BLOOMfontein

1 // Research Project — Academic Work

Course: ARCH 393

Location: Bloemfontein, South Africa

Date: September – December 2023

Role: Design, material research, digital modelling, visualization, prototyping

Collaborators: Andrew McDonald, Liam Engel

Instructor: David Correa

Software: Rhino, Enscape, Photoshop, Illustrator

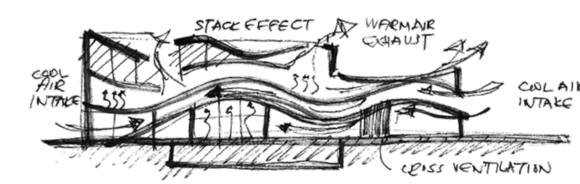
Exhibition: Riverside Projects Review 2024–2025

Awards: Architecture Student Experience Award 2025,
OAA Design Excellence in Sustainability Scholarship 2024

Publication and Presentation:
BLOOMfontein was published as a peer-reviewed paper and presented at the International Conference on Structures and Architecture (ICSA 2025) in Antwerp, Belgium, contributing to ongoing research on climate-responsive material systems.

How can architectural design effectively incorporate and test hygroscopic wood properties to address regional challenges such as power outages, while rethinking traditional ventilation methods for sustainable building practices?

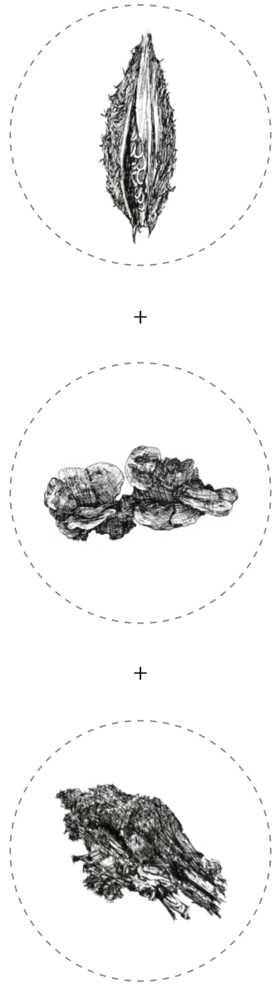
BLOOMfontein, situated in Bloemfontein, South Africa, addresses the challenge of frequent power outages through the development of a self-ventilating hygroscopic shingle system capable of regulating humidity without mechanical assistance. By studying the hygroscopic behaviour of wood and its capacity to absorb and release moisture, the project explores how natural material properties can be harnessed to achieve passive ventilation and environmental stability. A series of controlled experiments and iterative tests produced a functional prototype that demonstrated responsive movement, measurable airflow, and improved interior climate regulation. These findings suggest a scalable, low-energy approach to climate-responsive architecture in regions with limited infrastructure reliability.



This project interpolates Renzo Piano's Zentrum Paul Klee, drawing on its fluid integration of form, structure, and material as a conceptual framework. Rather than a conventional building proposal, BLOOMfontein functions as a material-driven façade study investigating how environmental feedback and natural systems can inform adaptive architectural surfaces. The research positions the building envelope as an active interface, capable of responding to climatic conditions through embedded material behaviour rather than external control, allowing performance to emerge directly from material properties. In doing so, the project emphasizes how architectural form can be shaped by material intelligence and environmental responsiveness rather than imposed through static design strategies.

This research project explores the application of biomimicry in architectural design, with a specific focus on the hygroscopic properties of plants to develop a responsive shingle system. By studying the curling behaviour of milkweed, turkey tail mushroom, and common moss, insights were gained that informed the development of a functional architectural solution. The resulting shingle system, incorporating wood veneers and plastic components, was tested in a greenhouse setting in Bloemfontein, South Africa, demonstrating its capacity to adapt to varying humidity levels.

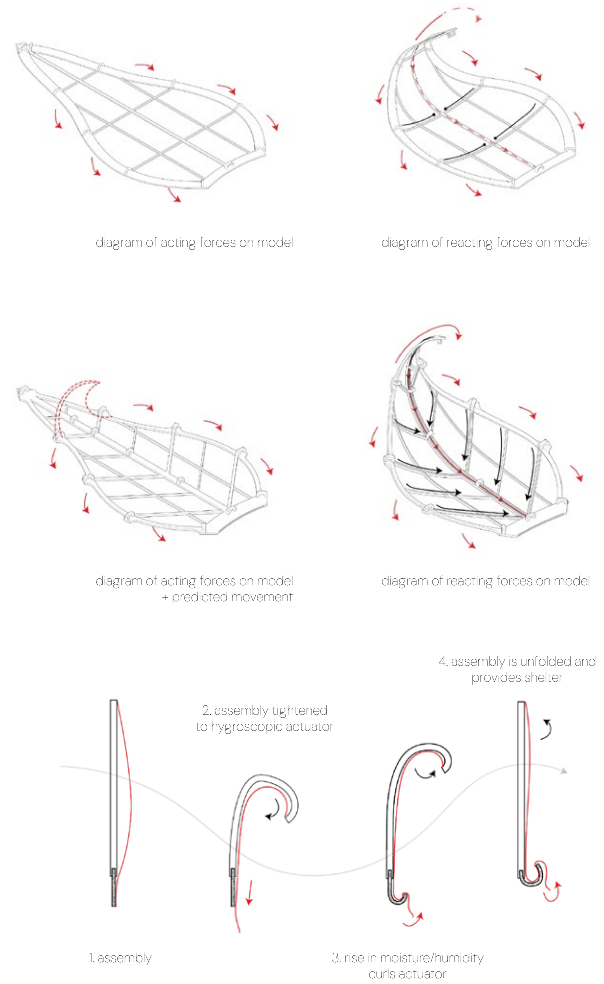
Biomimicry offers a sustainable pathway for architectural innovation by drawing from the adaptive processes and material intelligence found in nature. Building on this premise, the study investigates how the hygroscopic behaviour observed in plant species can be translated into a climate-responsive shingle system for greenhouse applications. By converting natural curling mechanisms into material form, the research explores the potential for a dynamic, self-regulating architectural envelope that responds passively to environmental change.



Microscopic Observation of Plant Structures

The investigation integrates principles from biology, material science, and architectural design to translate organic hygroscopic behaviour into a responsive architectural system. Initial studies examined the curling responses of milkweed, turkey tail mushroom, and common moss, informing early geometric and material logic. Subsequent experiments tested combinations of wood veneers, plastic elements, and laminated assemblies to replicate and amplify these natural movements.

The diagrams illustrate the acting and reacting forces within successive prototype iterations, mapping predicted deformation and directional movement as humidity increases. These force studies informed refinements in material layering, curvature, and connection points, which are demonstrated through the physical prototypes shown. Together, the drawings and models document the transition from biological observation to engineered assembly, resulting in a shingle system that exhibits measurable material responsiveness to humidity.



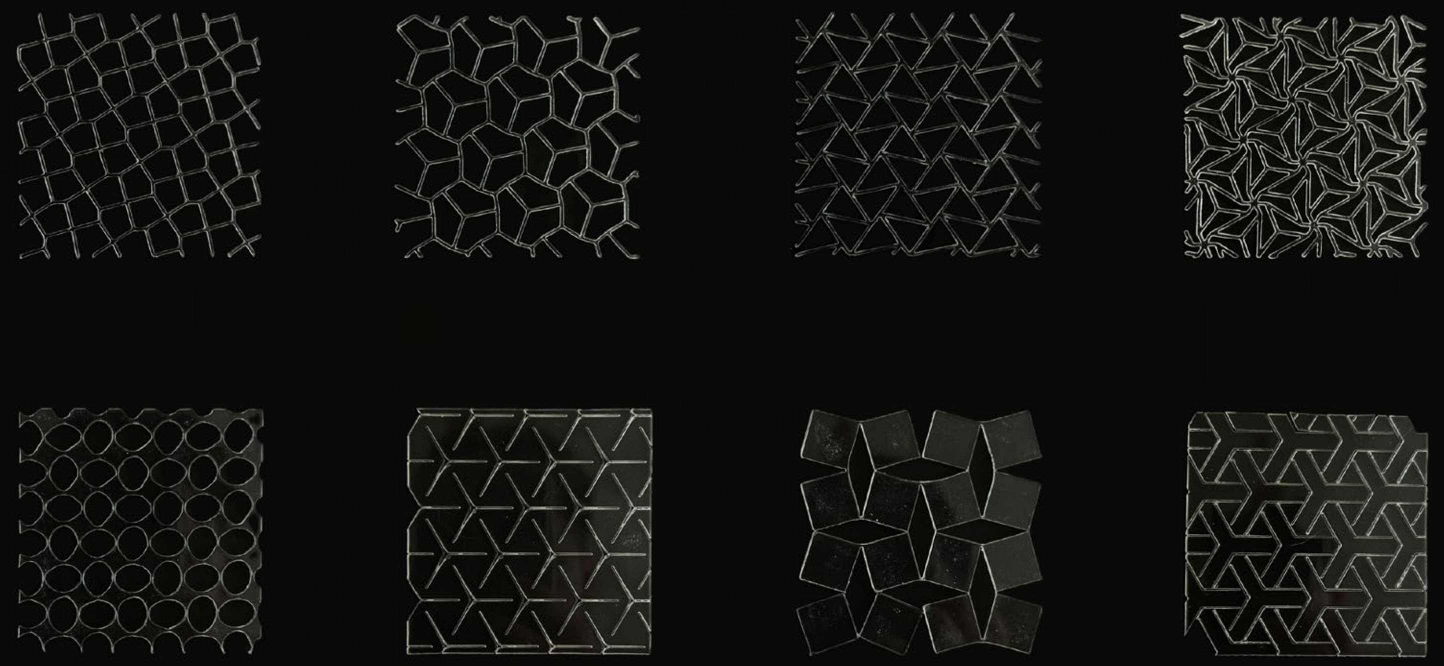
Hygroscopic Actuation

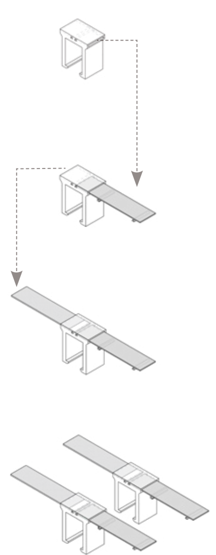
Turkey Tail Mushroom Hygroscopic Response Across Varying Temperature, Humidity, & Time

-------------- original ---------------------- 100% humidity @ 100° – 1 minute -------------- 10% humidity @ 60° – 1 minute ---

------ 10% humidity @ 60° – 2 minutes ------------- 10% humidity @ 60° – 3 minutes ------------ 10% humidity @ 60° – 5 minutes ---

Cell Pattern Fabrication – Plexiglass Prototypes



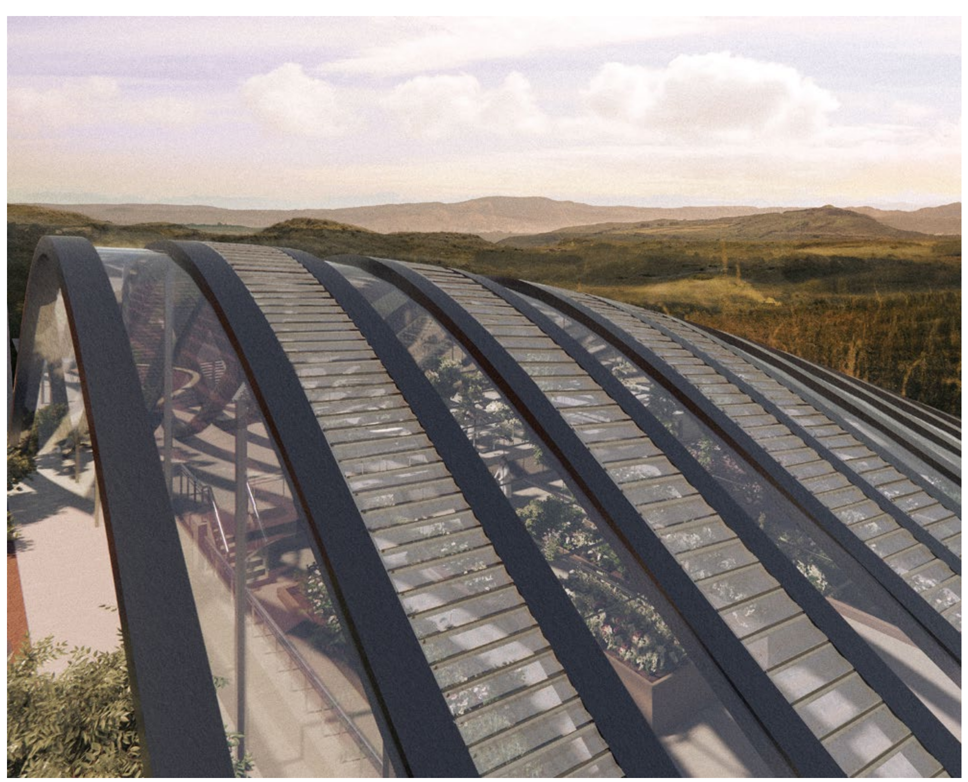


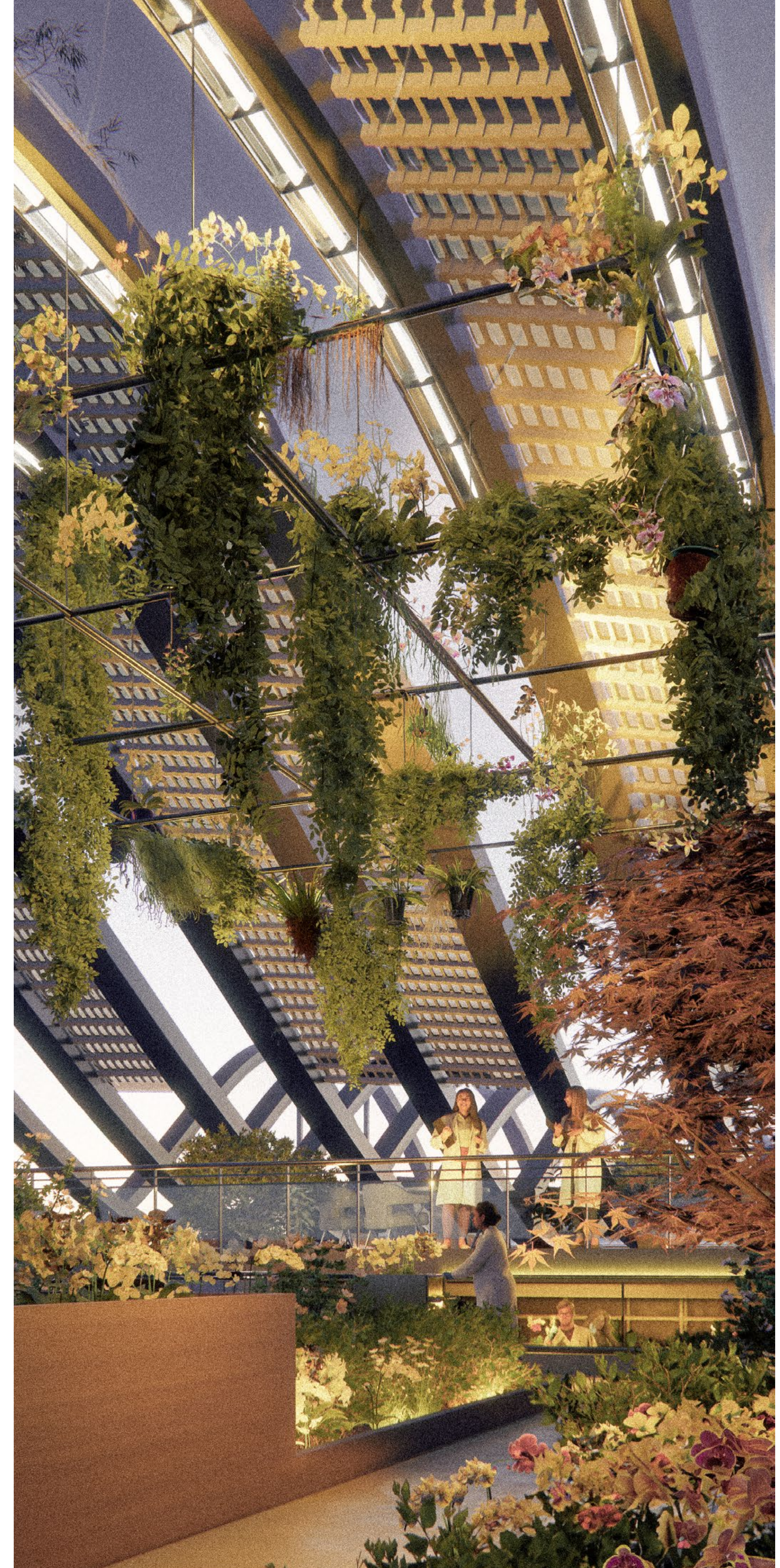
Wood Actuator Assembly

The wood actuator assembly begins with a 3D-printed PLA clip that attaches to the primary structure and accommodates a TPU notch for elastic engagement alongside a laminated wooden actuator. Once assembled, the unit clips onto the system without additional fasteners. When repeated and arrayed, these units form a responsive shingle system, scaling material behaviour from component to architectural assembly.

Long Section Perspective

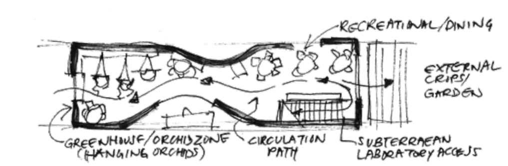
Material Behaviour at the Architectural Scale



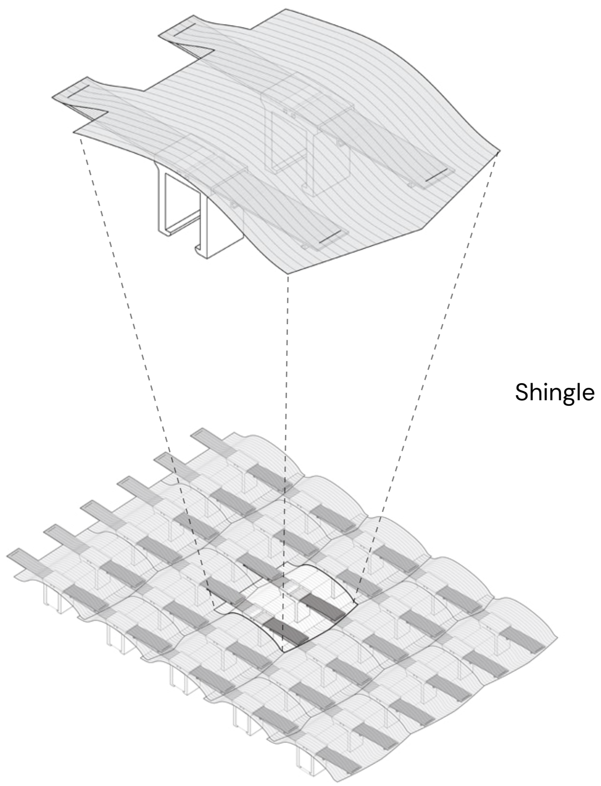


The hygroscopic shingle system forms the primary environmental regulator of the greenhouse envelope, responding directly to changes in humidity through material deformation. As humidity increases, the shingles curl open to promote ventilation and airflow; as conditions dry, they relax and close, reducing moisture loss. This responsive behaviour is driven entirely by the material properties of the system, allowing the envelope to adjust without mechanical input.

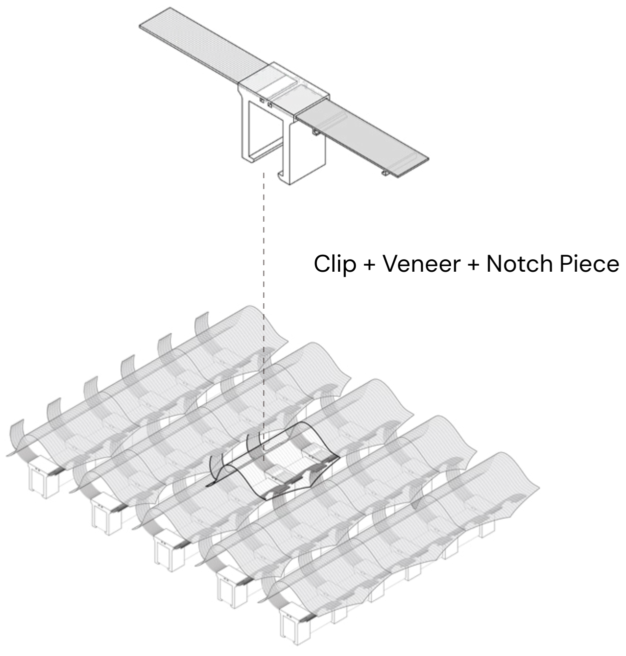
This mode of operation is especially significant for orchid cultivation in Bloemfontein, where stable growing conditions are often compromised by frequent power outages. Orchids rely on carefully balanced humidity and airflow, and interruptions to electrically powered systems can quickly disrupt these conditions. By operating autonomously, the shingle system maintains a consistent interior environment during periods of electrical instability, supporting orchid growth while reducing dependence on conventional, energy-intensive greenhouse infrastructure.



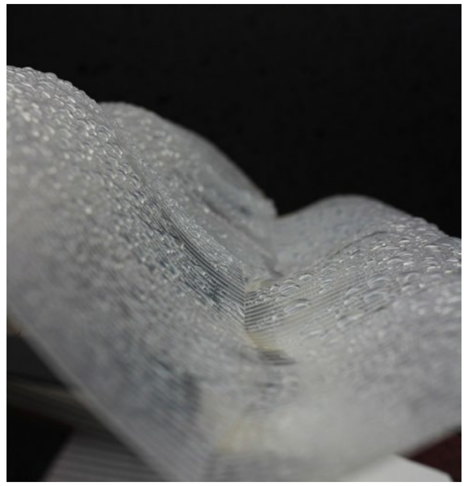
Shingle System Physical Model



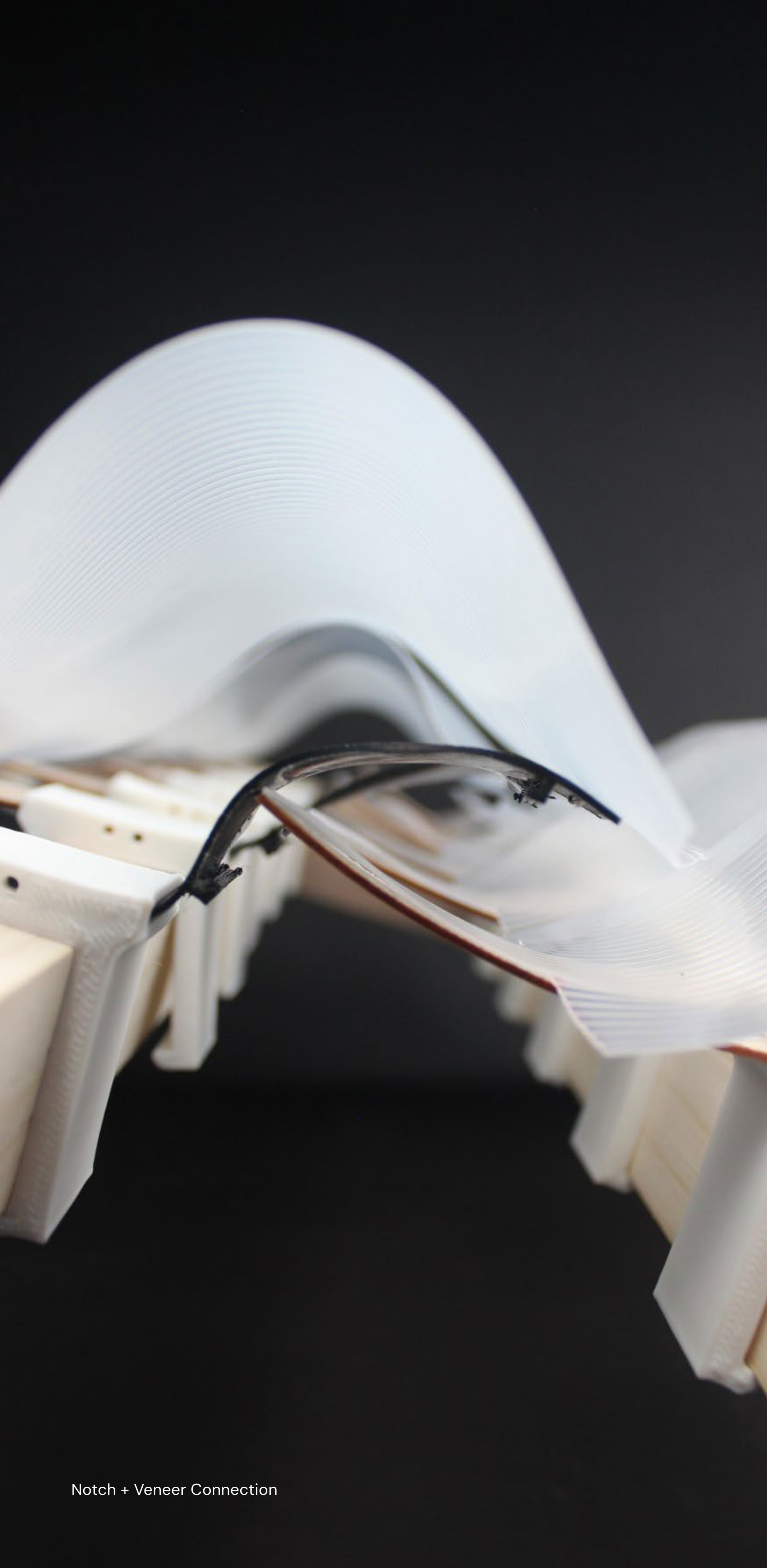
Closed Shingle Arrangement System



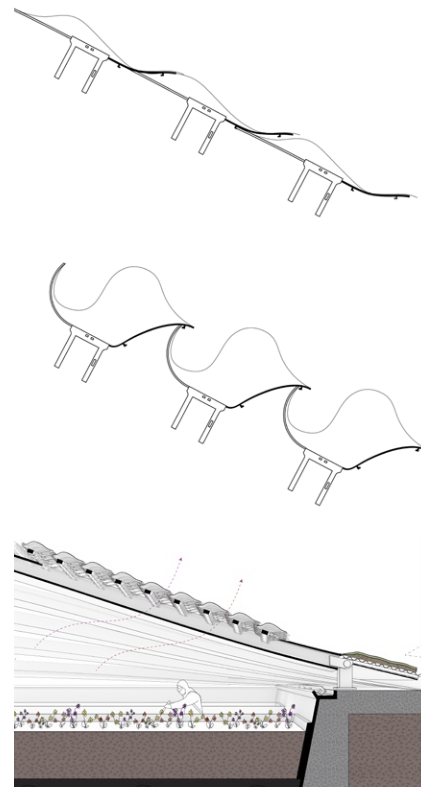
Open Shingle Arrangement System



The study produced a shingle system capable of dynamically responding to environmental conditions. Using clips, wooden veneers, and plastic notch components, the system demonstrated adaptability to changing humidity levels. Greenhouse testing highlighted its potential application in sustainable architecture. This biomimetic shingle system underscores the value of nature-inspired design, revealing a balance between architectural innovation and ecological sensitivity, while its adaptability to diverse climates suggests relevance for reducing environmental impacts in construction.



Notch + Veneer Connection

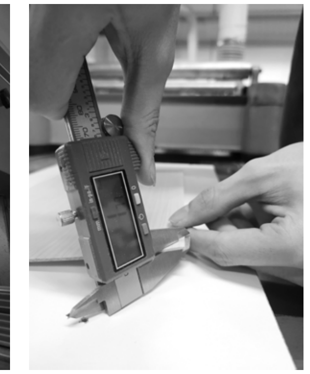


Biomimetic Ventilation Shingle

This study illustrates the effectiveness of biomimicry in creating sustainable architectural solutions. The developed shingle system, inspired by plant hygroscopic properties, offers a promising avenue for integrating natural processes into building design. Continued research and innovation in biomimetic design are essential for realizing environmentally conscious architectural solutions.

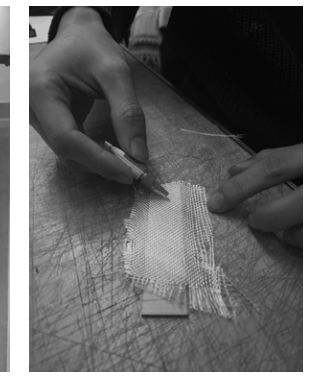
The building design comprises of two primary sections: the greenhouse area and a recreational dining space for scientists, as the greenhouse is also functioning as a subterranean laboratory. Influenced by the arrangement of typical crops, the building's design exhibits a seemingly aerodynamic aesthetic. Additionally, crops adorn the building's exterior, emphasizing continuity, while alternating shingle panels minimize ventilation requirements. To accommodate the growth habits of orchids, which often hang or cling to trees and branches, an integrated hanging mechanism is incorporated into one side of the structure. The building offers numerous opportunities for scenic vistas, with a laboratory situated below ground level yet providing views of the orchids.

Step 1. Rip cutting maple hardwood into thinner sheets (2 m × 31 cm × 5 cm)



Step 2. Planing veneer to 1.4 mm thickness for uniformity

Step 3. Laser cutting veneer sheets into strips (9.5 cm × 2.2 cm × 1.4 cm)



Step 4. Laminating veneer with fiberglass and cyanoacrylate to create final samples

Fabrication Process

The process began with rip cutting maple hardwood into thin sheets, which were subsequently planed into veneer to achieve a uniform thickness and controlled material behaviour. These veneer sheets were laser cut into narrow strips to ensure dimensional precision and repeatability across samples. Prior to lamination, the strips were conditioned in a low-humidity environment to reduce moisture content and minimize variability during activation. Once stabilized, the veneer was laminated with a fiberglass layer using cyanoacrylate adhesive, forming a composite system that couples the anisotropic, hygroscopic response of wood with the tensile reinforcement of the fiber layer. This hybrid assembly increases structural reliability while preserving the veneer's capacity for moisture-driven actuation, enabling consistent performance across repeated testing and fabrication iterations.