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Paola Gallo · Simon Elias Bibri · Francesco Alberti · Abraham R. Matamanda · Cristina Piselli · Hamid Rabiei · Rosa Romano · Ayse Ozcan-Buckley *Editors*

Urban and Transit Planning

Volume 2
Culture and Sustainability for Built Environment

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Editors
Paola Gallo
Department of Architecture (DIDA)
University of Florence
Florence, Italy

Francesco Alberti
Department of Architecture (DIDA)
University of Florence
Florence, Italy

Cristina Piselli
Department of Architecture (DIDA)
University of Florence
Florence, Italy

Rosa Romano
Department of Architecture (DIDA)
University of Florence
Florence, Italy

Simon Elias Bibri
School of Architecture
Civil and Environmental Engineering (ENAC)
Swiss Federal Institute of Technology Lausanne
Lausanne, Switzerland

Abraham R. Matamanda
Department of Urban and Regional Planning
University of the Free State
Bloemfontein, South Africa

Hamid Rabiei
School of Architecture
University College Dublin
Dublin, Ireland

Ayse Ozcan-Buckley
Department of Political Science and Public Administration, Faculty of Economics and Administrative Sciences
Giresun University
Giresun, Türkiye

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Interwoven Architectural Skins: Biobased Material Fiber Construction Using Chuspata

Olga Mesa and Nathan Fash

Abstract

This paper contributes to the growing body of research and application of biobased materials, an emerging technology in sustainable architecture, by specifically investigating potential architectural applications for the aquatic reed *Typha domingensis*. This invasive plant flourishes at the edges of lakes in the state of Michoacán, Mexico. Known locally as *chuspata*, the stalks are abundantly harvested for use by artisans in the region of Lake Pátzcuaro to produce domestic artcrafts and to clear the waterways for local fisherman. The *chuspata* artisans utilize the material through a weaving process that has deep cultural and pre-Hispanic origins and represents a circular process where environmental, economic, and cultural conditions intersect productively. Our research question asked whether *chuspata* could be employed at an architectural scale while building upon both the biological and cultural aspects of the raw material and its transformation through human processes. The pliability, cellular structure, linear rigidity, and sectional variability of the stalk were studied for their potential architectural performance along with the geometrical characteristics of common weaving patterns such as *cadena*, *petate,* and *torcido*. The study resulted in a collection of built prototypes and an exhibition pavilion developed in collaboration with artisans of Ihuatzio, along with architecture students and faculty from Mexico and the United States, featuring traditional and innovative weaving patterns to introduce porosity, rigidity, and three dimensionality, as a means to scale up the use of the material from small art craft objects to larger scale architectural components in horizontal and vertical configurations. Our outcomes point to the promise of employing rapidly renewable biobased materials to create light, aesthetically pleasing, and culturally resonant, temporary structures with low thermal mass to provide shade or as a screen in warm climates with significant urban heat islands. The low embodied energy and biodegradability of the material contribute to its sustainable use.

Keywords

Architectural biobased materials • Chuspata construction • Woven fiber construction • Sustainability • Typha domingensis

1 Background

In recent decades, the desire to lessen the environmental impact of construction by reducing energy consumption and related carbon emissions continues to inspire architects, engineers, and material scientists to develop and design with materials that are derived from living matter. These biobased materials (Curran 2010) are inherently renewable and biodegradable, allowing their growth, harvest, use, and regeneration to constitute a circular system. Biobased materials often have the capacity to store carbon during their service life and contribute to the wellbeing of building occupants through healthy indoor air quality as well as their visual, olfactory, and tactile presence. Examples of biobased materials include products like engineered wood such as cross-laminated timber (CLT) which continue to gain acceptance and increase market demand. Other biobased materials include bamboo, straw, and cork—prepared through various degrees of processing—as well as flax (Yan et al. 2014) and hemp (Lupu et al. 2022) that can be used as ingredients in composites. In recent decades we have also

O. Mesa (✉) · N. Fash
Associate Professor of Architecture, Roger Williams University, Bristol, Rhode Island, USA
e-mail: omesa@rwu.edu

N. Fash
e-mail: nfash@rwu.edu

O. Mesa
Research Associate, MaP+S Group Harvard Graduate School of Design, Cambridge, MA, USA

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seen the development of new materials, such as mycelium composite structures (Almpani et al. 2021), which have been tested in pavilions—like the Hy-Fi Pavillion, Monolito Pavilion, MY-CO SPACE, and Growing Pavilion—and confirmed as a material with insulating capacity and compressive strength (Biala and Ostermann 2022). Other innovations have explored the potential of collaborating with various species to create structures, such as the Silk Pavilion (Oxman 2015) which combined the biobased output of silkworms with digital fabrication technologies, or Das Algenhaus (Scholz et al. 2014) which utilized living micro-algae bioreactive panels to harvest solar energy through photosynthesis to create biomass that is used for space heating. While all the examples above have contributed to the advancement of biobased materials in architectural applications, this paper seeks to expand the potential use and impact of biobased materials by dovetailing them with climate, culture, and environment.

1.1 Introduction

The region surrounding Lake Pátzcuaro, in the Mexican state of Michoacán, has been inhabited by the Purépecha people since before the Spanish conquest. The lake environment has provided natural resources and ecosystem services to its inhabitants for centuries (Williams 2022). Today, the lake region is home to a variety of artisan communities, each working with different materials like copper, ceramics, wool, leather, wood, lacquer, and aquatic reeds. Many of these craft traditions predate the arrival of the Spanish and have long benefited from the availability of local natural resources. Since the arrival of the Spanish bishop Vasco de Quiroga in the 1530s and his efforts to organize the craft economies around the lake, the distinctive crafts based on those local resources have become associated more distinctly with individual Purépecha towns around the Lake. Santa Clara del Cobre, for instance, is known for its copper smithing, while Tzintzuntzan is known for its ceramics, and Ihuatzio is recognized as the hub for woven aquatic reeds. The woven reed tradition in Ihuatzio utilizes two aquatic plant species that grow throughout the edges of the lake. Southern Bulrush (Schoenoplectus californicus) is known locally as tule and is native to the lake, while Southern Cattail (Typha domingensis) is an invasive species in the lake and is known locally as chuspata.

The Southern Cattail is an aquatic plant that grows in temperate and tropical regions. Its adaptability has allowed it to thrive in wetlands and brackish water and other environmental contexts around the world. In Michoacán, Mexico, this perennial plant grows densely on the shores of lakes (Fig. 1), as well as on floating islands, and may reach upwards of 8 feet (2.5 m) in height. Although considered an invasive species in this part of the world, sharing its territory with the native Southern Bulrush, this nonnative species contributes to the regional ecosystem by providing habitat for the endemic Lake Patzcuaro Garter Snake (Thamnophis eques patzcuarensis) and other organisms (Maldonado and Voeks 2021). In addition, the presence of the Southern Cattail helps improve water quality through its ability to filter polluting particles (Moeder et al. 2017) as anthropogenic pressures on the endorheic lake and its watershed have resulted in high turbidity from increased erosion loads and human waste (Torres 1993).

While various parts of these aquatic reeds are used as food, animal feed, and medicinal purposes elsewhere around the world (Arenas and Scarpa 2003), in the Lake Pátzcuaro region, chuspata and tule have become part of the material culture of the area through their use in the weaving of crafts by the local artisans. Chuspata and tule are frequently pruned by mechanical means to clear waterway access for tourism (mainly to Janitzio Island) and other boat-based activities like fishing and recreation (Hall 2009). While both plants grow and regenerate without human intervention after being harvested, plants that are pruned constantly are not suitable for use as weaving material, as the plant grows back weaker and less substantial (Maldonado and Voeks 2021).

Today, both tule and chuspata are employed for weaving. At least one weaving pattern that can be found in the contemporary weaving crafts, known as *petate*, has pre-Hispanic origins and appears abundantly in recorded imagery across Mesoamerica as a woven mat used for sitting in ceremonial and quotidian practices. Tule is often reserved for smaller objects that benefit from its thinner more circular cross-section, while the broader chuspata reeds are preferred for their easily flattened crescent-shaped cross-section which covers larger areas more readily (Fig. 1). Chuspata is also softer and more pliable than tule and is increasingly favored among artisans because of its material properties. While the use of tule has been more long-standing than chuspata, in recent decades, the latter has become more available, and its use is more pervasive in the region.

While both reeds have great potential, for the purposes of this research, the authors chose to focus on the study of chuspata because of its availability and its popularity among current artisans, representing a circular process where environmental, economic, and cultural conditions intersect productively.

Urban areas in Mexico, as in other parts of the world, experience higher temperatures than outlying areas, creating urban heat islands (UHI) because of the heat absorption and transmission characteristics of the materials that are typically used to build cities and infrastructure. Numerous negative outcomes are associated with the UHI effect, including human discomfort, increased morbidity, increased water demand, and poor air quality (Jaregui 1997). Recently, UHI has also been

Fig. 1 Typha domingensis growing at Lake Pátzcuaro (left), chuspata (right, above) and tule (right, below). Photos by authors

shown to inequitably harm vulnerable populations in cities as climate change brings more frequent and severe high-temperature exposures globally (Romitti et al. 2022). Another known impact of UHI is an increase in cooling demand, which translates to additional electricity consumption and its related emissions. One of several recognized tools used to reduce urban heat islands is shading from solar radiation (Santamouris and Kolokotsa 2016). In hot climates, like many parts of Mexico, there is a significant environmental and socio-economic benefit to offsetting the UHI effect using passive solar strategies like shading with materials that have low thermal mass and low embodied energy. Because of its light weight, cellular structure, and its inherent insulating properties, Typha domingensis has been used as a key ingredient in economically and ecologically viable composite insulation panels (Hounkpatin et al. 2023). In our study, we explored the use of chuspata as locally available biobased shading material, which, when scaled up to the urban context, has the potential to reduce urban heat islands.

2 Problem Statement and Study Aim

In summary, our research sought to answer the question of how we can deploy chuspata at an architectural scale to provide shading and space-making while harnessing its environmentally favorable properties as a raw material and its cultural significance through the tradition of weaving. Using the vehicle of a pedagogical workshop and a pavilion developed in Pátzcuaro, Mexico, we illustrate how this biobased material can perform an architectural role in numerous ways while supporting the local habitat, economy, cultural heritage, and identity.

3 Methodology and Results

The authors designed and conducted a week-long workshop in collaboration with artisans from Ihuatzio along with architecture students and professors from Mexico and the United States. During this time, a series of interviews, conversations, and exchanges about chuspata crafts were recorded. The investigation included the design and fabrication of prototypes and an exhibition pavilion that addressed the research questions.

As part of the workshop, our collaborating artisans shared how to handle the material, from harvesting to weaving. Chuspata reeds can be collected throughout the year (Fig. 2), but material suppliers prefer the dry season to avoid staining caused by water during the rainy months. After being left to dry flat for approximately fifteen days, the desiccated material is gathered into arm-length bundles called *brazadas* containing several hundred stalks (Fig. 2). These dried *brazadas* can be stored for periods of several months under dry shelter. The day before weaving, dried chuspata must be partially rehydrated to restore its pliability. At the time of weaving, special attention is paid to the moisture content of the reed as its flexibility facilitates the process. Many of the artisans reported a preference for weaving in the morning hours when it is not dry or hot and the use of a spray bottle to moisturize the reeds (Fig. 2). Working with chuspata in and of itself is enjoyable and non-toxic. It is easy to handle, soft to the touch, and slightly moist while at the same time, it fills the room with a sweet and earthy aroma.

The artisans taught the participants how to weave using chuspata, sharing some working techniques and traditional patterns. They demonstrated the use of the few tools in their

Fig. 2 Chuspata being harvested (left), chuspata *brazada* (center), chuspata rehydration (right). Photos by authors

craft, primarily a handheld knife to cut the stalks to length, and a carefully selected river stone, which fits conveniently in the weaver's palm and is used to flatten the reeds and to hold the strands in place while weaving (Fig. 3). These stones are unique enough in their ergonomic geometry that they are very valuable to the craftspeople, often named and passed from one generation to the next. Weaving can be done on top of a blank, around an armature, or simply flat (Fig. 3).

Artisans typically use wooden blocks as blanks or any everyday object with the desired basic geometry, like a bowl or a cylindrical jar, onto which the reeds are molded. Artisans also collaborate with blacksmiths to weld small steel armatures around which surfaces are woven with the chuspata stalks. We observed that these practices and the main traditional patterns are possible due to the morphology of the stalk, including its variable section, pliability, and compressibility. The versatility of the stalk enables it to be twisted as in *torcido*, gathered and compressed as in *cadena*, and simply flattened and overlapped as in *petate* (Fig. 4).

After each participant produced small-scale objects using traditional weaving patterns, the next step was a creative leap. Drawing on tradition and the artisans' knowledge of materials, the participants made one-square-meter prototypes to address architectural design parameters. Using drawing and material tests that hybridized weave patterns,

Fig. 3 Weaving with a river stone (left), weaving on a blank (center), weaving on armature (right). Photos by authors

Fig. 4 Torcido weave (left), cadena weave (center), petate weave (right). Photos by authors

participants explored how the morphological characteristics of the chuspata reed—such as its pliability, cellular structure, linear rigidity, and sectional variability (Fig. 5)—could be harnessed along with the geometric characteristics of the common weave patterns to achieve porosity, shading, rigidity, visual appeal, and three-dimensionality. The most promising prototypes were selected to be further developed into either horizontal or vertical architectural surfaces (Fig. 6). A pavilion was built with a simple linear wooden armature (Fig. 6) to test and display the new woven configurations and to engage visitors in this new way of using chuspata. As the designed patterns were assembled into the prescribed panel dimensions, new observations emerged that addressed phenomenological and experiential qualities. For example, variable daylight conditions were considered to decide the density and geometry of the woven designs and their function as horizontal shading devices (Fig. 6).

The panels were also evaluated from various distances involving the human body through spatial interaction. The woven patterns on the vertical panels showed varying degrees of porosity to allow for spatial connectivity. Sometimes they were less dense to offer eye-level views while at other times their density was increased to provide more privacy (Fig. 7).

Walking through the pavilion, the alternating arrangement of panels allowed visitors to not only stop and take a closer look at the woven surfaces but also to visually overlap near panels with far ones, making connections between small-scale details and their overall graphic presence at a distance (Fig. 8). Although the individual panels were designed and woven by participants in groups of four, they were considered part of a large-scale installation visible from far away as the horizontal surfaces could be seen from three stories above.

4 Conclusion and Discussion

Chuspata offers designers a biobased material with great potential to create woven surfaces that can be deployed at an architectural scale, acting as space-defining elements, as shading devices, and as privacy screens that are rooted in culture and environment. Its low thermal mass, insulating properties, low embodied energy, and design flexibility, make chuspata a highly desirable material to utilize in shading structures that can contribute to the reduction of urban heat islands and reduce cooling loads and associated carbon emissions. Further study beyond the scope of this project will be needed to test a variety of water-repelling strategies that can help prolong the lifespan of chuspata when placed in exposed conditions.

While the plant in and of itself and its use in architectural applications provide clear environmental benefits, its capacity to carry visual meaning is imbued by the skillful manipulation and design of weavers. The artisans who weave with chuspata in the region of Lake Pátzcuaro are accustomed to producing small scale objects, but those who participated in the workshop reported that this experience expanded the use of chuspata into new design territories. This change was made possible by aiming to design woven surfaces on a larger scale than is typical and by addressing architectural parameters such as spatial definition, three-dimensionality, porosity, and structural integrity. The pavilion that emerged from the workshop demonstrated how weaving patterns can filter light, provide shade, and contribute to the visitor experience. A series of panels displayed a combination of woven patterns to provide visual and physical connectivity. Varied tonalities were achieved in the woven surfaces that were inherent to the material variegation

Fig. 5 Pliability of chuspata (left), linear rigidity (center), cellular structure (right). Photos by authors

Fig. 6 Prototype experimenting with new weave (left), wooden armature (center), shading test (right). Photos by authors

of the stalks. These panels simultaneously exhibited the intricate and culturally resonant weaving patterns at the detail scale and the graphic qualities that a large-scale installation affords (Fig. 9). More coordination between these scales could be investigated in the future as well as the potential transformation of the material and its coloration through time, incorporation of dyes, and color retention (Fig. 10).

Our methodology revealed that the artisans were highly skilled in their craft and generous in sharing their techniques, yet the jump to the architectural scale, the introduction of new architectural design parameters, and the collaborative endeavor stretched their typical working process and yielded unforeseen results. Using drawing as a means of pre-designing, exploring new weaving patterns, and projecting to a larger scale was new to the artisans. This along with the creation of physical prototypes and panels that were designed and woven in small teams provided an enriching social experience that aided in the collaborative creative process. Future experimentation points to the integration of other tools such as digital parametric drawing to investigate weaving geometrical orders at various scales without ignoring the material qualities brought up by the richness of the craft.

Fig. 7 Variable woven porosity (left), spatial experience between varied porosity of panels (right). Photos by authors

Fig. 8 Spatial overlap of panels (left), details juxtaposed with larger scale graphic presence (right). Photos by authors

When we consider the environmental benefits of the biobased material in and of itself, the advantages of working with a non-toxic material that pleasantly engages our senses, the cultural resonance embodied through the artisan weaving tradition, and the reduction of cooling energy demand provided by solar shading, we can see that numerous forms of qualitative and quantitative performance are at play, illustrating a concept which the authors have previously referred to as Performance^2 (Mesa and Fash 2021).

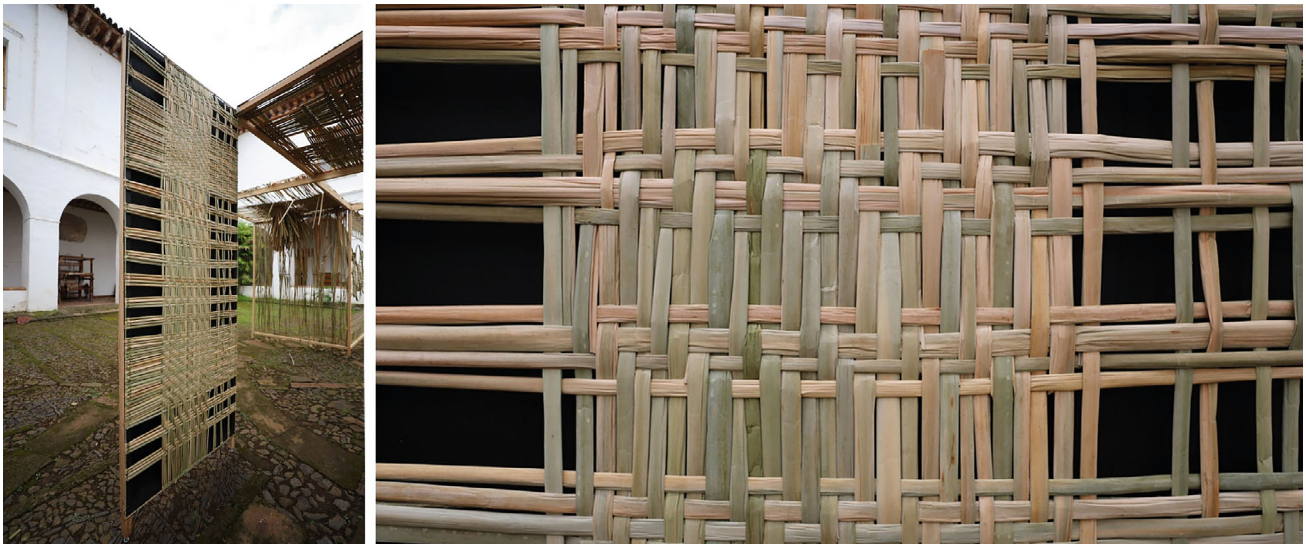

Fig. 9 Woven surface (left), detail of woven surface (right). Photos by authors

Fig. 10 Detail of woven surface. Photo by authors

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