computational processes such as structural and computational fluid dynamics (CFD) analyses are introduced to reduce the material usage and generate a series of customized hollow voids. These tools optimize the organization of member placement within the wall assembly, resulting in the use of 50% non-uniform recycled wood members. Each element can be measured, cut to scale, and assembled with instructional holographic guides in the MR environment. The significance of the project lies in its resourceful development of material experimentations with mixed reality technology to make mass customization an accessible goal with local skilled and unskilled labor in a rural-urban context.

A MIXED REALITY WORKFLOW FOR NONUNIFORM WOOD MATERIAL

The project utilizes what would otherwise be considered as waste wood from a regional collapsed barn through the employment of a mixed reality environment. Mixed Reality (MR) enables the interaction between human, computer, and one's immediate place through immersion of both physical and digital interfaces (Microsoft, 2020). Using Fologram, a mixed reality software with HoloLens, a mixed reality pair of smart glasses by Microsoft, non-uniformly sized boards and customized design can be modified and assembled with the use of virtual instruction within the MR environment.

Recent investigations in MR-aided workflow has provided designers with visual protocols to manage the design and construction process. For instance, Augmented Feedback, research developed by Chinese University of Hong Kong, employed the holographic environment to fabricate and install a bamboo pavilion. The research demonstrated that holographic guidance enabled participants to better understand the design complexity and construction protocols, significantly increases productivity and achieves design accuracy by minimizing on-site measurement (Goepel, 2021). Additionally, Timber Destandardized, research developed by Cornell University's RUBI Lab, a MR-informed workflow that enabled users to intuitively configure and assemble wood structures using irregularly-shaped logs (Lok et al., 2021).

The HoloWall explores the reassembling of salvaged construction materials by hybridizing a customized wood construction methodology with emerging MR technology. The 1:1 scale prototype is intended to provide outdoor seating space where users can be sheltered from the wind and interact with surrounding context through visual openings. The custom MR framework entails the following process: 1) MR tool was utilized to process nonuniform wood boards with specific holographic guidance; 2) design parameters were used to customize the structural and visual porosity of hollow-core cross-laminated timber (HCCLT) panels; 3) MR- and augmented reality (AR)–aided fabrication and installation process.

DESIGN CONSIDERATIONS

As a site-specific installation, the project leverages the cavity as a design parameter by selectively reducing core timber to customize the void volume. Contextual considerations such as wind deflection, view interaction, and structural performance informed the panel thickness and porosity (Figure 5). In response to the site's dominant wind directions from the south and the northwest. The configuration is faceted into five segments angled 45 to 90 degrees to the west, with the

PROJECT

Figure 1. Waste wood from a local collapsed barn that were used for the project (Top) and HoloWall installed on site (Bottom).

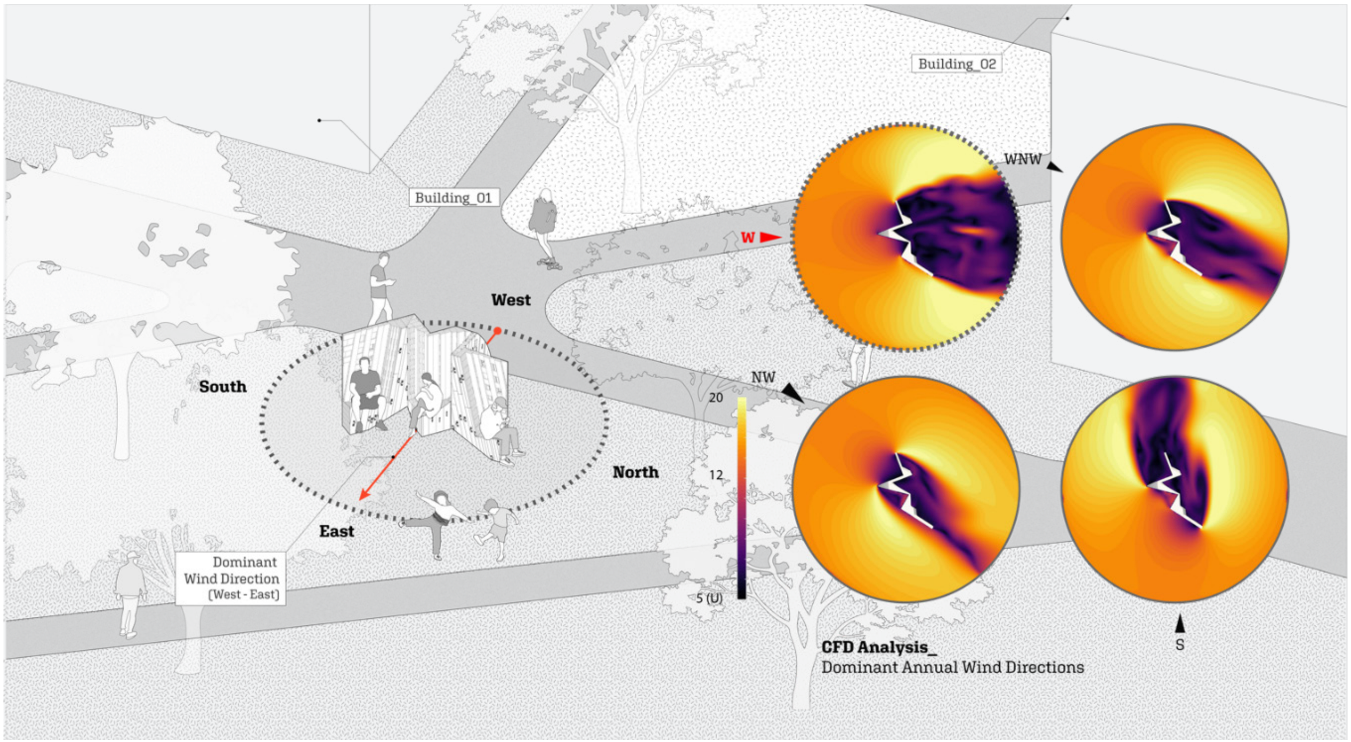

Figure 2. The Design of wall configuration and orientation in relation to CFD analysis with dominant wind directions at installation site.

seating area integrated on the east side shielded from the wind (Figure 7).

The composite layering used divertive angles and sizes of the cavity to generate unique porosity. These openings allow for air penetration and for users' visual interaction with the surroundings. The layering strategy involves the thinning and thickening of lamination to further calibrate porosity for view factors as a design consideration. The lamination thickens on the east side to incorporate seating for user interactions.

Additionally, structural performance informs the number of laminated layers. The cloud-base analytic tool Simscale is used to study the impact of porosity on structural stability. Iterative static analyses include CLT, regular HCCLT, and customized HCCLT, the simulations suggest that the omission of core elements does not significantly compromise the structural stability and further reveal that there is no apparent difference in pressure distribution between CLT and the customized HCCLT structure (Figure 8).

FABRICATION, ASSEMBLY, AND INSTALLATION

To process the salvaged wood, boards are transmitted to the MR interface with specific visual graphics that represent different material usage. Specifically, ¾"-thick standardized plywood is used for the inner layers, and nonuniform salvaged wood elements are used for the outer layers. Thin solid curves represent the wireframe of original wood geometries. Dashed lines illustrate the maximum usable material area for trimming. Red surfaces indicate trimmed portions save for reuse and green surfaces represents cut openings. The augmented boards are visualized in a linear assembly at an oblique angle to the working table (Figure 11). These holographic instructions allow users to view upcoming boards and to navigate through the labeled pieces for processing. The bespoke MR workspace allows both expert and nonexpert users to operate intuitively in real time to measure and mark physical materials with ease.

Next, the MR interface allows user to check geometric and dimensional accuracy and to laminate boards along the holographic gluing position (Figure 12). Users can shift from layer to layer by tapping the holographic up and down arrows. The inner core is coded by panel type, layer number, and element order from bottom to top for horizontal layers and left to right for vertical layers.

Finally, an AR process is used to install the structure at a predetermined orientation by aligning the virtual anchoring points with the physical steel plates (Figure 14). This workflow could be similarly applied to custom installations or construction processes. Through the HoloWall protoype, the project seeks to demonstrate the design possibilities and feasibilities of leveraging MR interface to facilitate the reuse of discarded wood wastes for customized HCCLT assembly.

Figure 3. HoloWall showcasing the thickening and thinning of layers and varied porosity.

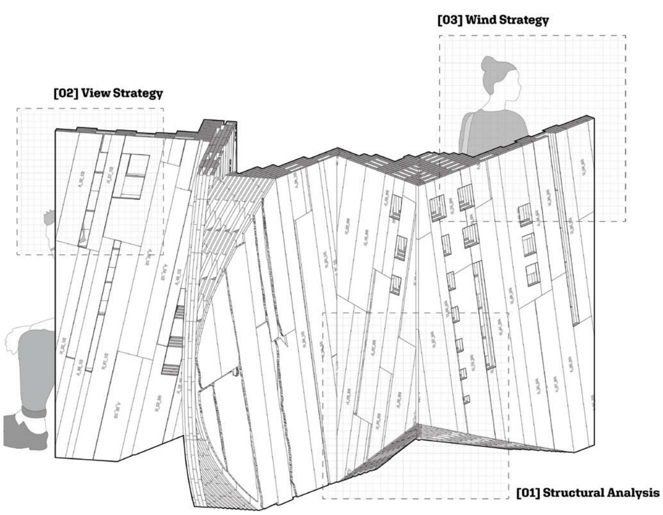

Figure 4. Design considerations: view, wind deflection, structural perforamnce, and seatings

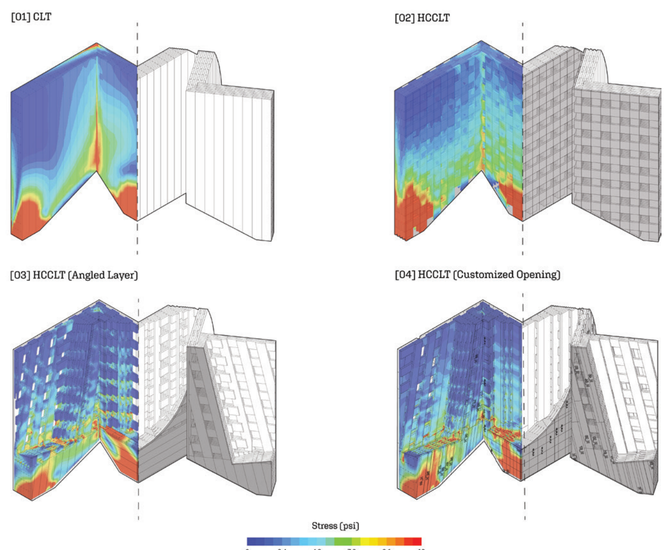

Figure 5. Structural analysis for optimizing hollowness and layer thickness for both CLT and HCCLT.

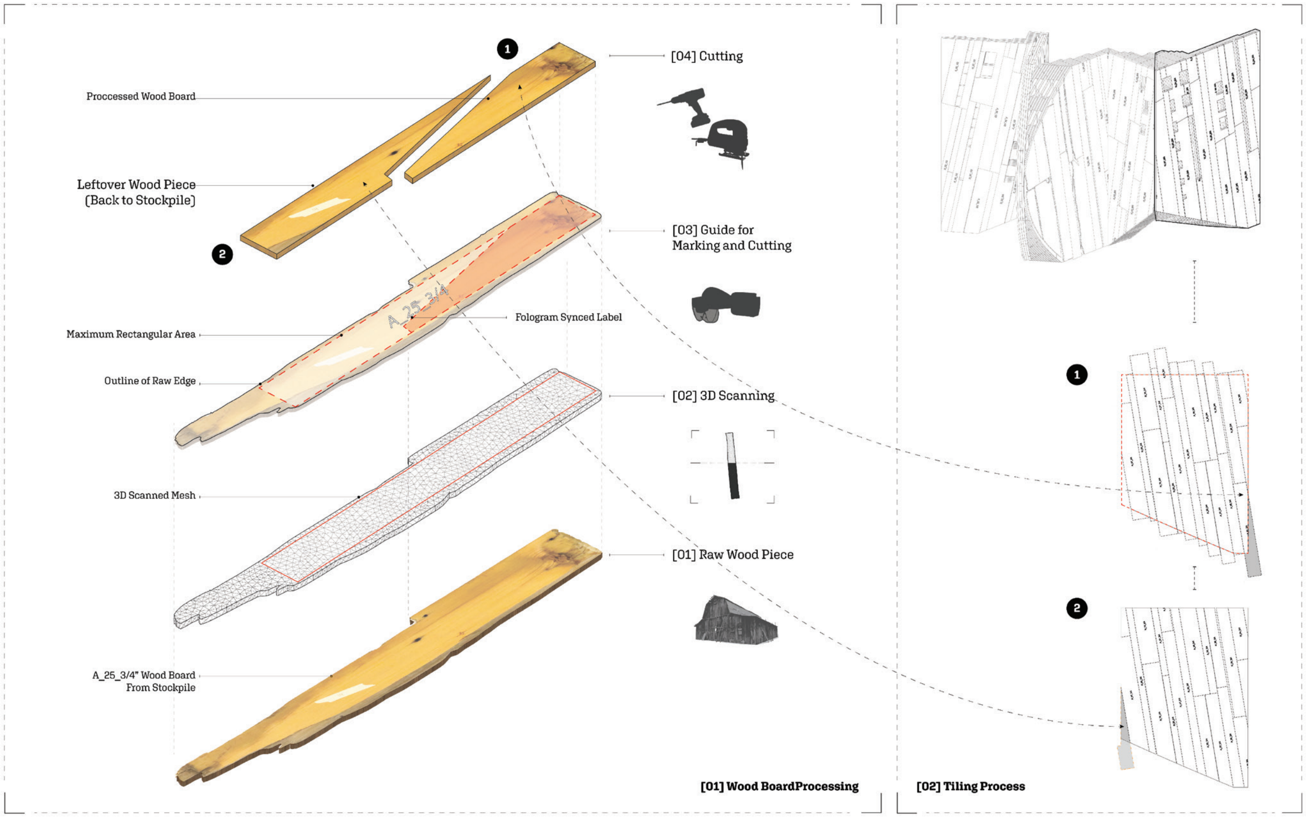

Figure 6. Mixed reality workflow for material processing and semiautomatic tiling protocol.

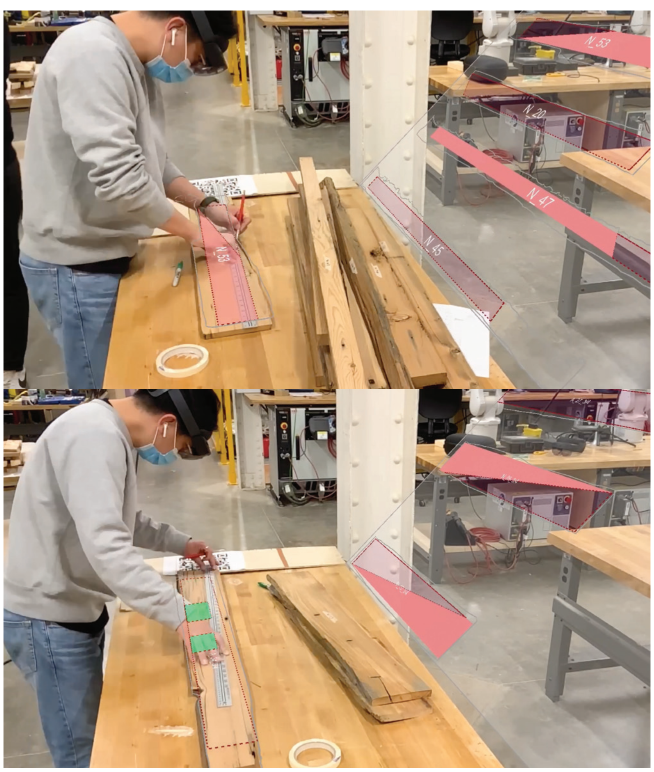

Figure 7. Mixed-reality guided marking and cutting process.

Figure 8. Mixed-reality guided laminating and gluing process.

Figure 9.Side view of HoloWall showing various degrees of porosity.

Figure 10. Close-up view of HoloWall.

ENDNOTES

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