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LIVING CANOPIES AND STRUCTURAL ROOTS: ADVANCING ARBOREAL FABRICATION IN MODERN DESIGN

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ABSTRACT

This research delves into the innovative idea of "Arboreal fabrication," which involves creating sustainable areas by shaping trees. As the demand for eco-friendly building solutions grows, the use of living elements in construction has become more popular. This research focuses on the techniques and strategies used to turn trees into architectural shapes, looking at their practicality, uses, and advantages for eco-friendly space planning. By looking at this topic from a cross-disciplinary perspective that includes architecture, plant science, and environmental planning, the study examines the various ways to shape, nurture, and develop trees into useful structures. It also looks into the environmental benefits, design opportunities, and social and cultural impacts of grown buildings as a way to enhance the connection between people and the natural world. By combining information from case examples, research projects, and academic discussions, this study seeks to improve the understanding and implementation of grown buildings in modern architecture. The results presented here add to the conversation on sustainable building and provide important insights for architects, planners, and decision-makers working to develop sustainable and self-regenerating built spaces.

Keywords: Tree Shaping, Living Structures, Nature, Bio Mimicry, Environmental Sustainability, Biophilic Design.

1 INTRODUCTION

The nexus between architecture and nature has seen a striking transformation in recent years, giving rise to creative strategies that conflate the built and natural worlds. The notion of "Arboreal Fabrication," is one such paradigm-shifting idea that represents a symbiotic relationship between architecture and trees to create sustainable spatial designs. By using tree's natural strength, flexibility, and ability to regenerate, this idea challenges preconceived ideas about construction by using them as the fundamental components of architectural structures. Arboreal fabrication offers a comprehensive approach to sustainable design that puts an emphasis on environmental stewardship and biophilic connections. It is a break from traditional building materials and techniques.

Through the practice of tree-cultivation and tree-shaping into useful architectural forms, designers and architects embrace the dynamic processes of growth and adaptation that are inherent in living organisms and push the boundaries of spatial innovation.

This introduction provides as a starting point for delving into the many facets of arboreal fabrication, from its historical origins to its modern uses in environmentally friendly interior design. This paper seeks to explore the potential of grown buildings as a transformative force in the pursuit of resilient, regenerative, and harmonious built environments through a synthesis of theoretical discourse, case studies, and state-of-the-art research.

Designing structures that primarily use trees as their main building material involves creative methods that bring together the fields of architecture, engineering, and forestry. Here are several ideas and methods for utilizing trees to form buildings:

1.1 Using Tree Trunks as Main Support

Instead of conventional wood, the trunks of trees can act as the primary support in the construction of buildings. By choosing and nurturing trees for the right trunk diameter and shape, it's possible to meet structural needs. Tools like careful pruning, bending trees with cables, and supporting them with braces can be used to make the trees grow in straight, tall lines, forming pillars or beams for support.

Tree-Shaped Building Framework: Trees can be shaped and guided while they mature, serving as a natural framework for buildings. Through targeted trimming and training, trees can be formed into the shapes required for walls, arches, or domes of buildings. After the concrete hardens, the tree framework can remain in the structure as a permanent feature or it can be removed, leaving behind an empty space.

Trees as Roofs and Walls: By vertically training trees, they can develop into living roofs and walls, offering natural insulation, shade, and habitat for animals. Methods like espalier and pleaching can be applied to guide the trees into flat, flat against a structure, creating living roofs and walls that seamlessly fit with the environment.

Tree Structures around Core Elements: This method involves growing trees around a central core of materials such as steel or concrete, gradually enveloping the core. It results in structures that are not only strong and long-lasting but also have a natural look. Trees can be pruned and shaped as they grow to ensure they fit well with the core material.

Combining Trees with Other Materials: Mixing trees with materials like bamboo, wood, or recycled materials can lead to structures that combine the best of both worlds. For instance, the trees can provide structural support while bamboo or wood are used for finishing and cladding.

Tree Assembly Units: Trees can be grown in separate, flexible units that can be put together to create larger structures. This method allows for adaptable designs, easy transport, and quick assembly on-site.

Tree Forms as Sculptures: Trees can be shaped into artistic forms that are both functional and aesthetically pleasing. Techniques like topiary, bonsai, and grafting can be used to form complex shapes and designs, adding to the beauty of buildings.
These ideas show the immense potential of trees as a varied and eco-friendly building material, offering avenues for creativity, innovation, and care for the environment in the fields of architecture and construction.

AIM

Aim is to critically analyze the concept of "Arboreal Fabrication" and its use in the planning and building of a structure.

OBJECTIVES

- To explore the historical and contemporary practices of arboreal fabrication and grown buildings, analyzing their evolution and relevance to sustainable spatial design
- To examine various techniques in arboreal fabrication, such as tree shaping, pruning, grafting, and integration into architectural structures, to assess their feasibility and potential uses.
- To evaluate the ecological benefits and environmental impacts of grown buildings, considering factors such as carbon sequestration, biodiversity enhancement, and mitigation of urban heat island effects.
- To assess the structural performance and longevity of grown buildings, examining their resilience to environmental stresses, structural integrity, and maintenance requirements over time.
- To contribute to the advancement of knowledge in the field of sustainable architecture by synthesizing insights from architecture, arboriculture, ecology, and design, and by offering practical recommendations for realizing resilient, regenerative, and harmonious built environments through arboreal fabrication.

SCOPE

Exploring arboreal fabrication techniques and the use of living trees as architectural elements. It studies the biological and structural behavior of trees, along with the environmental benefits offered by sustainable living architecture. The research also highlights recent technological advancements, such as digital fabrication and bioengineering methods, supported by relevant case studies and design examples. Furthermore, it examines the socioeconomic aspects, regulatory frameworks, and the future opportunities and challenges involved in applying arboreal fabrication within contemporary architectural practices.

LIMITATIONS

There may not be a lot of prior research or case studies to draw from because arboreal fabrication is still a relatively new and specialized field. Arboreal fabrication relies heavily on natural processes, which can be unpredictable and influenced by environmental factors such as climate, soil composition, and biodiversity.

Questions may arise regarding the long-term durability and maintenance requirements of grown buildings, particularly in terms of managing the health and growth of living materials over time.

2 METHODOLOGY

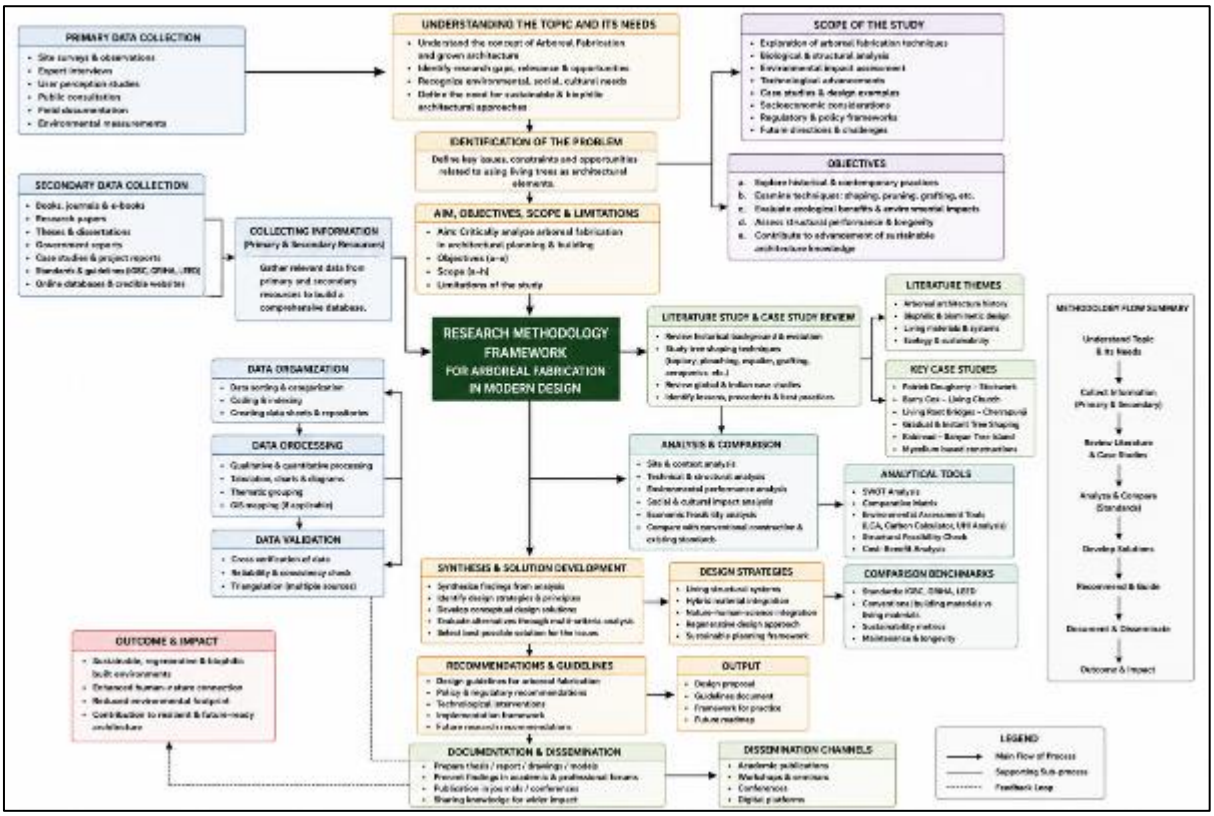


Figure 1: Methodology Framework

3 LITERATURE STUDY

3.1 Patrick Dougherty

Dougherty was raised in North Carolina despite being born in Oklahoma in 1945. He graduated from the University of North Carolina in 1967 with a B.A. in English and the University of Iowa in 1969 with an M.A. in Hospital and Health Administration. He later went back to the University of North Carolina to pursue studies in sculpture and art history. Patrick experimented with using tree saplings as building material and learned more about traditional building methods by fusing his love of the outdoors with his carpentry skills. The North Carolina Museum of Art sponsored the North Carolina Biennial Artists' Exhibition in 1982, which featured his debut piece, Maple Body Wrap. The following year, he presented his first independent exhibition at the Southeastern Center for Contemporary Art in Winston-Salem. The exhibition, titled Waiting' It Out in Maple, marked an important milestone in his artistic journey and introduced his work to a wider audience.

His oeuvre swiftly progressed from solo pieces on traditional pedestals to massive environmental works requiring truckloads of saplings. He has constructed more than 250 of these pieces over the past thirty years, earning him recognition on a global scale. His sculptures can be seen all over the world, including in Belgium, Scotland, and Japan.



Figure 2: Montreal Botanical Garden



Figure 3: View of Montreal Botanical Garden

The installation consists of a central tower measuring 24’ × 24’ with a height of 22’, accompanied by four gateways measuring 10’ × 5’ and rising 16’ high. Surrounding the structure are four pyramidal forms, each 5’ × 5’ in dimension and 16’ tall. The entire composition is constructed using willow.

The design draws inspiration from ancient astronomical observatories. A prominent oculus at the top of the central tower reinforces the experience of gazing upward toward the sky. The surrounding pyramidal elements evoke references to Stonehenge and similar monuments associated with early astronomical observation and celestial alignment.

3.2 Barry Cox church from living trees

The renowned, medieval-inspired Tree Church is located in the same region where scenes from The Lord of the Rings were filmed. Constructed entirely from dense, interwoven trees, the church creates a magical atmosphere as sunlight filters through the openings, producing a halo-like glow within the space. First initiated by Barry Cox in 2011, the living church has since grown to accommodate around 100 visitors.

- New Zealand architect Barry Cox is known for his innovative approach to architecture, particularly his unique concept of "living religion". Cox's living church is not an old heritage built building. Instead, it is a wonderful example of tree architecture that combines nature and religious symbols in a wonderful way.
- Barry Cox designed the 3 hectares of unique gardens that make up the Tree Church. It creates a living, breathing chapel by fusing his love of trees with church architecture.
- For many who come, the Tree Church evokes feelings of serenity, happiness, introspection, and comfort.
- The gardens feature perennial flower gardens, a pond modeled after Monet, a labyrinth, and collections with English and European influences.
- Chris and Bev Gatenby acquired the Tree Church in the middle of 2020, and they are currently continuing the legacy of this unique location. Chris had previously managed the Gardens and the Tree Church for Barry for four years.

The following trees were used in the construction of the church:Thuja Pyramidalis, Acer Globosum, Camelia Black Tie, Purple Dodonaea - Ake (Walls), and Alnus Imperialis - Cut Leaf Alder (Roof Canopy).

Information about Barry Cox's Living Church is as follows:

- **Location:** Cox's Living Church is located in Ohaupo, New Zealand, on his family's land. The tranquility of the c ountryside is the backdrop of this extraordinary house.
- **Design Concept:** With his love of trees and nature, Cox envisioned a church not only as a place of worship, bu t as a seamless blend of architecture and landscape. His desire is to create a sacred space that inspires awe an d reverence, bringing people closer to nature and spirituality.
- **Living Structure:** What sets Cox Church apart is the nature and structure of the living. In addition to building materials such as concrete or steel, the church was built with living wood, including centuries old oaks and other natural species.



Figure 4: Design Elements and Landscaping

3.3 Architecture and Symbolism

Cox's living church designs incorporate symbolic elements of traditional church architecture, including the nave, altar, and cross, and embrace the shapes and textures of the surrounding landscape. Sustainable Design: Beyond its aestheti c and spiritual significance, Cox's Living Church embodies the principles of sustainability and environmental stewards hip. By using live wood as the main building material, the construction contributes to carbon capture, promoting biodi versity and reducing the ecological footprint associated with construction project.

3.4 Community Involvement

Cox's Living Church has become a popular landmark in the community and a destination for visitors from around the world. In addition to being a place of worship, it is also used as a venue for weddings, concerts and other cultural even ts, promoting a sense of community and increasing appreciation for the beauty of nature.



Figure 5: Aerial view and Interior



Figure 6: View of The Living Church

The techniques which were used are as follows:

- Topiary
- Espaliers
- Hedges
- Pleaching



Figure 7: TOPIARY



Figure 8: ESPALIERS



Figure 9: HEDGES



Figure 10: PLEACHING

3.5 Aeroponic Root Culture

One of the earliest examples of shaping living woody plants can be seen in the living root bridges created by the indigenous Khasi communities of Cherrapunji. Formed by guiding tree roots across rivers and valleys, these bridges continue to symbolize the deep connection between nature and human ingenuity.

Research into aeroponics began in 1942 with W. Carter, followed by further advancements from researchers such as L. J. Klotz and G. G. Trowel. In 1957, F. W. Went introduced the term “aeroponics” to describe growing plants with roots suspended in air and nourished through nutrient mist.

In 2008, Ezekiel Golan developed a method that kept aeroponically grown woody roots flexible while allowing them to be shaped into desired forms. These innovations are now influencing eco-architecture, where living plants and roots are explored as materials for sustainable architectural structures.

The Living Root Bridge at War Khasi Hills is a wonderful example of the traditional architecture of the Indian state of Meghalaya, especially the Khasi and Jaintia Hills regions. These unique structures are created by training the roots of F icus elastica (rubber trees) to cross streams or rivers, creating a functional and sustainable natural bridge. Here are so me construction facts about Living Root Bridges:

Cultural Heritage: The Living Root Bridge is an important part of the heritage of the indigenous Khasi people. Over the centuries, they have taken advantage of the natural resources of the region to build these bridges, which serve as a tra nsport link in the rugged terrain of Meghalaya.

Construction Process: Building a living root bridge is a time and labor intensive process. Villagers use bamboo and stone scaffolding to hold the aerial roots of Ficus elastica trees close to the water. Over time, the roots become stronger and form a strong bridge to support the weight of people and animal.



Figure 11: Living Root Bridges, Cherrapunjee



Figure 12: Bridge view

Sustainability: Living root bridges are a sustainable alternative to traditional bridges made of steel or concrete. They require little maintenance and are long-lasting, with some bridges said to be over 500 years old. Natural materials blend well with the environment and reduce the ecological impact of infrastructure development.

Adaptability: Living root bridges are uniquely adaptable to their environment. Roots continue to grow and strengthen, making the bridge more resistant to the forces of nature, including heavy rains, floods and landslides. Unlike traditional bridges, which can break or collapse under these conditions, living root bridges have the ability to repair and rebuild.

Community Involvement: Building and maintaining living roots bridges is a collaborative effort with the entire community. Local knowledge and traditional skills are passed down from generation to generation, preserving the heritage. Bridges also play an important role in promoting social cohesion and cultural identity in Khasi society.

Tourism and conservation: In recent years, the living root bridge of War Khasi Hills has attracted -Tourists and researchers, who are interested in preserving and protecting these unique structures, focused on the development of sustainable tourism, the plan aims to promote responsible tourism and preserve the cultural and environmental integrity of the region.

War Khasi Hills Living Root Bridge is a living symbol of awareness, resistance and symbolic connection between man and nature. As a symbol of sustainable architecture, they provide valuable lessons about resources, adaptation and community cooperation that resonate far beyond the hills of Meghalaya.

3.6 Gradual Tree Shaping

Gradual tree shaping begins with careful planning and the creation of a supporting framework, both of which are essential for achieving the intended form. Once the structure is prepared, young seedlings or saplings, usually between 3 and 12 inches in length, are planted. The shaping process starts while the plants are still very young, allowing their stems and branches to be gently guided as they grow.

The most important stage occurs near the growing tip of the tree, where new growth develops and determines the future shape of the plant. This sensitive shaping zone requires regular attention, often on a daily or weekly basis, to carefully direct the growth along a planned path. Designers may use wooden frames, wire structures, or custom-made supports to train the tree into the desired form.

Because this method relies on natural growth, it requires patience and long-term commitment. For example, a living chair sculpture may take 8 to 10 years to fully mature, while some creations by Axel Erlandson took nearly 40 years to achieve their final shape.



Figure 13: Gradual Tree Shaping examples by different artists

3.7 Instant Tree Shaping

Instant tree shaping involves using more mature trees, usually around 6–12 feet tall with trunk diameters of 3–4 inches, which are carefully bent and woven into a desired form. Once positioned, the trees are secured in place until they naturally adapt and retain the new shape. Successfully carrying out this process requires a good understanding of how trees grow and respond to pressure and movement.

To create specific forms, controlled bending techniques are often used. If a tree is bent too sharply at one point, the trunk or branches may crack or break. To prevent this, the curve is created gradually through a series of smaller bends spread along the length of the tree. These bends are then supported for several years until the structure becomes stable and permanent. Depending on the complexity of the design, the initial shaping process may take only a few hours or an entire day.

In some cases, a technique called ring barking is used to regulate growth and maintain balance within the design. This method slows down overly vigorous branches or limits growth in unwanted areas by carefully removing or scoring portions of bark in varying degrees.



Figure- 14: Instant Tree Shaping examples by different artists

4 CASE STUDY

- Site Location: Kabirvad, Gujarat
- Main Focus: Banyan Tree Island, Kabirvad
- Near By Cities in 150 Km: Bharuch & Vadodara

Kabirvad is a well-known natural and spiritual destination located on an island in the middle of the Narmada River. Visitors can reach the island by boat from the nearby Shuklatirth Shiva Temple. The site is famous for its enormous banyan tree grove, which has expanded over centuries and now spreads across nearly 3 kilometers. Kabirvad derives its name from the revered saint Kabir, who is believed to have lived and meditated here for many years. The island also houses a significant Kabir Temple that attracts devotees and travelers alike. Beyond its historical and religious importance, the place is admired for its peaceful atmosphere and the sense of calm created by the vast banyan canopy.

4.1 Accessibility

- **By Road:** The Narmada River flows through parts of Gujarat, including the districts of Narmada, Vadodara, and Bharuch, before meeting the Arabian Sea near Bharuch. Several towns such as Bharuch, Rajpipla, Chanod, and Dabhoi are well connected by road and bus services. The Sardar Sarovar Dam can also be accessed by private vehicles.
- **By Rail:** The nearest railway station to Kabirvad is located in Bharuch.
- **By Air:** The closest airport is in Vadodara.

4.2 About the Narmada River

The Narmada River, also historically known as Rewa or Nerbudda, is one of the major rivers of central India and is considered among the country's most significant rivers after the Godavari and Krishna. Often referred to as the "Lifeline of Gujarat and Madhya Pradesh," the river plays a vital role in the ecology, culture, and economy of these regions. Originating from the Amarkantak Plateau near Anuppur district, the river traditionally marks the divide between North and South India. Flowing westward for approximately 1,312 kilometers, it eventually empties into the Gulf of Khambhat in the Arabian Sea near Bharuch.

The tree Kabirvad is situated in Gujarat near Bharuch or around 30 km from the city center of Bharuch city. This is said to be almost 600 years and its total area is around 4 acres. Kabirvad is an island of banyan tree that's in the center of Narmada River and Narmada flows on both sides of the island. The tree is designed by the forest department. The tree is checked and observed on different time intervals.

4.3 About The Tree Designing

The tree is designed and well maintained by the forest department to convert the tree roots into trunks. These roots then reach in the ground and in a time span they transform themselves into the trunk. And it is very difficult to distinguish between the main trunk and the supporting trunks because they become same as the main trunk after a long period.

4.4 Design Development

Root manipulation in Kabirvad, Gujarat is a fascinating intersection of horticulture, art and spirituality with centuries-old techniques used to intricately and intricately shape the roots of the magnificent banana tree. Here are some insights into Kabirvad root manipulation practices:

Cultural and Spiritual Significance: Kabirvad root manipulation has deep roots in local culture and spirituality, and the banana tree is revered as a sacred symbol of enlightenment and divine wisdom. The practice is believed to have originated with the mystical poet-saint Kabir, who is said to have meditated under the tree and inspired devotees to carve its roots as a sign of respect and reverence.

Artistic Expression: Kabirvad root manipulation goes beyond mere horticulture and acts as an artistic expression that blends perfectly with the natural beauty of the tree. Keepers and enthusiasts use various techniques such as pruning, weaving and grafting to turn the roots into intricate patterns and designs that inspire wonder and awe.

Techniques and Methods: While specific root treatments in Kabirvad can vary, they usually involve gentle manipulation of the roots over time to control their growth and direction. This process requires patience, skill and a deep understanding of the tree's natural physiology, and caretakers often use traditional methods that have been passed down from generation to generation



Figure 15: Formwork to create trunks of desired shape

Keeper Expertise: The ability to handle Kabirvad roots is usually passed down from experienced keepers to apprentices, ensuring the preservation of traditional knowledge and techniques. The caretakers have an intimate knowledge of the banana tree's growth habits, nutritional needs, and response to environmental conditions, allowing them to cut its roots with precision and care.

Ecological Considerations: Although root manipulation in Kabirvad is based primarily on cultural and aesthetic considerations, the caretakers also consider ecological factors to ensure the health and vigor of the tree. To reduce stress on the tree and prevent damage to its root system, techniques are used to promote long-term durability and resilience.

Visitor Experience: The sculpted roots of the Kabirvad banyan tree attract visitors from afar, offering a unique and immersive experience that fosters a deep connection with nature and spirituality. Visitors are encouraged to explore the complex forms of the tree, reflecting on the interconnectedness of all living things and the timeless wisdom of the ancient tree.



Figure 16: Root manipulation technique

The manipulation of Kabirvadi's roots is a testimony to the sustainable relationship between humanity and nature. It illustrates how traditional practices can enrich our lives and deepen our appreciation for the beauty and wonder of the earth. Through careful cultivation and artistic expression, the caretakers of Kabir Vad continue to shape and preserve this living masterpiece for future generations to marvel at and cherish.



Figure 17: Mature Trunks after Root manipulation at Kabirvad, Gujarat

5 METHODOLOGY: CREATING A HOUSE STRUCTURE WITH TREES:

A typical family home is generally made up of two essential components, each serving a different purpose. The first is the structural framework, which gives the house strength and stability, enabling it to withstand environmental forces and support its own weight. The second is the outer enclosure or envelope, which creates a protective barrier for the inhabitants against wind, cold weather, and external threats. Interestingly, nature itself provides inspiring methods for forming both of these elements.

One innovative approach involves cultivating artificial hollow trees through the process of grafting. Grafting is a natural technique in which branches from the same or different trees are joined together so they gradually grow as a single structure. This can be achieved using various methods such as tying with strings, cables, or even screws, depending on the type of wood and the desired outcome.

To create a living architectural form, the design of the house is first marked out on the ground. Seeds are then planted along the planned layout in parallel rows. As the young trees begin to grow, their stems and branches are carefully intertwined and guided together, encouraging them to graft naturally over time. Through patience and continuous shaping, the living structure slowly develops into a functional and organic architectural space.

Table 1: Comparison of Different techniques for creating a structure with tree as a material

Evaluation Criteria	**Instant Tree Shaping**	**Gradual Tree Shaping**	**Aeroponic Root Shaping**
Work Duration	Short	Long	Short
Construction Completion Period	Short to Moderate	Long	Moderate
Implementation Difficulty	Simple	Simple	Simple
Design Flexibility / Shaping Potential	Limited	Moderate	Extensive
Probability of Success	Low	High	Moderate to High
Reproducibility Potential	Very Low	High	Moderate
Existing Built Applications	Implemented in construction	Implemented in construction	Limited applications with small-scale structures
Industrial Feasibility	Not established	Potentially applicable	Potentially applicable (*Tree Novation*)

Suitable Tree Species	Poplar, Willow	Species-dependent (applicable to most trees based on characteristics)	Ficus, Eucalyptus, Acacia, and fruit-bearing trees such as Lemon, Fig, and Plum

5.1 Comparison of different type of trees for fabrication

Tree fabrication, an innovative practice of incorporating living trees and plants into architectural design, offers exciting opportunities for sustainable spatial design. Taking advantage of the unique properties of different types of wood, architects and designers can create buildings and structures that blend perfectly into the natural environment and reduce the ecological footprint of construction. For example, the fast growth and flexible branches of the rubber tree (Ficus elastica) make it ideal for creating living bridges or canopy walkways that offer both functional and aesthetic benefits. Also, the strength and durability of oak (Quercus) lends itself to structural elements such as roofs or cladding, providing longevity and flexibility to the built environment. Due to its rapid growth and renewable nature, bamboo offers opportunities for creating light but strong frames in architectural applications, promoting sustainability without compromising strength. By carefully selecting different types of wood and including them in the production of trees, designers can create buildings that not only fulfill a practical purpose, but also add beauty and vitality to the surroundings in a harmonious and environmentally friendly way.

Choosing the right trees for arboreal fabrication requires careful consideration of several important factors, including climate adaptability, growth speed, structural durability, lifespan, and environmental impact. These aspects help ensure that the living structures remain stable, sustainable, and well suited to long-term spatial design. Preference should also be given to native and indigenous tree species, as they support local biodiversity, strengthen ecological balance, and contribute to healthier and more resilient ecosystems.

When considering trees for arboreal fabrication in sustainable spatial design, various species offer different properties and characteristics that can be advantageous for specific architectural applications.

Table 2: The Strengths and Area of use for different type of Tree Species

Name of the tree	Strengths	Area of use
Ficus elastica (rubber tree)	Fast growth, extensive root system suitable for bridge-like structures, flexible branch. design, tolerance to environmental stresses.	Living root bridges, canopy walkways, organic stands.
Quercus (Oak)	Strong and durable tree, wide canopy for shade and shelter, extensive root system for stability.	Structural elements, roof, coatings, pergolas.
Bamboo	Fast growing, light but strong, flexible, abundant in tropical regions, renewable resource.	Structural framework, fords, coatings, furniture, temporary shelters.
Banyan tree (Ficus benghalensis)	large canopy suitable for shading, extensive aerial roots to support structure, aesthetic appearance.	Canopy structures, shade pavilions, natural arch doors.
Palms (eg coconut palm, date palm)	Tall and straight trunks, light but strong, flexible leaves for weaving or thatching.	Roofs, protections, shadows, fords, decorative elements.
Sequoia wood (Sequoia sempervirens)	Tall and straight trunk, strong and durable wood, resistant to decay and insects.	Structural elements, terraces, coatings, outdoor furniture.
Willow (Salix)	Fast growing, flexible branches suitable for weaving or shaping, tolerates wet environments.	Woven constructions, protections, fords, life fences.
Mango tree (Mangifera indica)	Large canopy that provides shade and protection, thick trunk suitable for structural support, fast growing.	Canopy structures, shade pavilions, pergolas, outdoor seating.
Eucalyptus (Eucalyptus spp.)	Fast-growing, tall and straight trunk, strong wood naturally resistant to decay and pests.	Structural elements, terraces, coverings, pergolas.

Cypress (Cupressus spp.)	Tall and straight trunk, rot-resistant wood, suitable for humid environments.	Structural elements, terraces, coatings, outdoor furniture.

6 EXPERIMENTAL APPROACH: DEVELOPING A BUILDING ENVELOPE WITH MYCELIUM

Once the primary structure of a building is completed, it becomes necessary to create an outer envelope that protects the occupants and improves the comfort of the living environment. In this context, mycelium has emerged as a highly promising material for sustainable building envelopes. Made up of fine interconnected filaments that grow in multiple directions, mycelium forms a lightweight yet solid material with strong insulating properties.

As a rapidly renewable and completely natural resource, mycelium can be cultivated into a wide variety of shapes and forms. Certain species also demonstrate impressive durability and resistance to fire, making them suitable for architectural applications. In 2007, Ecovative introduced a range of mycelium-based products, including particle boards that use mycelium instead of synthetic glue, insulation materials, packaging foam, and even do-it-yourself cultivation kits. These innovations inspired many artists and designers to experiment with mycelium in sculptures, lighting installations, and spatial design.

The research laboratory The Living, supported by Autodesk, further explored these possibilities by growing mycelium blocks inside molds and then drying them to create construction units. These blocks were later used to build the 13-meter-high Hy-Fi Project tower in New York. However, constructing such structures still involved industrial manufacturing, transportation, and high energy consumption, resulting in significant environmental and economic costs.

In contrast, this study proposes cultivating mycelium directly on-site to form the outer skin or bark of the structure. By eliminating the need for industrial production and transport, the approach aims to create a more environmentally responsible and self-sustaining architectural system.



Figure 18: Mycelium brick



Figure 19: Hy-Fi, The Organic Mushroom-Brick Tower

Hy-Fi Project was an innovative installation made up of a series of circular towers rising over 12 meters in height. The structure was constructed using nearly 10,000 biodegradable bricks created from crushed corn stalks bound together with mycelium, combining advances in biotechnology with modern computational design and engineering techniques.

Developed for the Museum of Modern Art PS1 Young Architects Program, the bricks were produced without generating industrial waste and required very little energy during fabrication. After serving as the centrepiece of the museum's summer cultural events in 2014, the entire structure was dismantled, and the organic bricks naturally decomposed into compost.

What makes the project remarkable is its transformation of agricultural waste into a functional building material. Corn stalk residue, combined with fungal mycelium, was grown into brick molds where the mycelium expanded and bonded the material together naturally. This created a lightweight, biodegradable, and environmentally responsible construction system.

The name "Hy-Fi" is derived from "hyphae," the thread-like structures of fungi that played a vital role in forming the living building blocks of the project. The installation demonstrated how biological materials and sustainable technologies could shape the future of architecture through low-energy and near emission-free construction methods.

6.1 HYPHA

A hypha is a thin, thread-like branching structure found in fungi, oomycetes, and certain bacteria such as actinobacteria. In fungi, these hyphae serve as the primary mode of vegetative growth and collectively form a network known as mycelium. Since mycelium is entirely organic in nature, it has gained increasing attention as a sustainable material for innovative architectural applications.

This concept was explored in the design created for the Museum of Modern Art PS1 Young Architects Program, where biological materials were combined with advanced computational engineering techniques. The resulting installation consisted of three interconnected circular towers that blended into one another, creating both a visually engaging structure and an experimental approach to future architectural design and construction.

The form of the towers was carefully designed to channel natural airflow through the spaces, allowing breezes to circulate and cool the shaded interior areas. At the same time, structural engineers incorporated detailed testing data of the mycelium bricks to ensure the installation remained safe and stable. Despite its experimental nature, the structure was engineered to withstand strong winds, heavy rain, and continuous public interaction, demonstrating the potential of bio-based materials in resilient and sustainable architecture.

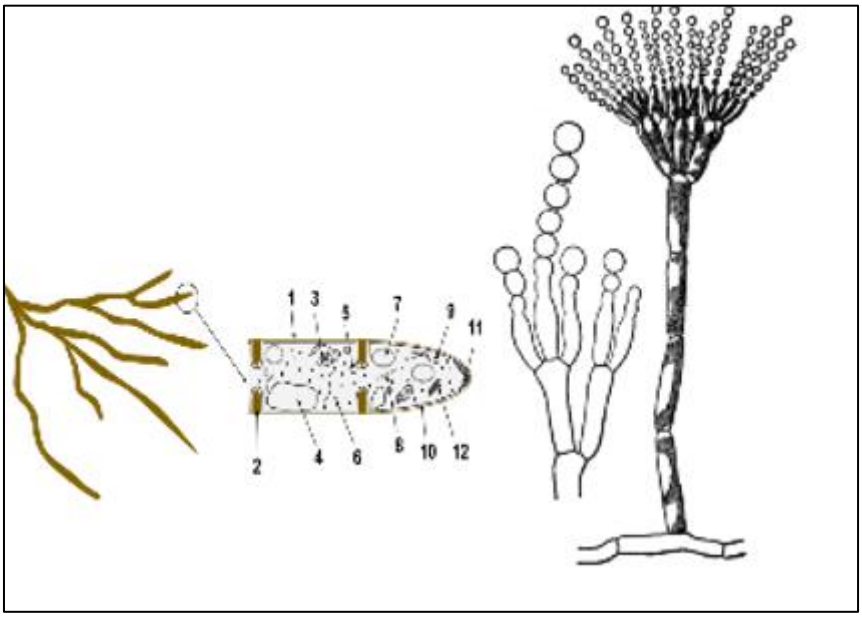


Figure 20: Biological representation of Hypha



Figure 21: Growth of Hypha

Since mycelium has the natural ability to grow densely by spreading through a supporting material, researchers proposed a simple and sustainable method for using it in architecture. The process begins by creating the desired building envelope or form using cardboard shaped around the structural framework. This cardboard is then inoculated with mycelium, which gradually feeds on the cellulose within the material and grows throughout the surface, slowly forming a solid and compact organic layer in the intended shape.

Once the mycelium has fully developed and achieved the required strength, the growth process is stopped by drying the material with hot air. This preserves the structure while maintaining the bonding and cohesion of the fungal cells. Through this approach, a complete mycelium-based envelope can be produced with minimal environmental impact and relatively low construction costs, using simple and biodegradable materials.

The effectiveness of this technique has encouraged companies such as Ecovative to expand the commercial use of mycelium products on a large scale. Today, the company manufactures millions of mycelium-based packaging units annually, including sustainable packaging solutions developed for IKEA.

7 CONCLUSION

In summary, Arboreal Fabrication presents an innovative approach to sustainable spatial design that utilizes the natural growth ability of trees and plants to create functional and environmentally friendly structures. During this research, we explored the possibilities of wood production techniques, such as using living organisms such as trees, fungi and bacteria to grow building materials and structural components. Taking advantage of the unique properties of different types of wood, architects and designers can create buildings that not only blend perfectly into the natural environment, but also promote ecological protection and increase biodiversity.

Going forward, it is necessary to continue to research and improve tree plant production techniques to address pressing challenges such as climate change, urbanization and resource depletion. By embracing the principles of wood production, we can create a more sustainable built environment that respects and celebrates the interconnectedness of all living organisms on our planet. Ultimately, Arboreal Fabrication offers a visionary path to a more harmonious relationship between architecture and nature, where buildings not only coexist with nature, but actively contribute to its preservation and flourishing

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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No conflict of interest to be disclosed.

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